Genetic Analysis of Udder Conformation Traits derived from AMS Recording in Dairy Cows

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Introduction

Udder conformation is an important trait in dairy cattle breeding because of its relation to milk production (Short and Lawlor, 1992), udder health (Samoré and Groen, 2006) and longevity (Vollema et al., 2000). Breeding values for udder conformation are usually estimated based on udder traits scored by classifiers which show substantial heritability. Alternatively, udder conformation traits can be derived from teat coordinates recorded by automatic milking systems (AMS).

Advantages of deriving udder conformation traits from AMS records as compared to classification scores are that AMS records are more objective, they are recorded every day, and records of not only heifers, but also of older cows are available. Carlström et al. (2016) and Byskov et al. (2012) showed that heritabilities of udder conformation traits derived from AMS records were higher than heritabilities of udder conformation traits scored by classifiers, and both studies showed that the genetic correlation between the two was close to unity. In both studies only data on first parity cows was used. However, AMS records teat coordinates of all visiting cows, including later parities.

Aim of the study was to estimate genetic parameters of udder conformation derived from AMS information in first and higher parities as well as genetic correlation between parities.

Material and methods

Trait definitions

The locations of the teat tips are recorded by AMS as Cartesian coordinates (x, y, z). The z coordinate is a measure of the distance from the teat tip to the floor, the y coordinate is a measure of the position of the teat on the axis parallel to the long side of the robot, and the x coordinate is a measure of the position of the teat on the axis perpendicular to the long side of the robot. The following traits were derived from teat coordinates: Front Teat Distance (FTD; in mm), Rear Teat Distance (RTD), Distance between Front and Rear teats (DFR), Udder Depth (UD, i.e. average distance (mm) between teat ends and the floor), Udder Balance (UB, i.e. average difference in distance (mm) to the floor between the front and rear teats)

The dataset

The dataset consisted of continuous milking records from the AMS. Records were obtained from 70 commercial dairy farms in the Netherlands in the time period from 14-03-2006 to 18-08-2016. The data included 85,023,135 AMS visits, with 39,668,935 AMS milking records on 20,017 cows. For this study every 20th visit was sampled to reduce data volume. The final dataset contained 1,535,290 records on 16,672 animals in 14 lactations, sired by 1913 sires. A pedigree file was available for all animals in the study.

Genetic analysis

For the AMS udder conformation traits in parity 1, 2 and 3, heritabilities were estimated using a univariate repeatability model, including age at calving, calving month and HYS classes as fixed effects as well as linear and cubic term of days in milk as covariates. Permanent environmental and animal effects (with a relationship matrix) were included as random terms. Genetic correlations were estimated in bivariate analyses with the same models as in the univariate analyses. Variance components were estimated with ASReml 4.1 (Gilmour et al., 2015).

Results and Discussion

Descriptive statistics

Averages of udder conformation traits in each of three parity classes are shown in Table 1. Distance between teats was largest in parity class 3 compared to class 1 and 2, e.g. average distance between front and rear teats (DFR) increased from 111.59 mm in parity 1 to 142.49 mm in parity 3. Mean UD decreased with parity class indicating that the average distance to the floor became lower which is a proxy for a deeper udder. Udder balance had a positive value in all parity classes representing that rear udder was higher above the floor than front udder. The lower value for udder balance in the 3rd parity class thus indicates that difference between rear and front udder in distance to the floor became smaller. Average rear teat distance, front teat distance and udder balance did not differ much across parity classes when considering the relatively large standard deviations.

Heritabilities

The heritabilities of AMS conformation traits ranged between 0.40 and 0.69 in parity 1, between 0.41 and 0.65 in parity 2 and between 0.37 and 0.67 in parity 3 (Table 1). Udder depth showed the highest heritabilities and udder balance the lowest. Byskov et al. (2012) and Carlström et al. (2016) found slightly lower heritabilities for udder conformation in first parity. The repeatabilities ranged between 0.89 and 0.97 and increased with parity. The high repeatabilities indicate that differences in udder conformation are rather consistent throughout each lactation and this is even more so for the higher parities. For most traits, the heritability decreased from parity 1 to 2 and from parity 1 to 3 (Table 1).

Table 1. Mean, SD, heritabilities () and repeatabilities () from the univariate analysis of the AMS udder conformation traits in parity 1, 2 and 3.

Traits[a]	Parity	Mean	SD		
RTD (mm)	1	62.98	22.48	0.47	0.89
	2	61.59	25.76	0.46	0.92
	3	64.07	28.12	0.37	0.94
FTD (mm)	1	136.28	28.31	0.60	0.92
	2	135.61	33.62	0.58	0.94
	3	137.50	36.58	0.53	0.94

UD (mm)	1	652.50	39.79	0.69	0.96
	2	602.33	44.61	0.65	0.97
	3	561.22	46.22	0.67	0.97
DFR (mm)	1	111.59	20.48	0.61	0.94
	2	132.81	24.43	0.56	0.94
	3	142.49	26.17	0.60	0.95
UB (mm)	1	19.54	14.66	0.40	0.90
	2	17.74	17.23	0.41	0.92
	3	13.79	18.65	0.38	0.93

Genetic correlations to later parity classes

For all traits, the genetic correlation between parity 1 and 2 and between 1 and 3 was the same and ranged between 0.94 and 0.99 (Table 4). Except for udder balance with a genetic correlation between parity 1 and 3 of 0.88, which is smaller than the genetic correlation between parity 1 and 2 (0.94). Since most genetic correlations were close to unity, traits are considered to be genetically similar over time. Permanent environmental correlations ranged from 0.81 to 0.94 between parity 1 and 2, and from 0.71 to 0.89 between parity 1 and 3, and were lower than the genetic correlations. The large permanent environmental correlations indicated that environmental factors with a permanent effect are responsible for a relatively large part of the variation, and these effects are consistent across parity classes.

Table 2. Genetic (), permanent environmental () and phenotypic () correlations between parities using a repeatability model. (standard errors were < 0.01).

	Parity 1-2			Parity 1-3		
Traits[a]						
RTD	0.97	0.87	0.79	0.96	0.79	0.72
FTD	0.98	0.90	0.84	0.97	0.85	0.79
UD	0.99	0.94	0.91	0.97	0.89	0.87
DFR	0.98	0.90	0.84	0.97	0.86	0.81
UB	0.94	0.81	0.74	0.88	0.71	0.65

[a] RTD: rear teat distance; FTD: front teat distance; UD: udder depth; DFR: distance front-rear; UB: udder balance.

Implications

Selection for udder conformation based on AMS information would be more effective than based on subjective scorings as breeding values with higher accuracy can be achieved. However, two important assumptions should be considered. Firstly, using a repeatability model within lactations would assume that genetic effects are consistent throughout lactations. As an alternative a random regression model can be applied in the analysis which gives the opportunity to better account for changes in genetic effects throughout lactations. Secondly, a study on the influence of stature on udder depth should be considered. The distance from the floor to the teats – the definition of udder depth derived from teat coordinates - may be in general higher for taller cows than for smaller cows. If there is indeed an effect of stature, then a correction for stature should be applied to prevent breeding of taller cows through breeding for improved udder depth.

Conclusion

The results of this study show that udder conformation traits can be derived from AMS teat coordinates and traits comprised large variation between animals in each parity class. Relative to the large variation, differences between parity classes 1, 2 and 3 were relatively small. Substantial heritability estimates were obtained with values of 0.40 and more in the first parity class. Repeatabilities were high which shows that phenotypic differences were substantially consistent within parities, but also between parities due to high permanent environmental correlations.

Genetic correlations of udder teat distances and udder depth with later parity classes were close to unity indicating that these traits are genetically similar.

Udder conformation based on AMS teat coordinates showed substantial genetic variance and high heritability estimates and selection on data from 1st parity will improve udder conformation in the 1st parity and because of the genetic correlations also in later parity classes.

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Acknowledgements

Dutch farmers that provided the data for this project are gratefully acknowledged. Lely Nederland is thanked for support in making data available for research.

Appendix

Table 1. Additive genetic (); permanent environmental ();residual ();phenotypic () variance), heritabilities () and repeatabilities () from the univariate analysis of the AMS udder conformation traits in parity 1, 2 and 3. SE between parentheses

Trait[a]	Parity						
RTD (mm)	1	231.75 (12.37)	202.38 (8.24)	55.56 (0.12)	489.69 (6.97)	0.47 (0.02)	0.89 (0.00)
	2	301.31 (19.63)	308.48 (13.61)	50.63 (0.12)	660.42 (10.69)	0.46 (0.02)	0.92 (0.00)

	3	299.44 (27.22)	449.95 (20.42)	51.47 (0.14)	800.86 (14.56)	0.37 (0.03)	0.94 (0.00)
FTD (mm)	1	483.06 (20.99)	254.18 (12.94)	61.28 (0.13)	798.52 (12.07)	0.60 (0.02)	0.92 (0.00)
	2	650.27 (33.76)	391.26 (21.68)	71.49 (0.16)	1113.0 (18.74)	0.58 (0.02)	0.94 (0.00)
	3	717.97 (48.97)	559.30 (33.49)	77.12 (0.21)	1354.40 (26.01)	0.53 (0.03)	0.94 (0.00)
UD (mm)	1	1123.44 (44.53)	453.17 (26.36)	60.82 (0.13)	1637.40 (25.93)	0.69 (0.02)	0.96 (0.00)
	2	1217.51 (58.28)	601.94 (36.35)	53.98 (0.12)	1873.4 (32.78)	0.65 (0.02)	0.97 (0.00)
	3	1401.69 (78.31)	634.10 (49.85)	55.72 (0.15)	2091.50 (42.35)	0.67 (0.03)	0.97 (0.00)
DFR (mm)	1	270.78 (11.74)	144.54 (7.24)	27.91 (0.06)	443.24 (6.78)	0.61 (0.02)	0.94 (0.00)
	2	316.28 (16.99)	212.26 (11.08)	32.00 (0.07)	560.54 (9.43)	0.56 (0.02)	0.94 (0.00)
	3	375.83 (23.00)	214.67 (15.10)	32.39 (0.09)	622.89 (12.25)	0.60 (0.03)	0.95 (0.00)
UB (mm)	1	82.72 (5.14)	102.07 (3.62)	19.90 (0.04)	204.69 (2.89)	0.40 (0.02)	0.90 (0.00)
	2	122.74 (8.58)	150.64 (6.12)	23.31 (0.05)	296.70 (4.71)	0.41 (0.02)	0.92 (0.00)
	3	131.79 (11.75)	190.93 (8.77)	23.16 (0.06)	345.88 (6.29)	0.38 (0.03)	0.93 (0.00)

[a] RTD: rear teat distance; FTD: front teat distance; UD: udder depth; DFR: distance front-rear; UB: udder balance.