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Genetic parameters of conformation traits in Polish Simmental cattle*

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The aim of the study was to estimate genetic parameters of 6 descriptive and 21 linear conformation traits in Simmentals. The data were obtained from FedInfo, the Polish national recording system, and were provided by the Polish Federation of Cattle Breeders and Dairy Farmers. A multi-trait animal model and a Bayesian method via Gibbs sampling (BLUPf90 package) were used to estimate the genetic parameters of 6 descriptive and 21 linear conformation traits. The analysis included 1.397 recorded Simmental cows and one generation of ancestors, totaling 2.330 individuals. The cows, born between 2007 and 2017, were daughters of 115 sires.

The heritability of descriptive traits was low to high and ranged from 0.09 for feet-and-legs to 0.55 for muscularity. Among the linear traits, the highest heritability was estimated for chest circumference (0.69), front-muscularity (0.61) and rear-muscularity (0.60). Traits related to legs were lowly heritable. Descriptive traits showed moderate to high genetic correlations; all were positive and ranged from 0.23 to 0.86. The lowest genetic correlations were estimated between udder and muscularity (0.23), whereas the highest between overall conformation and both udder (0.85) and muscularity (0.86). Among the linear traits the highest genetic correlations occurred between chest circumference and chest width (0.84), front-muscularity (0.88) and rear-muscularity (0.80), as well as between chest width and both front-muscularity (0.84) and rear-muscularity (0.82). Front-muscularity and rear-muscularity were also highly genetically correlated (0.89).

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Over many decades, genetic selection of dairy cattle was focused on improving the quantity and quality of milk. Selection for increased milk production led to worsened cow health and fertility. At the turn of the 20th and 21st centuries, many countries revised their selection indices to support more balanced breeding goals, emphasizing both functional and production traits. Conformation was one of the first nonproduction traits scored and included in the selection index for dairy cattle [De Haas *et al*. 2007, Němcová *et al*. 2011, Battagin *et al*. 2012].

Conformation traits can be measured relatively early during the first lactation and can be used as predictors useful for making decisions about the breeding, mating and selection of dairy cattle. The use of type traits as predictors of herd life has been also investigated [Vukasinovic *et al.* 2002]. Many conformation traits have relatively high heritability and are relatively strongly genetically correlated with other less heritable traits (milk production and functional traits), so selection for those traits with the use of conformation traits as predictors can be more effective [Schneider *et al*. 2003, Zavadilová and Štípková 2012].

At the national level, conformation traits are scored as linear or composite traits [Battagin *et al*. 2012, Otwinowska-Mindur *et al*. 2016]. Linear traits are measurements of individual type traits, whereas composite traits are groups of linear traits relating to a specific aspect of the body, such as size, type and conformation, feet and legs, udder, or muscularity. The linear traits are measured from one biological extreme to the other, usually on a scale of 1 to 9, and composite traits have assigned scores ranging from 50 to 100 [ICAR, 2011].

The Simmental breed is the second most important breed in Europe, following the group of Holstein-Friesian cattle and holsteinized populations. Dual-purpose Simmental cattle show high milk and meat production, good fertility, and profitability [Perišić *et al.* 2009, Xu *et al.* 2022]. The Polish population of Simmental cattle is small; the cows are traditionally kept in small herds, mainly in south-eastern Poland.

While the relationship between the conformation traits of dairy cows is studied extensively [De Haas *et al*. 2007, Němcová *et al*. 2011, Battagin *et al*. 2012, Zavadilová and Štípková 2012, Otwinowska-Mindur *et al.* 2016], research on dual-purpose Simmental cattle has rarely been done [Logar *et al.* 2011, Xu *et al*. 2022]. The heritabilities of composite traits estimated by Xu et al. (2022) were low to moderate (0.07-0.47), as were the heritabilities for linear traits (0.01-0.43). Traits describing feed and legs were the least heritable for both types of conformation traits (composite and linear), in line with the estimates obtained for Holstein cattle [Němcová *et al*. 2011, Otwinowska-Mindur *et al.* 2016]. To the best of our knowledge, the genetic parameters for all conformation traits have not been estimated for the Polish Simmental population. Consequently, to make such estimates for the Polish Simmental population was the aim of this study.

Material and methods

Data

Conformation data of Simmental cows come from the Polish National Recording System (FedInfo) and were obtained from the Polish Federation of Cattle Breeders and Dairy Farmers. To ensure the genetic parameters were estimable, the dataset was edited. After the editing, 1 397 individuals were used for calculations out of the original set of 10 283 recorded cows. The cows, born between 2007 and 2017, calved for the first time, came from-147 herds.

The conformation traits included 6 composite and 21 linearly scored traits (Tab. 1 and 2). The composite traits were expressed on a scale of 50 to 100. Most of the linear traits were scored on a nine-point scale, with two exceptions: stature and chest circumference, which were expressed in centimetres. The optimal values and biological extremes of the linear traits are presented in Table 2. All conformation traits were evaluated once between day 15 and 305 of the first lactation.

Table 1. Characteristics of the composite traits of Polish Simmental cows

Trait	Mean	Standard deviation
Size	78.69	4.27
Type and conformation	79.62	3.20
Feet and legs	77.16	2.72
Udder	77.87	3.14
Muscularity	77.55	3.34
Overall conformation	78.18	2.59

Table 2. Characteristics of the linear traits of Polish Simmental cows

Trait	Mean	Standard deviation	Optimal score	Score	
				1	2
Stature (cm)	137.73	3.35			
Chest circumference (cm)	189.45	8.99			
Body depth	6.30	1.30	6-7	shallow	deep
Chest width	5.22	1.59	6	narrow	wide
Rump angle	6.08	6.08	5	high pins	extreme slope
Rump width	5.67	5.67	7-8	narrow	wide
Rear legs – side view	5.22	1.29	5	straight	sickled
Foot angle	6.29	1.32	7	very low angle	very steep
Rear leg – rear view	5.86	1.63	9	extreme toe-out	parallel feet
Fore udder	5.81	1.20	7	weak and loose	extremely strong
Rear udder height	3.65	0.89	8	low	high
Central ligament	2.95	1.04	9	broken	strong
Udder depth	6.22	1.43	7	low	high
Udder width	6.42	1.53	9	narrow	wide
Rear teat placement	5.33	1.47	5	outside	inside
Front teat placement	4.31	1.48	4	outside of quarter	inside of quarter
Teat length	5.68	1.55	4-5	short	long
Teat thickness	5.55	1.31	5	thick	thin
Front muscularity	5.29	1.39	5-6	weak	strong
Rear muscularity	5.71	1.42	5-6	weak	strong
Locomotion	5.71	1.47	9	short stride	long stride

Data were restricted to a minimum of 2 daughters per sire and a minimum of 2 contemporaries per herd-year-season-classifier subclass. Only the cows that calved for the first time at age 18-48 months were selected. The cows were daughters of 115 sires and 1 073 dams, among which 255 had their own conformation trait data. One generation of ancestors was added to the selected set of cows with records. Thus, the calculations totalled 2 330 individuals. Two calving seasons were defined for the study: summer (April-September) and winter (October-March). Each cow was assigned to one of twenty 15-day lactation stages.

Statistical analysis

A multi-trait animal model and a Bayesian method via Gibbs sampling (BLUPf90 package) were used to estimate (co)variance components (Misztal, 2008). The linear model for k-th trait was as follows:

$$Y_{ijkl} = A_i + HYSC_j + L_k + \beta X_i + e_{ijkl}$$

Y_{ijkl} – conformation score for i-th cow calved at age X_l in j-th herd-year-season of calving-classifier subclass in k-th lactation stage;

A_i – random additive animal effect (2 330 levels);

$HYSC_j$ – fixed herd-year-season of calving-classifier effect (325 levels);

L_k – fixed lactation stage effect (20 levels);

β – linear regression on age at calving (X_l);

X_i – age at calving (18–48 months);

e_{ijkl} – residual effect.

The number of the generated samples of (co)variance components was 200 000. The first 20 000 samples were discarded as burn-in based on the plot of Gibbs samples. Then only every 10th sample was selected for use in calculations of heritabilities and correlations.

Results and discussion

Statistics of composite traits

The basic characteristics of all the analysed traits are presented in Tables 1 and 2. Among the composite traits, the mean values were the highest for type and conformation (79.62) and size (78.69), and the lowest for feet and legs (77.16). Slightly more variable than the others were muscularity (SD = 3.34) and size (SD = 4.27).

In literature, slightly lower values were obtained by Strapáková *et al.* [2021] for Slovak Simmental cows and by Xu *et al*. [2022] for the Chinese Simmental population, indicating potential breed or regional differences. Novotny *et al*. [2017] also presented scores lower than our scores for composite traits (from 75.60 for feet and legs to 77.84 for frame) for Czech Fleckvieh (Simmental-type) cattle.

Composite conformation traits can be scored differently. In Poland, they are scored on a 50-point scale (50-100), however, in countries such as Slovenia [Logar *et al.* 2011], Italy [Frigo *et al*. 2013] or Hungary [Török *et al*. 2021] these traits are evaluated on a 9-point scale. According to Török *et al*. [2021] the average score for the four composite conformation traits they obtained – size (5.6), muscularity (5.1), feet and legs (5.5) and udder (5.3) – are in the middle of the scale, with the optimum being 9. In Slovenia, Logar *et al*. [2011] proposed additionally a new 5-point scale for that trait. They found that muscularity scored for Slovenian Simmental cows had an average of about 6.0 on a 9-point scale and about 3.3 on a 5-point scale. In Italian Simmental cows, Frigo *et al.* [2013] reported that mean muscularity evaluated on a 9-point scale was about 6.0.

In Poland, stature and chest circumference are expressed in centimetres. Size traits such as stature and chest circumference are closely related to body weight, an important functional trait regulating feed efficiency and energy balance in dairy cattle [De Haas *et al*. 2007]. The mean stature of Polish Simmental cows in our study was about 138 cm, resembling that obtained by Xu *et al*. [2022]. The average chest circumference for Simmental cows (189.5 cm) was less than that obtained by Strapáková *et al*. [2021] for Slovak Simmental (about 197 cm).

The average linear scores ranged from 2.95 for central ligament to 6.42 for udder width. According to Strapáková *et al*. [2021] and Xu *et al*. [2022], many conformation traits relate to productive life. Cows with deeper udders, a stronger, tighter fore udder attachment and centrally placed teats have longer productive life, leading to increasing milk production and impacting the profitability of breeding. Therefore, the selection criteria combine production, reproduction, and conformation traits.

In our study the averages of 7 traits were closest to optimal scores (Tab. 2) e.g. body depth (6.30), rear legs – side view (5.22), rear (5.33) and front teat placement (4.31), front (5.29) and rear muscularity (5.71). For most linear conformation traits, the average scores were around or slightly above the middle of the scale (5.0), which is not always the desired value. Our scores are consistent with results presented by Erdem *et al*. [2017]. Novotny *et al*. [2017], Strapáková *et al*. [2021], Török *et al.* [2021] and Xu *et al*. [2022]. Török *et al*. [2021] obtained a higher score for central ligament (6.0) and a lower score for teat length (4.0) than those presented in our study. Logar *et al*. [2011], who proposed a new scale also for some linear conformation traits, obtained results also slightly above the middle of the scale for body depth on a 5-point scale (3.3) and on a 3-point scale (2.1).

Genetic parameters of composite traits

Table 3 presents the heritabilities and genetic (r_g) and phenotypic (r_p) correlations of composite traits for the Polish Simmental population. The highest heritability was estimated for muscularity (0.55) and size (0.40), which indicates that these traits are strongly influenced by genetic factors, suggesting their potential for effective selection. In contrast, feet, and legs (0.09) and udder (0.11) had the lowest heritability, suggesting that these traits are more affected by environmental factors. These results are crucial for breeding programs, as they highlight the traits that may require different methods during genetic improvement, especially since the environment has a considerable influence on low-heritable traits.

Both the genetic and phenotypic correlations were positive and moderate or high, ranging between 0.19 and 0.89. The genetic and phenotypic correlations were the lowest between udder and muscularity (r_g = 0.23, r_p = 0.19), indicating a relatively weak genetic connection between these traits. The correlations were the highest between overall conformation and udder (rg = 0.85, rp = 0.89), as well as between overall conformation and muscularity (rg = 0.86, rp = 0.82). This strong correlation implies that selecting for overall conformation may also lead to improvements in udder and muscularity traits, which could be important in breeding strategies aimed at several traits simultaneously.

The values of the genetic correlations were higher than the phenotypic ones, except for the correlation of udder with overall conformation (r_g = 0.85, r_p = 0.89). The lowest heritability for feet and legs is consistent with findings by Xu *et al.* [2022] for Chinese Simmental cattle and by Novotny *et al.* [2017] for Czech Fleckvieh cattle. Low heritability for feet and legs suggests difficulty in improvement of this trait. Those authors [Xu *et al*. 2022, Novotny *et al*. 2017] estimated heritabilities for size and muscularity similar to those we obtained, indicating uniformity of these traits across different Simmental populations. However, Xu *et al*. [2022] found higher heritability for udder, perhaps due to differences in the population structure, management practices and/or selection methods in the Chinese Simmental population.

Table 3. Heritability (on diagonal, in bold), genetic correlations (above diagonal), and phenotypic correlations (below diagonal) of composite conformation traits in Polish Simmental cows

Trait	Size	Type and conformation	Feet and legs	Udder	Muscularity	Overall conformation
Size	**0.40**	0.86	0.54	0.34	0.56	0.75
Type and conformation	0.70	**0.29**	0.57	0.49	0.73	0.83
Feet and legs	0.35	0.47	**0.09**	0.53	0.32	0.74
Udder	0.20	0.39	0.36	**0.11**	0.23	0.85
Muscularity	0.46	0.61	0.30	0.19	**0.55**	0.86
Overall conformation	0.52	0.67	0.62	0.89	0.82	**0.16**

Genetic parameters of linear traits

Table 4 shows the genetic parameters of linear type traits. Heritabilities of traits expressed in centimetres, i.e. stature and chest circumference, were moderate and

Table 4. Heritability (on diagonal, in bold), genetic correlations (above diagonal), and phenotypic correlations (below diagonal) of linear conformation traits in Polish Simmental cows

Trait	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	**0.47**	0.75	0.17	0.35	0.15	0.36	-0.15	0.02	0.25	0.22	0.35	0.16	0.48	0.24	0.17	0.13	0.05	0.72	0.58	0.44	0.36
2	0.63	**0.69**	0.61	0.84	-0.16	0.77	-0.31	0.29	0.35	0.10	-0.17	-0.16	0.00	0.08	-0.18	0.04	0.27	0.32	0.88	0.80	0.21
3	0.17	0.56	**0.21**	0.69	-0.04	0.14	-0.02	-0.02	0.20	-0.03	-0.11	-0.06	-0.29	0.13	-0.04	0.11	0.14	0.26	0.57	0.56	0.31
4	0.31	0.69	0.51	**0.14**	-0.01	0.34	-0.15	0.09	0.31	0.08	-0.03	-0.01	-0.02	0.11	-0.08	0.05	0.21	0.06	0.84	0.82	0.33
5	0.16	0.04	-0.06	0.01	**0.27**	0.08	0.01	-0.19	-0.20	-0.19	-0.07	-0.16	-0.03	0.11	-0.08	-0.02	-0.13	-0.08	-0.20	-0.20	0.33
6	0.31	0.59	0.22	0.32	0.05	**0.26**	-0.07	0.17	0.16	0.13	0.20	0.12	0.19	-0.01	0.16	0.10	-0.02	0.21	0.65	0.59	0.35
7	-0.14	-0.15	-0.04	-0.08	-0.03	-0.03	**0.13**	-0.36	-0.27	-0.18	-0.16	0.01	-0.21	0.27	0.17	-0.05	-0.04	0.07	-0.25	-0.19	0.06
8	0.16	0.16	0.10	0.11	-0.04	0.10	-0.14	**0.07**	0.32	0.10	0.23	0.15	0.22	-0.03	0.07	0.08	-0.18	0.18	0.31	0.24	0.50
9	0.11	0.21	0.11	0.12	-0.06	0.08	-0.25	0.21	**0.09**	0.22	0.19	-0.01	0.07	0.12	0.07	0.15	-0.05	0.12	0.35	0.37	0.20
10	0.07	0.11	0.02	0.04	-0.13	0.02	-0.13	0.09	0.12	**0.22**	0.27	0.31	0.69	0.10	0.23	0.27	0.04	0.23	0.21	0.21	0.23
11	0.16	-0.05	0.01	-0.04	-0.05	0.06	-0.07	0.07	0.12	0.27	**0.24**	0.13	0.38	0.66	0.30	0.14	0.04	0.50	-0.21	-0.26	0.21
12	0.05	0.01	-0.02	-0.04	-0.07	0.01	-0.02	0.03	0.04	0.29	0.25	**0.17**	0.40	0.10	0.63	0.43	-0.05	0.27	-0.13	-0.17	0.18
13	0.20	0.03	-0.26	-0.09	-0.09	-0.01	-0.12	0.05	0.06	0.45	0.22	0.27	**0.29**	-0.07	0.30	0.25	-0.04	0.34	-0.04	-0.09	0.13
14	0.16	-0.04	0.22	0.18	-0.03	0.19	-0.08	0.09	0.21	0.15	0.47	0.16	-0.09	**0.17**	0.29	0.27	-0.04	0.39	0.02	-0.07	-0.01
15	0.05	-0.14	0.01	-0.02	-0.05	0.02	-0.02	0.01	0.02	0.18	0.19	0.38	0.21	0.14	**0.30**	0.64	-0.13	0.32	-0.03	-0.04	0.21
16	0.04	0.03	0.04	0.02	-0.04	0.01	-0.02	0.02	0.03	0.19	0.09	0.20	0.16	0.11	0.47	**0.28**	-0.09	0.22	0.05	0.07	0.13
17	0.06	0.12	0.09	0.09	-0.04	0.04	-0.03	0.02	0.04	0.03	0.03	0.04	-0.03	0.06	-0.06	-0.06	**0.28**	-0.04	0.20	0.19	-0.07
18	0.44	0.12	0.25	0.10	0.02	0.17	-0.04	0.11	0.12	0.11	0.30	0.15	0.07	0.30	0.13	0.09	0.03	**0.27**	0.20	0.17	0.17
19	0.44	0.76	0.53	0.69	0.04	0.55	-0.15	0.17	0.24	0.16	-0.10	0.01	0.01	-0.07	0.01	0.03	0.12	0.13	**0.61**	0.89	0.34
20	0.35	0.68	0.51	0.65	0.03	0.51	-0.13	0.15	0.24	0.18	-0.13	-0.04	-0.01	-0.12	0.01	0.03	0.09	0.12	0.84	**0.60**	0.36
21	0.34	0.28	0.25	0.29	0.02	0.30	-0.24	0.34	0.28	0.16	0.21	0.19	0.12	0.08	0.12	0.10	0.01	0.07	0.32	0.22	**0.53**

1 – stature, 2 – chest circumference, 3 – body depth, 4 – chest width, 5 – rump angle, 6 – rump width, 7 – rear legs – side view, 8 – foot angle, 9 – rear leg – rear view, 10 – fore udder, 11 – rear udder height, 12 – central ligament, 13 – udder depth, 14 – udder width, 15 – rear teat placement, 16 – front teat placement, 17 – teat length, 18 – teat thickness, 19 – front muscularity, 20 – rear muscularity, 21 – locomotion.

high: 0.47 and 0.69, respectively. Findings from Xu *et al*. [2022] provided higher values for stature then our heritability ratio (0.56) in Simmental cows. De Haas *et al.* (2007) reported higher heritabilities for stature (0.64-0.74) in Brown Swiss, Holstein, and Red and White breeds, highlighting breed- and population-specific variation in genetic influence on stature. The heritability of stature estimated in our study is in line with data reported for various breeds, including Holstein-Friesian and Brown Swiss cows [DeGroot *et al*. 2002, Berry *et al*. 2004, Laursen *et al*. 2009, Samoré *et al.* 2010, Němcová *et al*. 2011, Dadpasand *et al.* 2012, Otwinowska-Mindur *et al*. 2016, Gibson and Dechow 2018]. Among the linear traits, the least heritable were traits describing leg structure, i.e. foot angle (0.07), rear leg – rear view (0.09) and rear legs – side view (0.13); the most heritable traits were chest circumference (0.69), front muscularity (0.61) and rear muscularity (0.60).

High heritability boosts the effectiveness of selection for this trait. Both front and rear muscularity were strongly genetically correlated with chest circumference (0.88 and 0.80, respectively) and with chest width (0.84 and 0.82, respectively), suggesting that these traits are strongly associated and that improvement of one could lead to correlated improvements of the others. The genetic correlation between chest circumference and chest width was also high (0.84), as was that between front muscularity and rear muscularity (0.89). These strong genetic correlations highlight the potential for simultaneous improvement of those traits related to muscularity and body.

The phenotypic correlations were weaker than the genetic ones among most linear conformation traits. In most cases they were of the same sign, indicating the same direction of both relationships. The heritabilities estimated by Xu *et al*. [2022] for many linearly scored traits resembled our results. Logar *et al.* [2011] estimated similar heritability for body depth (0.24) scored on a 5-point scale and lower heritability for that trait (0.01) scored on a 3-point scale. Notably, Xu *et al*. [2022] concluded that the differences in magnitude of the heritabilities observed in previous studies may be due to the scales used for measurement and scoring, the number of animals, the breeds, statistical models, data editing procedures, and consistency among evaluations.

Correlations between composite and linear traits

In many studies the relationship between conformation traits for different breeds is like or higher than our results from the Polish Simmental population [DeGroot *et al.* 2002, Berry *et al*. 2004, Ptak *et al.* 2009]. The genetic correlations between conformation traits reported in the literature differ among populations.

Generally, the genetic correlations are higher than the phenotypic ones. Table 5 shows the genetic and phenotypic correlations between composite and linear conformation traits. The estimated genetic correlations were positive in most cases, indicating that selection for one trait is likely to lead to improvements in another. The genetic correlations were high between stature and three composite traits: size (0.98), type and conformation (0.85) and overall conformation (0.74). Also highly genetically correlated were chest circumference and size (0.83) as well as chest circumference and overall conformation (0.80), which suggests that selection focused on chest circumference may serve to improve overall body size and conformation.

Table 5. Genetic correlations (r_g) and phenotypic correlations (r_p) between composite and linear conformation traits in Polish Simmental cows

Item	Size		Type and conformation		Feet and legs		Udder		Muscularity		Overall conformation	
	r_g	r_p	r_g	r_p	r_g	r_p	r_g	r_p	r_g	r_p	r_g	r_p
Stature	0.98	0.90	0.85	0.62	0.55	0.31	0.34	0.15	0.38	0.34	0.74	0.45
Chest circumference	0.83	0.50	0.70	0.46	0.32	0.22	0.19	0.14	0.72	0.57	0.80	0.59
Body depth	0.25	0.30	0.26	0.29	0.10	0.17	-0.03	0.11	0.39	0.32	0.13	0.22
Chest width	0.42	0.39	0.19	0.21	0.18	0.14	-0.05	0.06	0.80	0.52	0.16	0.18
Rump angle	0.12	0.13	-0.06	-0.02	-0.11	-0.04	-0.17	-0.08	-0.22	0.05	-0.09	-0.05
Rump width	0.40	0.35	0.30	0.25	0.28	0.14	0.15	0.08	0.48	0.38	0.32	0.19
Rear legs – side view	-0.13	-0.14	-0.02	-0.12	-0.63	-0.35	-0.11	-0.11	0.04	-0.03	-0.21	-0.21
Foot angle	0.29	0.18	0.25	0.17	0.69	0.42	0.20	0.10	0.07	0.05	0.35	0.23
Rear leg - rear view	0.27	0.14	0.23	0.17	0.49	0.44	0.17	0.17	0.26	0.31	0.29	0.28
Fore udder	0.22	0.09	0.28	0.17	0.40	0.23	0.71	0.47	0.15	0.08	0.58	0.43
Rear udder height	0.33	0.15	0.46	0.28	0.49	0.23	0.67	0.46	-0.31	-0.16	0.65	0.46
Central ligament	0.18	0.05	0.32	0.14	0.26	0.13	0.41	0.36	-0.27	-0.15	0.39	0.32
Udder depth	0.44	0.15	0.42	0.13	0.57	0.16	0.66	0.29	-0.12	-0.02	0.68	0.29
Udder width	0.26	0.22	0.36	0.31	0.22	0.27	0.51	0.46	-0.34	-0.17	0.48	0.48
Rear teat placement	0.17	0.06	0.28	0.11	0.13	0.09	0.41	0.27	-0.07	0.04	0.36	0.24
Front teat placement	0.21	0.05	0.21	0.09	0.18	0.08	0.44	0.22	-0.11	-0.10	0.36	0.20
Teat length	0.05	0.06	0.04	0.05	-0.04	0.07	0.01	0.06	0.02	-0.02	0.03	0.08
Teat thickness	0.72	0.50	0.94	0.77	0.45	0.34	0.48	0.35	0.09	0.04	0.03	0.55
Front muscularity	0.70	0.38	0.68	0.44	0.32	0.22	0.07	0.12	0.81	0.66	0.79	0.58
Rear muscularity	0.59	0.31	0.66	0.42	0.25	0.19	0.07	0.10	0.89	0.70	0.77	0.56
Locomotion	0.45	0.39	0.14	0.40	0.33	0.65	-0.11	0.22	0.38	0.37	0.27	0.47

Teat thickness and type and conformation were also strongly genetically correlated (0.94), whereas teat length was very weakly genetically correlated with all composite type traits (0.01-0.08). This weak correlation for teat length suggests that it is independent of overall body conformation. It is, however, an important trait due to the increasingly frequent use of milking machines in our country.

High positive genetic correlations were estimated between muscularity (as a composite trait) and three linear traits: chest width (0.80), front muscularity (0.81) and rear muscularity (0.89). These correlations point to the interconnectedness of muscular traits, suggesting that selection for one muscular trait could enhance overall muscularity.

For most pairs of composite and linear conformation traits the phenotypic relationships were weaker than the genetic ones. The high values of the genetic correlations suggest that genetic improvement of one of these traits could produce a correlated response in the correlated trait. Such knowledge is particularly valuable for breeders aiming to achieve multi-trait improvement. On the other hand, the genetic correlation between each pair of the linear traits that describe legs, i.e. rear legs – side view, foot angle and rear leg – rear view, were moderate (from -0.36 to 0.32).

Similar genetic correlations between foot angle and the other two leg traits (from -0.35 to 0.25) were reported by Ptak *et al*. [2009] for Holstein cows, with one exception: the genetic correlation between rear legs – side view and rear leg – rear view (-0.49). These moderate correlations suggest that while these traits are related, they are influenced by different genetic and environmental factors. Lower negative genetic correlations between rear legs – side view, foot angle and rear leg – rear view (from -0.11 to -0.05) were given by Häggman and Juga [2013] for Finnish Holstein cows.

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