Calf birth weight and its association with dam's subsequent lactation performance and lactation curve in Holstein dairy cows in Iran

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SUMMARY

In this study, 146,177 lactations on 81,677 cows distributed in 112 herds were used to investigate the association between calf birth weight (CBW) with dam's subsequent lactation curve, partial and 305-d lactation performance in Holstein cows in Iran. Based on the CBW, the records were classified into five categories: 20 to 37.5 kg, 37.6 to 40.5 kg, 40.6 to 42.5 kg, 42.6 to 45.5 kg, and 45.6 to 70 kg. The mean (SD) CBW was 41.42 (5.24) Kg. The mean (SE) CBW in primiparous cows giving birth to a bull or heifer was 41.70 (0.04), and 39.44 (0.04), respectively. The corresponding values in multiparous cows were 44.11 (0.04) and 41.58 (0.04) kg. There was a consistent association between CBW and dystocia, such that higher CBW was always associated with greater odds of dystocia. The mean rate of dystocia in primiparous cows was 10.48% and varied between 6.50% and 22.4% for cows belonging to the first and fifth category of CBW, respectively. In multiparous cows it was 5.46% and varied between 3.40% and 7.99% for cows belonging to the first and fifth category of CBW, respectively. Higher CBW was always associated with more lactation performance. Primiparous cows belonging to the fifth category of CBW in compared with those belonging to the first category of CBW produced 165 (8), 344 (15), 508 (23), 11 (0.8), and 13 (0.8) kg more 100-, 200- and 305-d milk, 305-d fat and 305-d protein, respectively. The corresponding values for multiparous cows were 357 (8), 630 (16), 802 (24), 25 (0.8), and 19 (0.8) kg. Multiparous cows belonging to the first category of CBW reached their peak most late and had the highest lactation persistency. In multiparous cows, higher CBW was always associated with earlier days in milk at peak. In both primiparous and multiparous, cows belonging to the first category of CBW had the lowest initial yield. However, there was no association between CBW with factors associated with the upward and download slopes of the lactation curve.

Keywords: Calf sex, calf birth weight, dystocia, lactation curve

INTRODUCTION

Factors including genetics, stage of lactation, milking frequency, parity, age, estrous cycles, pregnancy, dry period length, and metabolic diseases may affect the level of milk yield by a dairy cow (Atashi *et al.* 2013; Bernabucci *et al.* 2014; Vanholder *et al.* 2015). There are a number of calving related factors including calf gender, calf birth weight (CBW), birth number (singleton and doubleton), calving type (easy calving vs. difficult calving), stillbirth, retained placenta and metritis which are associated with dam's subsequent lactation performance (Meyer *et al.* 2001b; Tenhagen *et al.* 2007; Bicalho *et al.* 2008; Atashi *et al.* 2012; Græsbøll *et al.* 2015). Although the association of calf gender with dam's subsequent lactation performance has been widely investigated, the results are inconsistent. There are reports which showed Holstein cows that gave birth to heifer had higher milk yields than those gave birth to bull (Hinde *et al.* 2014; Gillespie *et al.* 2017). In contrast, Græsbøll *et al.* (2015) reported an increase in milk yield in Holstein dams that gave birth to a bull than those gave birth to a heifer. The association of calf gender with milk yield of the dam may be due to hormonal influences on the development of mammary gland or its effect on gestation length (Gillespie *et al.* 2017). Furthermore, compared with female calves, male calves have a higher birth weight; and giving birth to a heavier calf could reduce milk production in the subsequent lactation due to increased incidence of assisted calving, stillbirth, and metritis (Sieber *et al.* 1989; Johanson and Berger 2003; Linden *et al.* 2009). On the other hand, the foetus weight is correlated with placental weight (Sanin *et al.* 2001; Kabir *et al.* 2007; Panti *et al.* 2012), and larger placental mass may increase secretion of placental lactogen which may influence the mammary growth and increase the subsequent lactation performance. However, very few studies have been carried out to investigate the association of CBW with dam's subsequent lactation performance in dairy cows. Chew *et al.* (1981) reported a linear relationship between CBW and dam's subsequent 200- and 305-day yields of milk and fat in Holstein cows. The effect of CBW on dam's subsequent lactation performance may be quantified more accurately and in more detail, using mathematical models describing the lactation curve. Therefore, the aim of this study was to use an incomplete gamma function to quantify the association between CBW and dam's subsequent lactation curve, partial and 305-d lactation performance in Holstein cows in Iran.

MATERIAL AND METHODS

Data used in this study were records on Holstein cows collected from January 2000 to December 2015 by the Animal Breeding Center of Iran (Karaj, Iran). The evaluated herds were purebred Holsteins, managed under conditions similar to those used in most developed countries, and were under official performance and pedigree recording. The diet, fed as a total mixed ration (TMR), was consisted of corn silage, alfalfa hay, barley grain, fat powder, beet pulp, and feed additives. Monthly milk recording was performed by trained technicians of the Iranian Animal Breeding Center, according to the guidelines of the International Committee for Animal Recording (ICAR 2005). Farmers, upon observing parturition, subjectively assigned a calving ease score according to the degree of assistance provided. Recognized dystocia scores were as follows: 1 = no problem, 2 = slight problem, 3 = needed assistance, 4 = needed considerable force and 5 = extreme difficulty. In this study, dystocia scores of 1 or 2 were coded as easy calving, and scores of ≥ 3 were coded as difficult calving. Cows with missed birth date, calving date, breeding date, drying date, and parity number were deleted. The records of twins were excluded from the analysis. Cows were required to have a minimum of 5 test-day records per lactation. Tests before 6 d or after 320 d were excluded. First calving age (FCA) was calculated as the difference between birth date and calving date at first parity and was restricted to the range of 540 to 1,200 d. Ultimately, the data set used to describe lactation curve included 1,416,936 test-day records of 179,359 lactations on 100,381 cows distributed in 112 herds. To describe the lactation curve, an incomplete gamma function proposed by Wood (1967) was used.

This function that is the most popular model used for describing lactation curves in different ruminant species (Ruiz *et al.* 2000; Macciotta *et al.* 2005; Santos and Silvestre 2008; Macciotta *et al.* 2011), can be generalized as following: $y_t = at^b e^{-ct}$, where y_t is the daily milk yield (kg/d) at days in milk (DIM) *t*, the variable *t* represents the length of time since calving, *e* is the Neper number, *a* is a parameter representing yield at the beginning of lactation, and *b* and *c* are factors associated with the upward and downward slopes of the lactation curve, respectively. The incomplete gamma function was transformed logarithmically into a linear form as: $\ln(y_t) = \ln(a) + b\ln(t) - ct$, and fitted to 1,416,936 test-day milk records corresponding to 179,359 lactations using a simple program written in Visual Basic (Microsoft Corp., Redmond, WA). The time at which peak lactation occurred (T_{max}) was defined as: $T_{max} = (b/c)$, expected maximum yield (y_{max}) was calculated as: $y_{max} = a(b/c)^b e^{-b}$, lactation persistency (s) was calculated as: $s = -(b + 1)\ln(c)$, and total yield from the time of calving up to 100, 200, and 305 DIM was calculated as: $y = a\int_1^n t^b e^{-ct}\,dt$, where n = 100, 200, and 305, respectively.

Typical lactation curve has positive *a*, *b*, and *c*, then a curve with negatives *a*, *b,* or *c* is considered atypical. Of 179,359 lactations, 33,182 (18.50%) were atypical and were excluded. Finally, 1,159,416 test-day milk records corresponding to 146,177 lactations on 81,677 cows distributed in

112 herds were used to determine the association between CBW with lactation performance and the incidence of dystocia during the subsequent lactation. In order to investigate the association between CBW with dam's subsequent lactation performance and dystocia, the CBW was classified into five categories: 20 to 37.5 kg, 37.6 to 40.5 kg, 40.6 to 42.5 kg, 42.6 to 45.5 kg, and 45.6 to 70 kg. Cows were also grouped by parity: primiparous (n = 81,677) and multiparous (n = 64,500) cows.

The association between CBW with dam's subsequent lactation curve, partial and 305-d lactation performance was investigated using multiple regression mixed models in PROC MIXED (Institute 2015). The independent variables were fixed effects of CBW in a 2-way interaction with parity, calf gender, dystocia, herd-calving year-calving season combination (HYS), covariate effect of FCA, and random effect of dam's sire. The association between CBW and dystocia was investigated using a multivariable logistic regression model through the maximum likelihood method in PROC GENMOD (Institute 2015). In the model, the dependent variable, dystocia score, was 0 for easy calving and 1 for difficult calving, and the independent variables were herd, calving year, calving season, CBW, parity, calf sex, covariate effect of FCA, and random effect of service sire.

RESULTS AND DISCUSSION

CBW

Descriptive statistics of CBW is presented in Table 1. The mean (SD) CBW was 41.42 (5.24) Kg. The birth weight for more than 63% of all calves was between 37.6 and 45.5 kg (Table 1). In addition to herd, calving season, and calving year, factors including calf gender, parity and service sire influenced the calf birth weight ($P < 0.05$). The mean (SE) CBW in primiparous cows giving birth to a bull or heifer was 41.70 (0.04), and 39.44 (0.04), respectively. The corresponding values for multiparous cows were 44.11 (0.04) and 41.58 (0.04) kg.

Association of calf gender and CBW with dam's dystocia

The association of calf gender and CBW with dam's dystocia is presented in Table 2. Of 146,177 births, 92.70% required no assistance, whereas 7.30% required assistance of some sort.

Table 1. Categories, corresponding range, means, standard deviation, and frequency distribution of calf birth weight (n = 146,177)

Category number[1]	Primiparous n	Primiparous Mean(Kg)	Primiparous SD(Kg)	Multiparous n	Multiparous Mean(Kg)	Multiparous SD(Kg)	Total n	Total Mean(Kg)	Total SD(Kg)	Range(Kg)
1	19611	34.03	3.14	7591	34.15	3.25	27202	34.06	3.17	20.0 – 37.5
2	26146	39.25	0.87	13770	39.37	0.83	39916	39.29	0.86	37.6 – 40.5
3	12889	42.58	0.49	9989	41.62	0.49	22878	41.60	0.49	40.6 – 42.5
4	14318	44.01	0.86	15540	44.10	0.86	29858	44.06	0.86	42.6 – 45.5
5	8713	48.50	2.67	17610	49.44	3.31	26323	49.13	3.14	45-6 – 70.0

[1]Based on the calf birth weight, the records were classified into five categories: 20 to 37.5 kg, 37.6 to 40.5 kg, 40.6 to 42.5 kg, 42.6 to 45.5 kg, and 45.6 to 70 kg.

Table 2. Odds ratios (OR) and 95% CI for the effect of 2-way interaction of calf birth weight (CBW[1]) with parity (primiparous or multiparous) on dystocia in Holstein cows (n = 146,177)

Pairs of categories	Primiparous Mean (%)	Primiparous OR	Primiparous 95% CI	Multiparous Mean (%)	Multiparous OR	Multiparous 95% CI
CBW-2 vs. CBW -1	8.34 vs. 6.50	1.35	1.25 – 1.46*	3.72 vs. 3.40	0.92	0.79 - 1.08^{ns}
CBW-3 vs. CBW -1	9.52 vs. 6.50	1.62	1.48 - 1.79*	4.14 vs. 3.40	0.95	0.80 - 1.13^{ns}
CBW-4 vs. CBW -1	13.36 vs. 6.50	2.44	2.24 - 2.67*	5.48 vs. 3.40	1.45	1.24 - 1.71*
CBW-5 vs. CBW -1	22.41 vs. 6.50	4.90	4.40 - 5.47*	7.99 vs. 3.40	2.46	2.12 - 2.85*
CBW-3 vs. CBW -2	9.52 vs. 8.34	1.21	1.11 - 1.31*	4.14vs. 3.72	1.03	0.87 - 1.21^{ns}
CBW-4 vs. CBW -2	13.36 vs. 8.34	1.81	1.68 - 1.96*	5.48vs. 3.72	1.57	1.37 - 1.81*
CBW-5 vs. CBW -2	22.41 vs. 8.34	3.64	3.30 - 4.01*	7.99vs. 3.72	2.66	2.34 - 3.02*
CBW-4 vs. CBW -3	13.36 vs. 9.52	1.50	1.39 - 1.63*	5.48vs. 4.14	1.53	1.32 - 1.78*
CBW-5 vs. CBW -3	22.41 vs. 9.52	3.01	2.74 - 3.31*	7.99vs. 4.14	2.59	2.25 - 2.99*
CBW-5 vs. CBW -4	22.41 vs. 13.36	2.01	1.84 - 2.18*	7.99vs. 5.48	1.69	1.53 - 1.86*
Male calf vs. female calf	13.64 vs. 10.41	1.54	1.45 - 1.62*	5.50 vs. 4.39	1.37	1.27 - 1.49*

[1]Based on the calf birth weight, the records were classified into five categories: 20 to 37.5 kg, 37.6 to 40.5 kg, 40.6 to 42.5 kg, 42.6 to 45.5 kg, and 45.6 to 70 kg; CI = Confidence Interval; *Significant at $P < 0.05$.

Factors associated with the presence of dystocia were calving year and season, calf birth weight, calf sex, herd, parity, and age of dam ($P < 0.05$). The probability of dystocia was higher in dams giving birth to a bull than in those with a heifer. Primiparous cows had a higher mean rate of dystocia than multiparous cows ($P < 0.05$). The mean rate of dystocia in primiparous cows giving birth to a bull (13.64%) or heifer (10.41%) was significantly different (OR ± (95% CI) = 1.54 (1.45-1.62) for primiparous cows giving birth to a bull vs. primiparous cows giving birth to a heifer). The mean rate of dystocia in multiparous cows was lower than that in primiparous cows but again its mean in cows giving birth to a bull (5.50%) was higher than that in those giving birth to a heifer (4.39%) (OR ± (95% CI) =1.37 (1.27 – 1.49) for multiparous cows giving birth to a bull vs. multiparous cows giving birth to a heifer). The mean rate of dystocia in primiparous cows was 10.48% and varied between 6.50% and 22.41% for cows belonging to the first (calf birth weight ≤ 37.5 Kg) and fifth (calf birth weight > 45.5) category of CBW, respectively. In primiparous cows, there was a consistent association between CBW and dystocia, such that higher CBW was always associated with greater odds of dystocia (Table 2). The mean rate of dystocia in multiparous cows was 5.46% and varied between 3.40% and 7.99% for cows belonging to the second (37.5 < calf birth weight < 40.5 Kg) and fifth (calf birth weight > 45.5) category of CBW, respectively. In multiparous cows, there was a consistent association between CBW and dystocia, such that higher CBW was always associated with greater odds of dystocia (Table 2). However, the rate of dystocia for cows belonging to the first, second and third category of CBW was not significantly different (Table 4).

Association of calf gender and dystocia with dam's subsequent lactation performance

The association of calf gender and dystocia with subsequent lactation performance is presented in Table 3. In both primiparous and multiparous, the mean 100-, 200-, and 305-d milk yield, as well as mean peak yield was higher in dams giving birth to a heifer than that in those giving birth to a bull. Primiparous cows giving birth to a heifer than those giving birth to a bull produced 30 (4.2), 48 (7.8), and 55 (12.2) kg more 100-, 200, and 305-d milk, respectively. The corresponding values for multiparous cows were 34 (4.6), 48 (8.6), and 46 (13.4) Kg, respectively. However, an inverse pattern was found for lactation persistency and the time at which peak lactation occurred. All cows giving birth to a bull reached their peak lately than those giving birth to a heifer (Table 3). The cows giving birth to a bull had a higher lactation persistency than those giving birth to a heifer. Calf gender was associated with initial yield, but not with factors associated with the upward and downward slopes of the lactation curve. The mean initial yield was higher in primiparous cows giving birth to a heifer than in those giving birth to a bull. In primiparous cows, calf gender was associated with 305-d fat and protein yield, such that primiparous cows giving birth to a heifer produced more 305-d fat and protein than those giving birth to a bull. Multiparous cows giving birth to a heifer produced more 305-d fat than those giving birth to a bull, but there was no association between calf gender and 305-d protein yield in multiparous cows.

Dystocia was significantly associated with dam's subsequent lactation performance (Table 3). In both primiparous and multiparous cows, the mean 100-, 200-, and 305-d milk yield, as well as mean peak yield was lower in cows experienced dystocia than that in those with eutocia. However, an inverse pattern was found for lactation persistency and the time at which peak lactation occurred. All cows experienced dystocia had a higher lactation persistency and reached their peak lately than those with eutocia. Dystocia affected neither 305-d fat yield nor 305-d protein in primiparous cows. However, multiparous cows with dystocia produced less 305-d fat and 305-d protein yield than those with easy calving. Dystocia was associated with higher DIM until peak in primiparous cows (Table 3). Peak yield (SE in parentheses) for primiparous cows with dystocia or eutocia occurred on d 95.4 (0.51) and 93.8 (0.32), respectively. The corresponding values for multiparous cows were 60.0 (0.75) and 57.3 (0.31) d.

Association of CBW with dam's subsequent lactation performance

The association of CBW with dam's subsequent lactation performance is presented in Table 4. In both primiparous and multiparous cows, there was a consistent association between CBW with partial and 305-d milk, peak yield, 305-d fat and 305-d protein yield. The result showed that higher CBW was always associated with more lactation performance. Similar pattern but with a slightly less steadiness was found in primiparous cows. Primiparous cows belonging to the fifth category of CBW in compared with those belonging to the first category of CBW produced 166 (8), 343 (15), 508 (23), 11 (0.8), and 13 (0.8) kg more 100-, 200- and 305-d milk, 305-d fat and 305-d protein, respectively. The corresponding values for multiparous cows were 357 (8), 630 (16), 802 (24), 25 (0.8), and 19 (0.8) kg. There was an association between CBW with lactation persistency and the time at which peak lactation occurred. Multiparous cows belonging to the first category of CBW reached their peak most late and had the highest lactation persistency.

Table 3. Least squares means (SE) of the 2-way interaction of calf gender and dystocia (EC = easy calving; DC = difficult calving) with parity (primiparous and multiparous) for lactation performance of Holstein cattle of Iran (n = 146,177).

Parity	Calf Gender	305-d milk[1]	100-d milk[2]	200-d milk[3]	305-d fat	305-d protein	Peak yield[4]	Peak day[5]	Persistency[6]
P	Male	9378 (17.9)^{b}	3127 (6.2)^{b}	6417 (11.6)^{b}	258 (0.62)^{b}	250 (0.65)^{b}	35.0 (0.06)^{b}	95.3 (0.38)a	7.55 (0.007)^{a}
	Female	9433 (18.3)^{a}	3157 (6.3)^{a}	6465 (11.8)^{a}	260 (0.63)^{a}	252 (0.66)^{a}	35.3 (0.06)^{a}	93.9 (0.39)b	7.53 (0.007)^{b}
M	Male	10021 (22.1)^{b}	3905 (7.6)^{b}	7401 (14.3)^{b}	286 (0.77)^{b}	280 (0.79)^{a}	42.9 (0.08)^{b}	59.0 (0.47)a	7.00 (0.008)^{a}
	Female	10067 (22.2)^{a}	3939 (7.6)^{a}	7449 (14.3)^{a}	288 (0.77)^{a}	280 (0.79)^{a}	43.3 (0.08)^{a}	58.3 (0.47)a	6.98 (0.008)^{b}
P	EC	9455 (15.0)^{a}	3163 (5.1)^{a}	6476 (9.7)^{a}	260 (0.53)^{a}	251 (0.56)^{a}	35.3 (0.05)^{a}	93.8 (0.32)^{b}	7.52 (0.005)^{b}
	DC	9356 (24.1)^{b}	3121 (8.3)^{b}	6406 (15.6)^{b}	259 (0.81)^{a}	250 (0.85)^{a}	35.0 (0.09)^{b}	95.4 (0.51)^{a}	7.55 (0.009)^{a}
M	EC	10182 (14.5)^{a}	3986 (5.0)^{a}	7531 (9.4)^{a}	290 (0.51)^{a}	283 (0.54)^{a}	43.7 (0.05)^{a}	57.3 (0.31)^{b}	7.00 (0.005)^{b}
	DC	9906 (35.3)^{b}	3857 (12.1)^{b}	7319 (22.8)^{b}	285 (1.20)^{b}	278 (1.20)^{b}	42.5 (0.12)^{b}	60.0 (0.75)^{a}	7.02 (0.013)^{a}

$^{a\text{-}b}$ Least squares means with different superscripts (within parity) differ significantly (P < 0.05); [1] Total yield from calving up to DIM of 305 calculated as: $y = a\int_1^{305} t^b e^{-ct}dt$; [2] Total yield from calving up to DIM of 100 calculated as: $y = a\int_1^{100} t^b e^{-ct}dt$; [3] Total yield from calving up to DIM of 200 calculated as: $y = a\int_1^{200} t^b e^{-ct}dt$; [4] Peak yield, calculated as: $a(b/c)^{b}e^{-b}$; [5] DIM at peak yield, calculated as: (b/c).; [6] Persistency, calculated as: s = -(b + 1)ln(t).

Table 4. Least squares means (SE) of the 2-way interaction of calf birth weight (CBW[1]) with parity (primiparous and multiparous) for lactation performance of Holstein cows in Iran (n = 146,177).

	CBW	305-d milk	100-d milk	200-d milk	305-d fat	305-d protein	Peak yield	Peak day	Persistency
Primi-parous	1	9129 (20.1)^{e}	3049 (7.1)^{e}	6252 (13.4)^{e}	253 (0.71)^{c}	244 (0.76)^{d}	34.1 (0.07)^{e}	94.7 (0.44)^{ab}	7.54 (0.008)^{ab}
	2	9330 (19.3)^{d}	3118 (6.6)^{d}	6390 (12.4)^{d}	257 (0.67)^{b}	249(0.71)^{c}	34.9 (0.06)^{d}	94.6 (0.41)^{ab}	7.54 (0.007)^{ab}
	3	9427 (21.8)^{c}	3149 (7.5)^{c}	6452 (14.1)^{c}	259 (0.76)^{b}	251(0.79)^{c}	35.2 (0.08)^{c}	93.9 (0.46)^{b}	7.52 (0.008)^{b}
	4	9503 (21.0)^{b}	3181 (7.2)^{b}	6514 (13.5)^{b}	262 (0.73)^{a}	254(0.76)^{b}	35.6 (0.07)^{b}	94.3 (0.45)^{ab}	7.53 (0.008)^{b}
	5	9637 (23.5)^{a}	3214 (8.1)^{a}	6596 (15.2)^{a}	264 (0.81)^{a}	257(0.84)^{a}	36.0 (0.08)^{a}	95.5 (0.50)^{a}	7.56 (0.008)^{a}
Multi-parous	1	9566 (28.1)^{e}	3711 (9.6)^{e}	7052 (18.1)^{e}	274 (0.97)^{d}	269(1.00)^{d}	40.9 (0.10)^{e}	60.8 (0.60)^{a}	7.03 (0.010)^{a}
	2	9990 (24.7)^{d}	3894 (8.4)^{d}	7379 (15.9)^{d}	285 (0.86)^{d}	279(0.89)^{c}	42.8 (0.08)^{d}	58.8 (0.53)^{b}	7.00 (0.009)^{c}
	3	10092 (26.2)^{c}	3942 (9.0)^{c}	7461 (16.9)^{c}	288 (0.92)^{c}	281(0.95)^{c}	43.3 (0.09)^{c}	58.1 (0.56)^{bc}	6.99 (0.009)^{c}
	4	10203 (24.0)^{b}	3994 (8.2)^{b}	7550 (15.5)^{b}	291 (0.83)^{b}	284(0.86)^{b}	43.9 (0.08)^{b}	58.0 (0.51)^{bc}	7.98 (0.009)^{c}
	5	10368 (23.5)^{a}	4068 (8.1)^{a}	7682 (15.1)^{a}	299 (0.81)^{a}	288(0.83)^{a}	44.7 (0.08)^{a}	57.4 (0.50)^{c}	7.98 (0.008)^{c}

^{a,b} Least squares means with different superscripts (CBW within parity) differ significantly (P < 0.05).
[1]Based on the calf birth weight, the records were classified into five categories: 20 to 37.5 kg, 37.6 to 40.5 kg, 40.6 to 42.5 kg, 42.6 to 45.5 kg, and 45.6 to 70 kg.

In multiparous cows, higher CBW was always associated with shorter DIM until peak. In primiparous cows, the association of CBW with lactation persistency and the time at which peak lactation occurred was significantly different. Primiparous cows belonging to the third category of CBW had the lowest lactation persistency and reached their peak earliest. In both primiparous and multiparous, cows belonging to the first category of CBW had the lowest initial yield (Figures 1 and 2). However, neither in primiparous nor in multiparous cows there was no association between CBW with factors associated with the upward and download slopes of the lactation curve (results not showed).

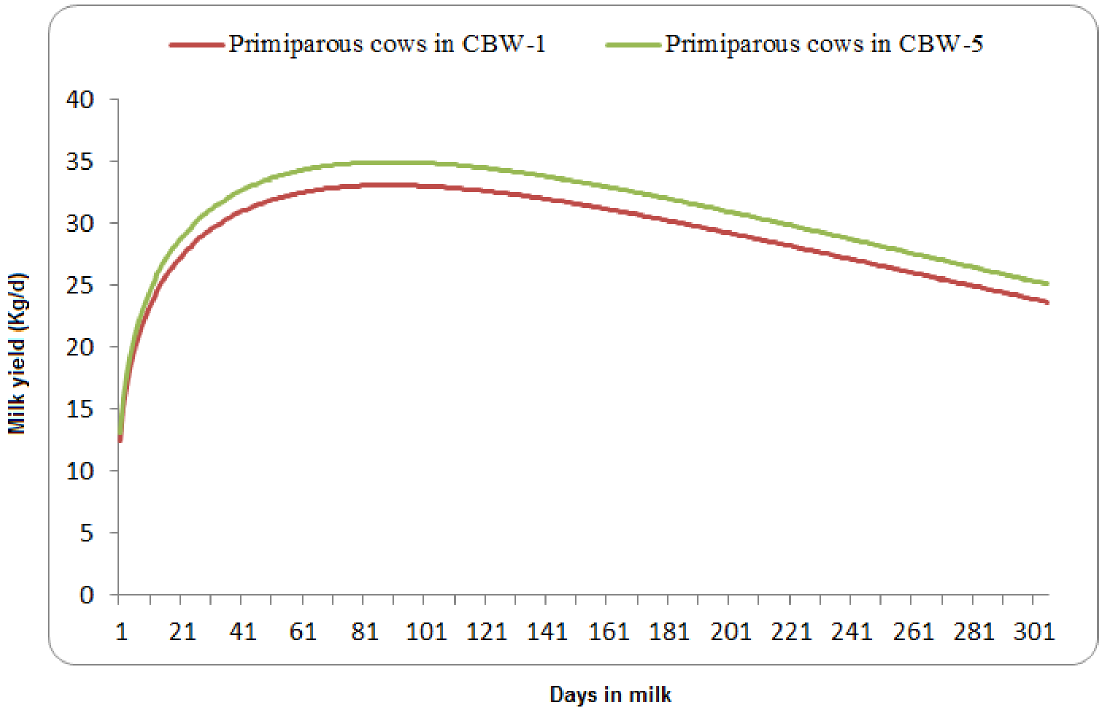

Figure 1. Lactation curves of primiparous cows belonging to the first (calf birth weight ≤ 37.5 Kg) and fifth category (calf birth weight > 45.5) of calf birth weight.

The mean (SD) CBW was 41.42 (5.24) Kg. In addition to herd, calving season, and calving year, factors including calf gender, parity and service sire influenced the calf birth weight. The mean (SE) CBW in primiparous cows giving birth to a bull or heifer was 41.70 (0.04), and 39.44 (0.04), respectively. The corresponding values for multiparous cows were 44.11 (0.04) and 41.58 (0.04) kg. These results are in close agreement with earlier researches (Johanson and Berger 2003; Linden *et al.* 2009; Olson *et al.* 2009). The mean rate of dystocia was 7.30%, which was comparable to other international estimates (Berry *et al.* 2007; Mee 2008; Linden *et al.* 2009). However, the literature showed a higher rate of dystocia in the U.S. Holstein (Meyer *et al.* 2001a; Johanson and Berger 2003; Lombard *et al.* 2007). Besides herd, calving year and calving season, factors including calf gender, parity, calf birth weight and random effect of service sire influenced the dystocia rate.

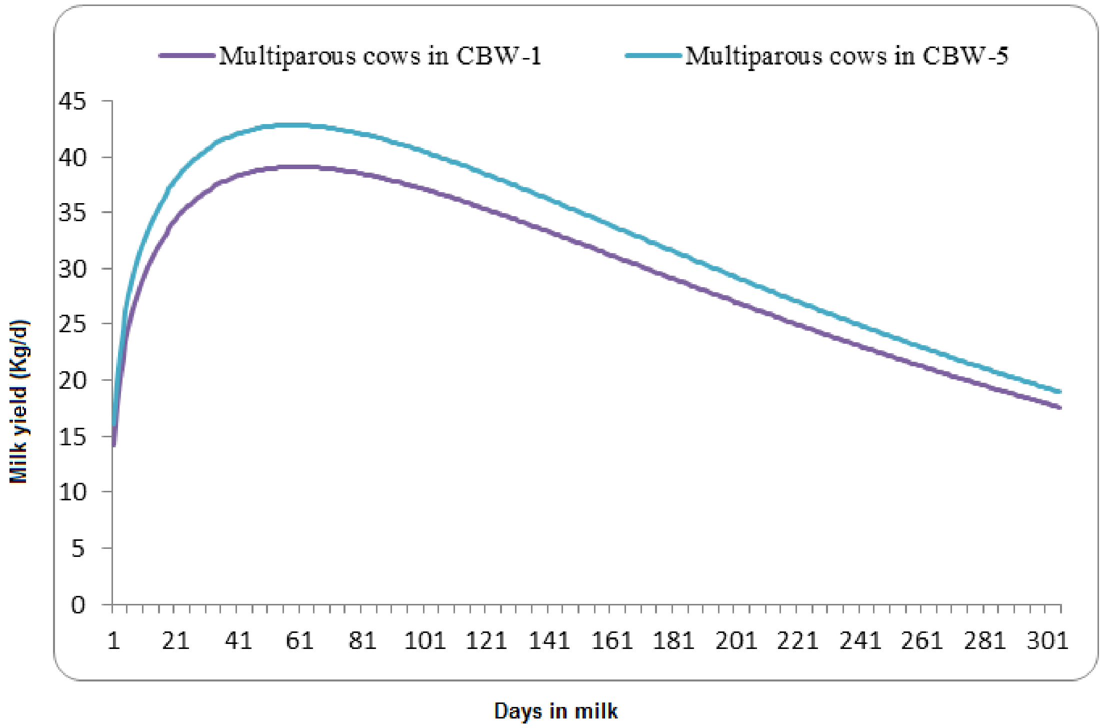

Figure 2. Lactation curves of multiparous cows belonging to the first (calf birth weight ≤ 37.5 Kg) and fifth category (calf birth weight > 45.5) of calf birth weight.

Despite the inclusion of calf weight in the statistical model, the mean rate of dystocia in cows giving birth to a bull was higher than that in those giving birth to a heifer, in line with previous reports (Johanson and Berger 2003; Berry *et al.* 2007; Lombard *et al.* 2007; Linden *et al.* 2009). In both primiparous and multiparous cows, there was a linear association between CBW and dystocia, so that higher CBW was always associated with greater odds of dystocia, which is in a close agreement with previous researches (Johanson and Berger 2003; Berry *et al.* 2007; Uematsu *et al.* 2013). In Holstein dairy cows, Johanson and Berger (2003) reported that increasing one kg in calf birth weight would increase the probability of dystocia by 13%. Calf birth weight has been reported as the most important risk factor for dystocia in Japanese Black cattle (Uematsu *et al.* 2013). Incompatibility between calf size and dam size, as well as pelvic and vulvar conformation is likely to have a great effect on calving difficulty (Berglund *et al.* 2003). In both primiparous and multiparous cows, the mean 100-, 200-, and 305-d milk yield, as well as mean peak yield was higher in dams giving birth to a heifer than that in those giving birth to a bull. Although, the association of calf gender with dam's subsequent lactation performance has been widely investigated, the results are inconsistent. There are reports which showed Holstein cows that gave birth to heifer had higher milk yields than those gave birth to bull (Hinde *et al.* 2014; Gillespie *et al.* 2017). Hinde *et al.* (2014) using 2.39 million lactation records on 1.49 million Holstein dairy cows reported that dams giving birth to a heifer produced more milk than those giving birth to a bull. In the New Zealand dairy cattle population, it was reported that dams giving birth to a heifer produced more milk than those giving birth to a bull (Hayr 2014). In contrast, Græsbøll *et al.* (2015) reported an increase in milk yield in Danish Holstein dams that gave birth to a bull than those gave birth to a heifer. In the red deer, it has been shown that mothers of sons produced more milk protein, and fat than those of daughters (Landete-Castillejos *et al.* 2000). In the Rhesus Macaques, it has been reported that mothers of sons produced lower milk but with higher energy density, such that the available milk energy was the same for sons and daughters (Hinde 2009). In the Human, it has been found that mothers of sons produced milk of higher energy density than mothers of daughters (Powe *et al.* 2010). This point should be taken into consideration that we estimated the effect of calf gender corrected for birth weight which always had a linear relationship with lactation performance. Chew *et al.* (1981) reported that calf gender had no impact on lactation performance when calf birth weight was included into the model. The results of this study showed that the cows giving birth to a bull had higher lactation persistency and reached their peak lately than those giving birth to a heifer. In contrast, Chegini *et al.* (2015) reported that cows giving birth to daughter had a higher lactation persistency than those giving birth to a son. However, different measures have been used to measure lactation persistency in these two studies. Primiparous cows giving birth to a heifer produced more 305-d fat and 305-d protein than those giving birth to a bull. Multiparous cows giving birth to a heifer produced more 305-d fat than those giving birth to a bull. Calf gender was associated with initial yield, but not with the upward and downward slopes of the lactation curve. The association of calf gender with dam’s subsequent lactation performance may be due to hormonal influences on the development of mammary gland or its effect on gestation length (Gillespie *et al.* 2017). However, more researches are needed to identify its potential biological explanations.

The present study showed a consistent association between CBW and lactation performance in both primiparous and multiparous cows, in line with previous reports (Jeffery *et al.* 1971; Chew *et al.* 1981). Chew *et al.* (1981) reported a linear relationship between CBW and dam's subsequent 200- and 305-day yields of milk and fat in Holstein cows. In dairy cattle, the majority of mammary growth takes place during pregnancy and signals from the placenta could be involved in controlling mammogenesis. The fetus weight is correlated with placental weight (Sanin *et al.* 2001; Kabir *et al.* 2007; Panti *et al.* 2012), and larger placental mass may increase secretion of placental lactogen and estrogen. Placental lactogen, which is produced during pregnancy, may be one factor involved in controlling mammary growth (Collier *et al.* 1995; Horseman and Gregerson 2014). However, further investigation is needed to identify potential biological explanations for any such difference.

Conclusions

The results confirm the hypothesis that calf birth weight is associated with dam's subsequent lactation performance, such that higher CBW was always associated with more milk yield. The association between the calf birth weight with lactation performance and dystocia suggests the need to think about formal genetic evaluation for calf birth weight in Holstein. Although, higher calf birth weight, due to increased incidence of dystocia, is associated with lower calf and cow survivability and higher veterinary cost, its linear relationship with lactation performance should be taken into account in any economic evaluation.

Conflict of interest statement
The authors declare that they have no conflict of interest.

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