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Genetic parameters for linear type traits including locomotion in Italian Jersey cattle breed

Chiara Roveglia[a], Giovanni Niero[a,*], Tania Bobbo[a], Mauro Penasa[a], Raffaella Finocchiaro[b], Giulio Visentin[b], Nicolas Lopez-Villalobos[c], Martino Cassandro[a]

[a] Department of Agronomy, Food, Natural resources, Animals and Environment (DAFNAE), University of Padova, Viale dell'Università 16, Legnaro (PD) 35020, Italy
[b] Associazione Nazionale Allevatori della Razza Frisona e Jersey Italiana (ANAFIJ), Via Bergamo 292, Cremona 26100, Italy
[c] School of Agriculture and Environment, Massey University, Private Bag 11 222, Palmerston North 4442, New Zealand

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ABSTRACT

This study aimed to estimate genetic parameters for 19 linear type traits related to frame, udder, and feet and legs, and for final score of 10,305 first-parity Jersey cows evaluated between 2004 and 2016. Since scoring of locomotion in Jersey breed started in 2009, a subset of 6853 animals was extracted from the original data and used to investigate sources of variation and heritability of locomotion score, and its associations with the other traits. Univariate animal models were used to estimate variance components of type traits and bivariate analyses were implemented to obtain genetic correlations between traits. Fixed effects were herd-year-classifier, season of evaluation, stage of lactation at scoring and age at calving, and the random effects were additive genetic animal and the residual. Herd-year-classifier was the major source of variation affecting the traits. Heritabilities were low with the only exception of a moderate heritability (0.32 ± 0.02) for stature. The lowest heritabilities were estimated for feet and legs traits with values between 0.04 ± 0.02 (rear leg set side view, rear leg set rear view and locomotion) and 0.07 ± 0.02 (foot angle). The final score had heritability of 0.20 ± 0.02. Genetic correlations were generally stronger than their phenotypic counterparts. Overall, frame traits were weakly correlated with feet and legs, and udder traits, except for rump width, which showed moderate correlations with almost all traits, and angularity which showed the greatest correlations with rear udder height (0.61 ± 0.10) and rear udder width (0.62 ± 0.11). Genetic correlations between locomotion and frame traits ranged from 0.08 ± 0.22 (angularity) to 0.32 ± 0.16 (stature). The strongest correlations were estimated between locomotion and other feet and legs traits, but also with front teat placement (0.97 ± 0.19) and with rear teat placement (0.88 ± 0.17). Results of the present study will be used to enhance genetic evaluation of linear type traits in Jersey cattle breed.

1. Introduction

The Jersey cattle breed is characterized by smaller body size, lower production and milk with higher fat and protein percentages, compared with other cosmopolitan dairy breeds. These features make Jersey cows suitable for both intensive and non-intensive farming systems, such as grazing and once-a-day milking (Lembeye et al., 2016). Also, Jerseys are generally appreciated for their longevity, fertility and biological feed efficiency, expressed as kilograms of fat and protein per kilogram of body weight (Lopez-Villalobos et al., 2014; Roveglia et al., 2019). These aspects are translated into greater incomes for farmers inserted in quality-based payment systems. Milk of Jersey cows has better coagulation properties and results in greater cheese yield than milk of Holstein cows (Auldist et al., 2004; Visentin et al., 2015); this might be of particular interest in the Italian dairy industry where more than 70% of milk is used for cheese making, and almost 50% of this percentage is destined to manufacture Protected Designation of Origin products (Pretto et al., 2013).

Type traits have attracted the attention of farmers and scientific community due to the increasing awareness about animal welfare and consumer demands for healthy and welfare-friendly animal products (Egger-Danner et al., 2015). An example is locomotion which is directly

* Corresponding author.
E-mail addresses: chiara.roveglia@phd.unipd.it (C. Roveglia), giovanni.niero@phd.unipd.it (G. Niero), tania.bobbo@unipd.it (T. Bobbo), mauro.penasa@unipd.it (M. Penasa), raffaellafinocchiaro@anafi.it (R. Finocchiaro), giuliovisentin@anafi.it (G. Visentin), n.lopez-villalobos@massey.ac.nz (N. Lopez-Villalobos), martino.cassandro@unipd.it (M. Cassandro).

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associated with animal welfare, with particular regard to lameness (Jabbar et al., 2016). For these reasons, over the past years great emphasis has been placed on the inclusion of functional traits into selection programmes (Egger-Danner et al., 2015; Miglior et al., 2005). Selection for type traits has been commonly carried out in several genetic programs of cattle populations worldwide due to the economic importance of some conformation features (Miglior et al., 2012). Indeed, udder type traits have shown strong associations with longevity in US Jersey cattle (Caraviello et al., 2003) and Canadian Jerseys (Sewalem et al., 2005). Favourable genetic correlations of type traits with milk yield, body weight, fertility and somatic cells of primiparous Holstein-Friesian cows have been reported by Berry et al. (2004), supporting the feasibility of indirectly selecting for improved fertility and health of animals.

While phenotypic and genetic aspects of linear type traits have been widely documented in Holstein and other cattle breeds (Battagin et al., 2013; Gibson and Dechow, 2018), a paucity of information has been reported for Jersey (Biscarini et al., 2003; Cue et al., 1996; du Toit et al., 2012). In particular, Biscarini et al. (2003) estimated genetic parameters for 16 type traits in first-lactation Italian Jerseys; results led to a subsequent inclusion of three udder type traits, namely udder depth, udder support and fore udder attachment in the current selection index of Italian Jersey breed (IQJ), which at the beginning considered only production traits (Biffani et al., 2003). The study of Biscarini et al. (2003) is quite dated and there is a need to update estimates of genetic parameters of type traits on a larger dataset and to include locomotion score, which is a novel trait of economic relevance in the dairy herd. Therefore, the aims of the present study were to assess sources of variation of type traits, including locomotion and final score, and to estimate their genetic parameters in Italian Jersey cows.

2. Materials and methods

2.1. Dataset and editing

Data were provided by the National Association of Holstein and Jersey Breeders (ANAFIJ, Cremona, Italy) and consisted of 15,816 linear type trait records of first-lactation cows (one record per cow) in 1055 herds. Type traits ($n = 19$) were evaluated by trained classifiers according to a linear scale from 1 to 50 points, with 1-unit increments. In the present study, traits were divided in 3 groups, namely the “frame” group, which included 6 descriptors: stature, chest width, body depth, angularity, rump angle and rump width; the “feet and legs” group, which included 5 descriptors: rear leg set side view, rear leg set rear view, foot angle, feet and legs functionality, and locomotion; and the “udder” group, which included 8 descriptors: fore udder attachment, rear udder height, rear udder width, udder support, udder depth, front teat placement, front teat length and rear teat placement. In addition, the final score, which is a weighted combination of structure traits (20%), dairy strength traits (20%), feet and legs traits (20%) and udder traits (40%), was available; this overall trait is assessed using a linear scale from 50 to 100 points, with 1-unit increments.

First-lactation cows were required to have age at calving between 18 and 42 months and to have been evaluated between 5 and 305 days after calving. Contemporary groups were defined as cows scored in the same herd-year by the same classifier, and contemporary groups with less than 3 observations were discarded from the dataset. Following these edits, 10,305 cows scored by 42 classifiers in 231 herds from 2004 to 2016 were available for statistical analysis. Because the recording of locomotion started in 2009, fewer observations were available for this trait. Therefore, a subset of 6853 cows scored by 35 classifiers in 154 herds from 2009 to 2016 was extracted from the previous dataset and used to investigate sources of variation and heritability of locomotion, and its associations with other traits.

2.2. Statistical analysis

Preliminary analysis showed that all traits were normally distributed. Sources of variation of linear type traits and final score were investigated using the GLM procedure of SAS version 9.4 (SAS Institute Inc., Cary, NC) according to the following linear model:

$$Y_{ijkl} = \mu + \text{hyc}_i + \text{stage}_j + \text{age}_k + \text{season}_l + e_{ijkl},$$

where Y_{ijkl} is the dependent variable (a linear type trait or final score); μ the overall mean; hyc_i the fixed effect of the ith herd-year-classifier (i = 1–731; for the subset, i = 1–438); stage_j the fixed effect of the jth class of stage of lactation at scoring (j = 1–10, with classes of 30 days each); age_k the fixed effect of the kth class of age at calving (k = 1 to 9, the first being a class from 18 to 22 months, followed by 7 classes of 2 months each, and the last being a class from 36 to 42 months); season_l the fixed effect of the lth season of evaluation (l = winter: December, January, February; spring: March, April, May; summer: June, July, August; autumn: September, October, November); and e_{ijkl} the random residual $\sim N(0, \sigma_e^2)$.

Variance and covariance components of type traits were estimated through univariate and bivariate animal models, respectively, using the package VCE6 (Neumaier and Groeneveld, 1998; Groeneveld et al., 2010). Fixed effects considered in the animal models were the same described above. The pedigree file was provided by ANAFIJ and included cows with phenotypic records and their ancestors up to 6 generations back, for a total of 22,577 animals (18,290 for the subset). Heritability (h^2), genetic correlations (r_a) and phenotypic correlations (r_p) were calculated as:

$$h^2 = \frac{\sigma^2{}_a}{\sigma^2{}_a + \sigma^2{}_e},\ r_a = \frac{\sigma_{a1,a2}}{\sigma_{a1}\cdot\sigma_{a2}} \text{and } r_p = \frac{\sigma_{p1,p2}}{\sigma_{p1}\cdot\sigma_{p2}},$$

where σ_a^2 and σ_e^2 are the animal additive genetic and residual variances, respectively, $\sigma_{a1,a2}$ ($\sigma_{p1,p2}$) is the additive genetic (phenotypic) covariance between traits 1 and 2, and σ_{a1} (σ_{p1}) and σ_{a2} (σ_{p2}) are the additive genetic (phenotypic) SD of traits 1 and 2, respectively.

3. Results

3.1. Descriptive statistics and significance of fixed effects

The mean of linear type traits ranged from 22.30 (front teat length) to 30.13 (rear udder width) and the final score averaged 80.27; these results denote cows with favourable dairy attitude, slightly shorter-looking teats and wide udder (Table 1). Within the frame group, body depth had the greatest average score (28.92), followed by angularity (28.72). As regard feet and legs group, locomotion averaged 25.05 with a SD of 5.74, meaning that most animals had a medium stride length. Finally, within udder traits group, rear udder width showed the greatest average score (30.13) followed by udder support (27.47) and rear udder height (26.20; Table 1).

Herd-year-classifier and stage of lactation were the most important sources of variation for all studied traits ($P < 0.05$), with the exception of fore udder attachment which was not affected by stage of lactation (Table 2). Age at calving was significant ($P < 0.05$) in explaining the variation of final score, and frame and udder traits, except for rump angle and rear udder height, and among feet and legs traits, it was important for foot angle and feet and legs functionality. Season of evaluation was an important source of variation for final score and frame traits, with the exception of chest width. With regard to feet and legs, and udder traits, season of evaluation was important only for rear leg set side view, foot angle, fore udder attachment, udder support and udder depth. The coefficient of determination ranged from 0.17 (udder support and front teat placement) to 0.55 (stature).

Table 1
Descriptive statistics, coefficient of genetic variation (CV_g) and heritability (h^2)[a] for linear type traits and final score[b] of first-parity Jersey cows (*n* = 10,305)[c].

Trait	Mean	SD	CV_g (%)	h^2	Descriptor Minimum (1)	Maximum (50)
Frame						
Stature	24.14	8.18	13.52	0.32	Short	Tall
Chest width	25.28	5.47	6.33	0.12	Narrow	Wide
Body depth	28.92	4.79	5.14	0.12	Shallow	Deep
Angularity	28.72	4.78	4.36	0.08	Coarse	Angular
Rump angle	24.84	6.03	8.62	0.14	High pins	Low pins
Rump width	25.01	6.35	5.35	0.06	Narrow	Wide
Feet and Legs						
Rear leg set side view	26.98	5.03	3.60	0.04	Straight	Sickle
Rear leg set rear view	26.69	5.94	4.05	0.04	Hocked in	Correctly straight
Foot angle	24.85	5.84	5.71	0.07	Low	High
Feet and legs functionality	24.33	5.71	5.34	0.06	Low	High
Locomotion score	25.05	5.74	4.01	0.04	Short stride	Long stride
Udder						
Fore udder attachment	23.56	6.38	10.13	0.16	Loose	Tight
Rear udder height	26.20	6.01	6.70	0.10	Low	High
Rear udder width	30.13	5.91	4.57	0.07	Narrow	Wide
Udder support	27.47	5.94	6.37	0.10	Weak	Strong
Udder depth	25.59	6.83	11.40	0.22	Deep	Shallow
Front teat placement	23.43	5.34	5.98	0.08	Wide	Close
Front teat length	22.30	6.05	7.55	0.10	Short	Long
Rear teat placement	24.18	8.36	9.90	0.09	Wide	Close
Final score	80.27	2.34	1.19	0.20		

[a] For all estimates of heritability, the standard error was 0.02.
[b] Linear type traits and final score evaluated on a 1- to 50-point and 50- to 100-point scale, respectively.
[c] *n* = 6853 for locomotion.

3.2. Genetic parameters of type traits

Overall, heritability estimates of the investigated traits were low, with the only exception of a moderate heritability (0.32) for stature (Table 1). Among other frame traits, heritabilities ranged from 0.06 (rump width) to 0.14 (rump angle), and for udder traits they ranged from 0.07 (rear udder width) to 0.22 (udder depth). The lowest heritabilities were observed for feet and legs traits, with estimates of 0.04 for rear leg set side view, rear leg set rear view and locomotion, and 0.07 for foot angle. The final score had heritability of 0.20. For all studied traits, standard error of heritability was 0.02. The coefficient of genetic variation for linear type traits ranged from 4.01% (locomotion) to 13.52% (stature), and it was 1.19% for final score.

The strongest phenotypic correlations were observed between locomotion and feet and legs functionality (0.65), chest width and body depth (0.61), and foot angle and feet and legs functionality (0.60; Table 3). All other phenotypic relationships between linear type traits were moderate to low, with the overall strongest associations estimated within group. In particular, correlations within the frame traits were stronger than 0.20, except for the relationships involving rump angle. Phenotypic correlations within feet and legs traits ranged from 0.43 to 0.65, except for rear leg set side view which was negatively associated with other traits (from −0.35 with rear leg set rear view to −0.18 with locomotion). These negative values were likely due to the way rear leg set side view is scored on the linear scale: low scores are desirable for this trait, whereas high scores are desirable for all other descriptors

Table 2
F-value and significance of fixed effects included in the analysis for linear type traits and final score of first-parity Jersey cows.

Trait	Herd-year-classifier	Season of evaluation	Stage of lactation	Age at calving	R^2	RMSE
Frame						
Stature	13.76***	3.45*	11.20***	20.37***	0.55	5.69
Chest width	5.50***	0.23	19.51***	22.82***	0.33	4.65
Body depth	4.15***	7.24***	27.86***	22.71***	0.27	4.26
Angularity	3.32***	16.06***	6.93***	3.32***	0.21	4.41
Rump angle	2.99***	5.64***	4.71***	1.46	0.19	5.63
Rump width	4.45***	9.37***	6.13***	11.23***	0.26	5.68
Feet and Legs						
Rear leg set side view	2.87***	7.18***	7.74***	1.24	0.19	4.70
Rear leg set rear view	3.53***	1.33	4.13***	0.88	0.22	5.45
Foot angle	3.05***	5.81***	3.37***	1.77*	0.20	5.43
Feet and legs functionality	3.35***	0.55	4.50***	1.68**	0.21	5.27
Locomotion	3.50***	0.08	2.44**	0.44	0.20	5.35
Udder						
Fore udder attachment	3.33***	6.00**	1.28	1.99*	0.21	5.90
Rear udder height	3.28***	0.42	5.30***	1.75	0.21	5.54
Rear udder width	5.11***	1.18	3.41***	1.95**	0.30	5.14
Udder support	2.49***	5.31**	3.70***	13.73***	0.17	5.61
Udder depth	3.93***	10.30***	4.50***	12.41***	0.25	6.16
Front teat placement	2.56***	0.53	3.27***	4.16***	0.17	5.05
Front teat length	4.06***	1.12	3.03**	3.12**	0.26	5.39
Rear teat placement	3.02***	0.50	9.27***	6.67***	0.20	7.74
Final score	4.32***	4.61**	2.21*	1.95*	0.26	2.10

Table 3
Genetic (below the diagonal) and phenotypic (above the diagonal) correlations for linear type traits and final score of first-parity Jersey cows. Standard error of genetic correlations ranged from 0.02 to 0.22.

Trait	STA	CWD	BD	ANG	RAN	RW	RLS	RLR	FAN	FL	LOC	FU	RUH	RUW	US	UDT	FTP	FTL	RTP	FS
Frame																				
Stature (STA)		0.43	0.43	0.22	0.12	0.26	−0.03	0.11	0.16	0.16	0.16	0.05	0.09	0.12	0.05	0.05	0.03	0.13	0.02	0.25
Chest width (CWD)	0.81		0.61	0.25	0.06	0.32	−0.04	0.18	0.19	0.22	0.21	0.11	0.11	0.19	0.07	−0.02	0.06	0.13	0.04	0.29
Body depth (BD)	0.71	0.98		0.42	0.05	0.33	−0.02	0.18	0.20	0.24	0.26	0.10	0.15	0.26	0.09	−0.07	0.07	0.14	0.07	0.33
Angularity (ANG)	0.44	0.43	0.63		0.07	0.22	0.01	0.14	0.17	0.20	0.24	0.13	0.24	0.29	0.14	0.00	0.09	0.09	0.07	0.37
Rump angle (RAN)	0.26	0.28	0.14	0.08		0.00	0.02	0.01	0.01	0.01	0.02	−0.05	−0.02	0.04	0.01	−0.02	0.02	0.03	0.02	0.01
Rump width (RW)	0.75	0.77	0.65	0.41	0.10		−0.06	0.18	0.20	0.22	0.23	0.18	0.16	0.20	0.14	0.06	0.09	0.12	0.08	0.33
Feet and Legs																				
Rear leg set side view (RLS)	−0.01	−0.10	0.12	0.01	0.02	−0.20		−0.35	−0.27	−0.28	−0.18	−0.05	−0.04	−0.03	0.01	−0.03	−0.01	−0.04	0.06	−0.14
Rear leg set rear view (RLR)	0.22	0.18	0.05	0.04	0.04	0.50	−0.92		0.43	0.49	0.43	0.14	0.13	0.17	0.09	0.05	0.06	0.10	0.01	0.36
Foot angle (FAN)	0.30	0.23	0.16	0.27	0.04	0.43	−0.68	0.79		0.60	0.47	0.20	0.23	0.17	0.12	0.10	0.09	0.13	0.06	0.44
Feet and legs functionality (FL)	0.31	0.18	0.24	0.14	0.03	0.48	−0.96	1.00	0.92		0.65	0.21	0.21	0.20	0.15	0.11	0.11	0.12	0.06	0.52
Locomotion (LOC)	0.32	0.25	0.21	0.08	0.11	0.29	−0.85	1.00	0.72	0.97		0.23	0.23	0.22	0.16	0.12	0.12	0.10	0.08	0.52
Udder																				
Fore udder attachment (FU)	0.07	0.25	0.10	0.11	−0.25	0.47	−0.24	0.57	0.63	0.63	0.67		0.41	0.23	0.34	0.47	0.31	0.05	0.21	0.58
Rear udder height (RUH)	0.21	0.07	0.15	0.61	−0.05	0.35	−0.12	0.53	0.57	0.54	0.63	0.76		0.42	0.30	0.18	0.22	0.08	0.16	0.48
Rear udder width (RUW)	0.16	0.05	0.20	0.62	0.24	0.13	0.03	0.35	0.26	0.54	0.27	0.28	0.81		0.27	−0.01	0.13	0.07	0.12	0.38
Udder support (US)	0.14	0.11	0.12	0.13	0.04	0.33	−0.24	0.45	0.38	0.33	0.37	0.54	0.61	0.27		0.32	0.38	0.05	0.34	0.46
Udder depth (UDT)	0.10	0.08	0.11	−0.18	−0.18	0.31	−0.26	0.38	0.47	0.56	0.40	0.86	0.44	−0.12	0.48		0.26	−0.01	0.18	0.44
Front teat placement (FTP)	0.12	0.29	0.26	0.09	−0.15	0.36	−0.40	0.63	0.66	0.50	0.97	0.75	0.61	0.23	0.77	0.70		−0.09	0.45	0.39
Front teat length (FTL)	0.36	0.37	0.27	0.01	0.10	0.39	−0.46	0.38	0.36	0.19	−0.06	−0.05	−0.04	−0.29	−0.13	0.01	−0.10		−0.05	0.12
Rear teat placement (RTP)	0.12	0.24	0.27	0.21	0.02	0.45	0.05	0.46	0.24	0.32	0.88	0.50	0.50	0.34	0.75	0.33	0.93	−0.09		0.24
Final score (FS)	0.40	0.42	0.43	0.30	0.03	0.66	−0.45	0.80	0.78	0.82	0.75	0.91	0.78	0.40	0.49	0.72	0.77	0.01	0.59	

(Table 1). Phenotypic correlations within udder traits were > 0.10, except for the associations involving front teat length, and the relationship between rear udder width and udder depth. Phenotypic associations between linear type traits of different groups were low and comprised between −0.07 (body depth and udder depth) and 0.29 (angularity and rear udder width). The final score showed positive phenotypic correlations with linear type traits, from 0.12 with front teat length to 0.58 with fore udder attachment, except for a negative association with rear leg set side view (−0.14) and a null relationship with rump angle (Table 3).

Genetic correlations were generally stronger than their phenotypic counterparts (Table 3). Within the frame group, genetic associations varied from 0.41 ± 0.14 (rump width and angularity) to 0.98 ± 0.03 (body depth and chest width), except for the genetic correlations between rump angle and other traits which were ≤0.28. Strong genetic correlations were assessed within feet and legs traits, with estimates from 0.72 ± 0.17 (locomotion and foot angle) to 1.00 ± 0.03 (rear leg set rear view with locomotion, and with feet and legs functionality), and −0.96 ± 0.11 to −0.68 ± 0.14 between rear leg set side view and other traits. Locomotion was also strongly associated with feet and legs functionality (0.97 ± 0.05) and rear leg set side view (−0.85 ± 0.16). Within the udder group, front teat length and rear udder width were generally weakly correlated with other traits, except for a strong association between rear udder width and rear udder height (0.81 ± 0.08). All other udder traits were moderately to strongly correlated to each other, with estimates that ranged from 0.33 ± 0.11 (rear teat placement and udder depth) to 0.93 ± 0.05 (rear teat placement and front teat placement). In particular, fore udder attachment strongly correlated with udder depth (0.86 ± 0.04), rear udder height (0.76 ± 0.06) and front teat placement (0.75 ± 0.07); udder support was strongly associated with front teat placement (0.77 ± 0.08) and rear teat placement (0.75 ± 0.10); and udder depth was strongly associated with front teat placement (0.70 ± 0.09). Considering genetic correlations between traits belonging to different groups, a wide range of estimates was obtained. Overall, frame traits were weakly correlated with feet and legs, and udder traits, except for rump width, which showed moderate correlations with almost all features, and angularity, which showed the greatest correlations with rear udder height (0.61 ± 0.10) and rear udder width (0.62 ± 0.11). Genetic associations between locomotion and frame traits ranged from 0.08 ± 0.22 (angularity) to 0.32 ± 0.16 (stature). The correlations between feet and legs, and udder type traits were generally moderate to strong, except for rear leg set side view which correlated moderately only with front teat placement (−0.40 ± 0.17) and front teat length (−0.46 ± 0.15). The strongest associations were estimated between locomotion and front teat placement (0.97 ± 0.19), and locomotion and rear teat placement (0.88 ± 0.17). The final score was almost uncorrelated with rump angle and front teat length, and moderately to strongly positively correlated with other traits (0.30 ± 0.11 to 0.91 ± 0.03), except for a negative relationship with rear leg set side view (−0.45 ± 0.02). Locomotion strongly correlated with final score (0.75 ± 0.12).

4. Discussion

Genetic and phenotypic variation of linear type traits have been extensively documented in Holstein (e.g. Battagin et al., 2013; Bilal et al., 2016; Cassandro et al., 2015), as well as in Brown Swiss (e.g. Dal Zotto et al., 2007; de Haas et al., 2007; Gibson and Dechow, 2018), whereas less information is available for Jersey breed (Biscarini et al., 2003; Cue et al., 1996; du Toit et al., 2012). In the present study, the average score of each linear type trait (except for final score) was close to 25, which was somewhat expected, since type evaluations are recorded on 1- to 50-point scale. On a scale ratio, findings of the present study were comparable with those reported by Cue et al. (1996), Caraviello et al. (2003) and du Toit et al. (2012), who evaluated type traits in New Zealand, American and South African Jersey cows, respectively, using a 1- to 9-point scale. Also, our results agreed with findings of Cassandro et al. (2015) in first-parity Holstein cows, who reported means of type traits that ranged from 21.0 (front teat length) to 31.6 (rear udder width). The average locomotion score was slightly greater than the value (23.48) reported by Battagin et al. (2013) in first-lactation Holsteins. Since locomotion evaluates the walking ability of the cow, high scores are desirable because they are associated with feet and legs functionality and long strides without abduction. One of the major factors affecting locomotion is the herd. Onyiro and Brotherstone (2008) reported that different housing systems explained a significant variability of locomotion. In our study, HYC effect was very important in determining the variability of locomotion and results from an additional analysis of variance that included herd, year of scoring and classifier as separate effects, revealed that herd explained a larger proportion of variation than year of scoring and classifier.

4.1. Heritability estimates

Overall, heritabilities for type traits were low (Table 1); however, coefficients of genetic variation suggest that there is room to select for type traits in Italian Jersey cows. Results observed in the present study, showing the greatest heritability estimates for frame and udder, and the lowest for feet and legs traits, agreed with those reported by several authors in different cattle breeds (Dal Zotto et al., 2007; Cassandro et al., 2015; du Toit et al., 2012). Stature was the most heritable trait (0.32), in accordance with the estimate reported by Dal Zotto et al. (2007) in first-parity Italian Brown Swiss cows, whereas du Toit et al. (2012) and Cassandro et al. (2015) estimated lower heritability (0.20) for stature in multiparous South African Jersey and first-parity Italian Holstein cows, respectively. Using a repeatability animal model, Gengler et al. (1997) obtained heritabilities of linear type traits for first- and second-lactation US Jersey cows that were higher compared with those reported in the present study. Heritability of locomotion was intermediate between estimates of 0.03 and 0.05 reported by Zink et al. (2011) and Battagin et al. (2013) in first-parity Czech and Italian Holsteins, respectively. Conversely, Onyiro and Brotherstone (2008) and Berry et al. (2004) estimated higher heritability (0.11 and 0.14) in first-lactation UK and Irish Holstein-Friesian cows, respectively. In general, the discrepancies among studies may be the result of differences in scale used for scoring type traits, editing procedure, statistical model, breed and parity. Also, the classifier may have an impact on the magnitude of heritability (Veerkamp et al., 2002).

4.2. Correlation estimates

The IQJ includes two production traits (milk yield and protein yield) and three udder type traits (fore udder attachment, udder support and udder depth); the latter were added to the selection index in 2005 to improve cow's functionality, in particular udder health. The IQJ gives great emphasis to protein yield, which has a weight of 64.7% in the index, followed by milk yield (−19.3%), and less emphasis to type traits: 12.8% udder depth, 1.6% udder support and 1.6% fore udder attachment. Genetic parameters estimated in the present study might be a starting point to explore if additional type traits, including locomotion, are of potential interest to be considered in the IQJ to further enhance functionality of the breed. The improvement of conformation traits is desirable especially on the light of the genetic selection programmes adopted in the last decades that gradually have changed the shape and the size of dairy cows, leading to a more difficult animal management and to an increased vulnerability for mechanical impacts and wounds (EFSA, 2009). In particular, claw disorders and lameness are among the most frequent reasons of involuntary culling in dairy cattle, and thus they have a negative impact on profitability of the dairy herd and raise several animal welfare issues; a cow with claw health issues reduces feed intake, loses body condition, produces less milk, is less fertile, and is more prone to udder and metabolic health issues (Sadiq et al., 2017; Heringstad et al., 2018). Heringstad et al. (2018) nicely reviewed genetic aspects of claw diseases in cattle and discussed perspectives of genetic selection to improve cow resistance to lameness. Those authors recognized that direct information from trimming is the most valuable source of phenotypic information to maximize genetic gain of claw health. At the same time, Heringstad et al. (2018) suggested that the use of indirect traits favourably associated to claw health, such as locomotion, would be beneficial to increase reliability of genetic evaluations for claw health itself. Regarding udder health, Bobbo et al. (2019) suggested that the combination of udder type traits and alternative somatic cell count traits into a new udder health index would be beneficial to improve Jersey cow welfare and health.

4.2.1. Correlations between type traits of the same group

All genetic and phenotypic correlations within frame group were positive, differently from Biscarini et al. (2003), who estimated negative genetic correlations of angularity with body depth (−0.06), rump with (−0.15) and chest width (−0.36). In the present study, the genetic correlation between chest width and body depth (0.98) was stronger than genetic relationships of 0.90 and 0.80 assessed by Biscarini et al. (2003) and Berry et al. (2004) in first-lactation Italian Jersey and Irish Holstein-Friesian cows, respectively. Genetic associations between stature, body depth and rump width were stronger than those reported by de Haas et al. (2007) in primiparous cows of three Swiss dairy cattle breeds. Brotherstone (1994) and Berry et al. (2004) reported a genetic correlation of 0.41 between stature and angularity in first-lactation Holstein-Friesians (0.41), which is very close to our estimate (0.44). Genetic correlations of final score with traits included in frame group were moderately favourable, except for the null correlation with rump angle. These findings agreed with Brotherstone (1994), except for rump angle, which was unfavorably correlated with final score (−0.37).

Strong and positive genetic correlations were estimated between feet and legs traits, suggesting that they reflect similar characteristics of the legs. This is particularly true for the genetic correlations of rear leg set rear view with locomotion, feet and legs functionality and rear leg set side view, and for the genetic correlation between locomotion and feet and legs functionality, which were all greater than 0.90 in absolute value. These findings suggest that the number of traits to be included in the genetic evaluation could be reduced to avoid redundancy and increase selection efficiency. Strong and favourable correlations were found between feet and legs traits and final score, with the exception of rear leg set side view. Moreover, Van Dorp et al. (2004) concluded that cows with high locomotion score had also better body condition score. Unfortunately, a comparison is not possible since body condition score is not currently recorded in Italian Jersey breed.

Within udder group, fore udder attachment and udder depth were strongly genetically correlated, as previously reported by Biscarini et al. (2003) and Brotherstone (1994), followed by moderate correlations between fore udder attachment and udder support, and udder depth and udder support. Also in this case, the strong positive genetic correlation between fore udder attachment and udder depth was comparable with results obtained in US Brown Swiss (Gibson and Dechow, 2018). The genetic association between front teat placement and rear teat placement estimated in the present study was stronger than that reported by Cue et al. (1996) in New Zealand Jersey. Front teat length had a negative association with the majority of udder traits, similarly to previous findings on Italian Jersey (Biscarini et al., 2003). Overall, udder traits were moderately to strongly associated with final score (0.40 to 0.91), except for front teat length, in agreement with findings of Brotherstone (1994) in HolsteinFriesian.

4.2.2. Correlations between type traits of different groups

Opposite to our study, Berry et al. (2004) estimated a stronger genetic and a null phenotypic correlation between angularity and locomotion in Irish Holsteins. The favourable genetic correlations between angularity, rear udder width and rear udder height agreed with previous findings on Jersey cows (Biscarini et al., 2003; Gengler et al., 1997), suggesting that increased animal sharpness is associated with improvement of udder conformation. Similarly to results of the current study, Gibson and Dechow (2018) reported a favourable relationship between udder traits and mobility score, meaning that improved udder conformation was also associated with improved locomotion. Indeed, in the present study, the genetic correlations between locomotion score and udder traits group were moderate to high; the negative association between front teat length and locomotion was the exception, as previously reported by Berry et al. (2004) in primiparous Holstein-Friesians.

5. Conclusion

The present study assessed the main sources of variation of linear type traits, including locomotion and final score, and estimated their genetic parameters in Italian Jersey cattle breed. Fixed effects of herd-year-classifier and stage of lactation were the most important sources of variation for the studied traits; on the other hand, age at calving and season of evaluation contributed to a minor extent to explain the variation of type traits. Heritability estimates were generally low, but additive genetic variation suggested that there is room to select for improved functionality in this breed. Moreover, some strong genetic correlations revealed redundancy, meaning that the number of evaluated traits might be reduced by losing minor information and increasing genetic selection efficiency at the same time.

Declaration of Competing Interest

The authors declare that there is no conflict of interest associated with this publication and there has been no significant financial support for this work that could have influenced its outcome.

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