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Estimation of lactation curve parameters and its correlation with udder type traits in Iranian Holstein dairy cattle using Wilmink's function

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Knowledge of the lactation curve allows prediction of total milk yield from lactation curves, which are used to describe the milk production measured at several test days early in lactation and it is valuable tools in farm management (Jeretina *et al.* 2013). Among the linear type traits, udder traits have strongest effect on the survival of cows. Udder traits have the strongest relationship with functional herd life and production compared to other structural body traits (Schneider *et al.* 2003).

This study included 2 data sets: 8,222 records for genetic evaluation of lactation curve, and 2,325 records for udder type traits of first parity Holstein cows were obtained from Agricultural-Jihad Organization in Khorasan Razavi province (Northeast of Iran) between years 1998 to 2012. Further information in the data set included cow age, herd, year, season of calving and pedigree. To describe the lactation curve and associated production characteristics, Wilmink's function was applied in this study. The function is as following:

$$Y_t = W_0 + W_1 t + W_2^{e-0.05t}$$

where, *t,* number of days in milk; Y_t, milk yield (kg) at day *t*; W_0, associated with the level of production; W_1, associated with production decrease after peak yield; and W_2,associated with production increase towards peak yield. Based on the estimated lactation curve parameters, some production characteristics including, peak time (PT), peak milk yield (PM), and total 305-day milk yield (TM305) were also calculated for individual cows as following:

$$PT= -20(\ln 20\ W_1 /W_2)$$

$$PM=W_0+W_1\ (-20\ (\ln 20\ W_1 /W_2)\ +W_2^{e-0.05-20(\ln 20W1/W2)}$$

$$TM305=305W_0+46665W_1+19.50416W_2$$

The following type traits scored on 1 to 9 scale except rear udder height and rear udder width as in the Iranian classification system were analyzed. Eight udder traits included fore udder attachment, rear udder height, udder depth, rear udder width, suspensory ligament, teat length, front teat placement and rear teat position. Data were also analyzed by uni- and bi-variate models, which consisted of the fixed and random effects as those included in bivariate settings. The linear model was as below:

$$Y_{ijk} = \mu + HYS_i + A_j + Age_k + e_{ijk}$$

where, Y_{ijk}, record of particular type trait; HYS_i, fixed effect of herd, year and season of calving; Age_k, fixed effect of age related to kth animal; A_j, random effect of animal additive genetic effect; and e_{ijk}, residual effects.

Descriptive statistics for udder type traits and lactation curve parameters are given in (Table 1) and for month of lactation are shown in Table 2. The means for front teat placement obtained in this study are well within the range of results reported in the literature (Short *et al.* 1992). Comparing of linear type traits scores with results obtained in similar studies is rather difficult because of differences in scoring systems, various traits that are being evaluated, as well as breed (Panteliæ *et al.* 2011). According to Macciota *et al.* (2005), the parameter W_0 is always greater than 0 in the Wilmink's function, our results supported this statement. As per Table 1, average daily milk yield increased from the beginning of lactation (26.2 kg) towards peak yield (30.2) in peak time (62 days) and afterwards it decreased gradually towards the end of lactation. Heritability of traits, including udder type traits and lactation curve parameters are shown in Table 1. Generally, traits associated with production had a lower heritability than udder type traits. In this study, heritability estimates for udder type traits were low to moderate. The lowest heritability 0.03 estimated for suspensory ligament trait were similar to those described by Panteliæ *et al.* (2011), indicating that little response to selection could be expected in these trait. This result showed the importance of environmental effects and non-additive genetic effects in the total variation of these traits. The heritability estimates for parameters W_0, W_1 and W_2 are in agreement with those reported by Farhangfar and Rowlinson (2007) for Wood's incomplete gamma function. Muir *et al.* (2004) using first parity data in Holstein, found heritability of 0.45 for total 305-day milk yield which is in disagreement with our results. Rekaya *et al.* (2000) using first parity data, found heritability as 0.26 for total 305-day milk yield, which is same with our results. Additionally, heritability computed as the average values from all bivariate analyses were almost

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similar to those estimated from single trait analyses. Generally, low heritability estimates were obtained for the parameters of Wilmink's function and peak time suggesting that these traits were substantially influenced by the environmental factors and genetic variation between cows for these traits was low. This implies that direct selection for the lactation curve parameters may not change the shape of the lactation curve effectively and successfully (Farhangfar and Rowlinson 2007). Genetic correlations between lactation curves parameters and udder type traits are shown in Table 2. All genetic and phenotypic correlations were positive between total 305 day milk yield and other traits. A very high genetic correlation of 0.74 was revealed between front teat placement and total 305-day milk yield. Genetic correlations between lactation curves parameters and udder type traits were low to high. A strong negative genetic correlation existed between W_0 and teat length (–0.52); cows with shorter teat length tended to have higher initial level of production (W_0) while a strong positive genetic correlation existed between W_1 and teat length (0.99); cows with longer teat length had the highest of production decrease after peak yield. A strong positive genetic correlation existed between W_2 and front teat placement (0.36); cows with close front teat placement had the highest of production increase towards peak yield. A strong negative genetic correlation existed between peak milk yield and teat length (–0.66) while a strong positive genetic correlation existed between peak milk yield and suspensory ligament (0.83); cows with shorter teat length and deep suspensory ligament reached earlier to peak yield during lactation. Genetic correlations between all udder type traits and total 305-day milk yield were positive and seem to be moderate to high in magnitude. Berry *et al*. (2004) calculated a negative genetic correlations between the milk yield and teat length (–0.14) for registered cows in the south of Ireland, which is in contrast our results. Misztal *et al.* (1992) reported a negative genetic correlation between milk yield and udder depth (–0.44). Good udder of an animal has direct bearing on its productive life. High producing cows have higher rear udder, lower udder depth, tightly front teat placement and weaker suspensory ligament of udder than cows with lower milk production (Buenger *et al.* 2001). A high positive genetic correlation (0.74) existed between front teat placement and total 305-day milk yield. Therefore, selecting cows in the first lactation that have close front teat placement could increase total 305-day milk yield in later lactations. Genetic parameter estimates for udder type traits from our study will allow the updating of genetic evaluation procedures for exterior characteristics of Iranian Holstein cattle. We recommend their inclusion in the classification system of Iranian Holstein cattle. Milk yield and type traits play major roles in determining the profitability of dairy herds. This study demonstrated the relationship of lactation curve parameters and udder type traits in the Iranian dairy cattle population. This research indicated a desirable relationship between production and udder type traits. However, udder type traits had positively genetic correlation with total 305-day milk yield that shows

Table 1. Descriptive statistics for udder type traits and lactation curve parameters

Trait	Mean (SD)	No. of records	h^2	Trait	Mean (SD)	No. of records	h^2
FTP	4.32(1.03)	2325	0.23	W0	32.29(5.09)	8222	0.13
RTP	5.17(1.13)	2325	0.26	W1	–0.05(0.06)	8222	0.07
RUH	27.8(2.53)	2325	0.26	W2	–0.04(0.02)	8222	0.45
RUW	18.0(2.19)	2325	0.31	PT	61.97(9.90)	8222	0.06
FUA	6.67(1.73)	2325	0.27	PM	30.02(4.72)	8222	0.10
SL	6.03(1.04)	2325	0.03	TM 305	8186.5(1532.26)	8222	0.20
TL	4.98(1.01)	2325	0.22	-	-	-	-
UD	5.55(1.05)	2325	0.32	-	-	-	-

FTP, Fore teat placement; RTP, rear teat placement; RUH, rear udder height; RUW, rear udder width; FUA,fore udder attachment; SL, suspensory ligament; TL, teat length; UD, udder depth; PT, peak time; PM, peak milk.

Table 2. Genetic correlations between lactation curves parameters and udder type traits

Trait	W_0	W_1	W_2	Peak time	Peak yield	TM305
FTP	0.42(0.04)	0.96(0.4)	0.36(0.08)	0.55(0.09)	0.50(0.02)	0.74(0.08)
RTP	–0.03(0.03)	0.98(0.3)	0.10(0.05)	0.28(0.03)	0.11(0.03)	0.47(0.09)
RUH	0.13(0.03)	–0.09(0.05)	–0.14(0.02)	0.09(0.04)	0.02(0.01)	0.31(0.06)
RUW	–0.46(0.10)	0.86(0.05)	–0.16(0.03)	0.03(0.05)	–0.44(0.02)	0.31(0.07)
FUA	–0.13(0.03)	0.97(0.03)	0.12(0.08)	0.39(0.05)	–0.03(0.02)	0.59(0.10)
SL	0.44(0.05)	0.88(0.08)	0.14(0.06)	–0.51(0.05)	0.83(0.05)	0.51(0.01)
TL	–0.53(0.20)	0.99(0.08)	0.09(0.09)	0.37(0.03)	–0.66(0.06)	0.47(0.20)
UD	0.01(0.01)	–0.16(0.08)	–0.09(0.28)	0.03(0.01)	0.50(0.02(	0.31(0.09)

FTP, Fore teat placement; RTP, rear teat placement; RUH, rear udder height; RUW, rear udder width; FUA, fore udder attachment; SL,suspensory ligament; TL, teat length; UD, udder depth.

selecting for udder type traits would increase milk and could be changed the shape of the lactation curve and selection for udder type traits seems to have merit for genetically improving production performance.

SUMMARY

This study included 2 data sets: 8,222 records for genetic evaluation of lactation curve and 2,325 record for udder type traits of first parity Iranian Holstein cows between years 1998 to 2012. Genetic parameters were estimated by Wombat software with univariate and bivariate procedures. Wilmink's function was fitted to describe the lactation curve and associated production characteristics. Results for genetic relation between lactation curves parameters and udder type traits showed that cows with shorter teat length tended to have higher initial level of production; cows with longer teat length experienced a sudden decrease in production after peak yield; cows with close front teat placement would increase in their production shortly towards peak yield; while cows with shorter teat length and deep suspensory ligament reached earlier to peak yield during lactation. On the other hand cows with close front teat placement, tended to have more total 305–day milk yield.

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