Phenotypic associations and genetic correlations between claw health disorders and, milk production, fertility, somatic cell score and type traits in Holstein Spanish dairy cattle

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Abstract

The objective of this study is to estimate phenotypic and genetic associations between claw health and feet and legs traits, production, somatic cell score and fertility performance in Spanish dairy cattle. Information of 6 claw disorders: dermatitis (DE), sole ulcer (SU), white line separation disease (WL), interdigital hyperplasia (IH), interdigital phlegmon (IP), and chronic laminitis (CL), and also a combined trait called overall claw disorder (OCD), defined as the absence or the presence of at least one of the six claw lesions, was used. Trimmers score up each disorder as mild or severe lesion for each claw. Claw trimming data including 108,468 records, collected from 2012 to 2014 in 804 Holstein dairy herds by 25 trimmers, and were merged with dairy milk recording and type classification data to estimate phenotypic associations between claw disorders, energy corrected daily milk production, somatic cell score, calving first service, calving conception service, services per conception and feet and legs traits score. A total of 49,963 claw health records corresponding to 35,337 cows with conformation data on feet and leg traits, yield data (305-d first lactation milk, fat and protein), somatic cell score, and days open between the first and the second calving in first lactation were used to estimate genetic correlations with claw disorders. The presence of claw disorders was associated with a significant decrease in milk production and an increase in SCS, especially for SU, WL and OCD. The presence of SU and WL during early lactation period was associated with an increase in the calving first service interval and calving service conception interval, mainly for severe lesions. Genetic correlations between feet and legs and claw disorders were low to moderate, although some of them seemed to be more negatively correlated to specific lesions, such as locomotion, and rear legs rear view. Cows with a good locomotion score are less likely to claw disorders. However, feet and legs conformation traits are not efficient as indicator traits for claw health selection. As expected, genetic correlation between claw disorders and production traits were positive, supporting that high yielding cows were more prone to claw disorders, especially to CL and IP. Our results showed a positive genetic relationship between claw health problems and poor fertility, as well as higher somatic cell score in animals affected by sole ulcer.

Key words: phenotypic and genetic association, claw disorders, feet and legs traits, production, somatic cell, fertility.

Introduction

The intensive selection for yield production during the last decades, jointly with the intensification of modern cattle husbandry and keeping larger herds of cows in loose-housing systems have led to higher risk of claw disorders. Claw disorders reduce profitability in dairy industry and involve an overuse of antibiotics. Then, nowadays

claw disorders are becoming a big source of economic loss and a big concern for the dairy farmer. These losses were mainly due to a reduced milk production (Green *et al.*, 2002) and poor fertility performance of lame cows (Barkema *et al.*, 1994).

In 2012, a centralized electronic recording system called I-SAP for 6 claw disorders was implemented in Spain and genetic parameters for claw disorders were estimated in order to perform the genetic evaluation for claw health traits (Charfeddine and Pérez-Cabal, 2014b). To include claw health traits in our breeding goal, economic values of claw disorders require the estimation of the associated decrease in the milk production, the increase in somatic cell score and the deterioration in the fertility performance. At the same time, genetic relationship with other traits evaluated in Spanish dairy cattle and included in Spanish merit index are needed. Then the main purpose of the present study is to estimate the phenotypic associated effect of claw disorders on milk production, test day somatic cell score, and reproductive performance, such as calving to first service interval and calving to conception interval and number of services per conception. Another aim of this study is to estimate the genetic correlations of claw disorders with feet and legs traits, production traits, and other functional traits, as lactation somatic cell score and days open.

Material and methods

Data

Claw health disorders

Claw trimming data included 108,468 records, collected from 2012 to 2014 in 804 Holstein dairy herds by 25 trimmers, involved in I-SAP program (Charfeddine and Pérez-Cabal, 2014a). This information was merged with dairy milk recording and type classification database to generate the data set for each analysis. Six claw diseases are recorded: Interdigital and digital dermatitis (DE), sole ulcer (SU), white line disease (WL), interdigital hyperplasia (IH), interdigital phlegmon (IP), and chronic laminitis (CL). Claw health data were scored as categorical trait (0: absence of disorder, 1: mild lesion and 2: Severe lesion) for each claw. A combined claw disorder trait which included all disorders was created. The new combined trait was called Overall Claw disorder (OCD), indicating the absence, or the presence as mild or severe lesion of at least one of the six claw disorders. In the case there is more than one disorder, the highest score is kept for OCD. A detailed description of each claw disorder recorded within I-SAP was given by Charfeddine and Pérez-Cabal (2014a).

Phenotypic association

The test-day milk recording data within 48,895 lactations obtained from the official milk recording system provided by CONAFE were used to perform phenotypic association analysis between milk production, somatic cell count and claw disorders. Daily milk yield, fat and protein content, were used to calculate daily energy corrected milk (ECM), which determines the amount of milk produced and adjusted to 3.5% fat and 3.2% protein. ECM was used as outcome variable in milk production analysis. The test day somatic cell count was transformed to somatic cell score (SCS). After a preliminary analysis in order to test the significance level, claw health diagnosis date corresponding to each milk test-day were limited to diagnosis within 4 weeks before and after test-day milk date. For each specific claw disorder a disease index variable was created for each test day date in order to estimate the effect on daily ECM and SCS. Claw health index variable was defined as follows: 1= test day collected between 15 d and 28 d before the claw diagnosis, 2= test day collected within14 d before claw diagnosis, 3 test day collected within 14 d after claw diagnosis, 4: test day collected between 15 d and 28 d after claw diagnosis, and 5= cow had not been diagnosed with any disease during the interval 28 d before and 28 d after the test day (used as the reference level).

To avoid the confounding effect of different claw disorders present at the same time, only records of healthy cows and records of cows with only a specific disorder at a time were included in the analysis. Due to the low frequencies of IP, CL and IH, the phenotypic associations were performed only for DE, SU, WL and the overall claw disorder OCD.

Days from calving to first service (CFS), days from calving to conception (CSC), and number of services per conception (SPC) of 15,159 lactations with claw disorder diagnosis data within the first 100 days of lactation (CD100) were used to estimate the effect of claw disorders on fertility performance. As the same as with production and SCS only cows with only one claw disorder at a time and cows without any disorder within 100-d of lactation were used in each analysis.

Conformation traits were routinely recorded by professional classifiers from CONAFE. Six feet and leg traits were considered to analyse phenotypic association and genetic correlations with claw disorders: feet and legs composite (F&L), foot angle (FA), bonne quality (BQ), rear leg side view (RLSV), rear leg rear view (RLRV) and locomotion (LOC).

Genetic analyses

For the genetic analyses, 49 963 claw health records, corresponding to 35 337 cows were used. Far visits with less than 5 cows trimmed were excluded. The data set has repeated records for a given cow because a trimmer visits the farm more than once a year and lesion status could change from one observation date to the next. The average number of trim per cow in the final data set was 1.4. Trimmers who scored hind and fore claw may be different, therefore for genetic parameters estimation, only rear leg claw disorders were included. Conformation data on feet and leg traits and yield data in first lactation were merged with claw health data. Yield traits were 305-d first lactation milk, fat and protein. Somatic cell count per test day was transformed to somatic cell score, then adjusted and averaged per lactation and considered as lactation somatic cell score (LSCS). Days open was calculated as the interval between the first to the second calving minus the pregnancy period. Pedigree of cows with records was the traced back for all the generations available. A total of 116 298 animals were included in pedigree file.

Models

Phenotypic association analysis

The phenotypic associations between the outcomes and potential predictor variables were evaluated using repeated measures analyses of variance using PROC MIXED of SAS Ver. 9.2 (SAS Institute Inc., Cary, NC). Initially, the predictor variables and their respective interactions were screened using a univariate approach, where variables with $P<0.20$ were retained in the general full model.

For ECM and SCS, the model included cow and herd as random effects, and as systematic effects season of calving, lactation number grouped as first and second or later lactations, age at calving, stage of lactation and the claw disorder diagnosis index.

For CFS, CSC and SPC, the model included the random effect of cow, and herd, and the systematic effects season of calving, lactation number grouped as first and second or later lactations, the production level (categorized as low and high level), and the claw disorder diagnosis within the first 100 days of lactation.

Genetic parameters estimation

Genetic correlations between claw health traits and type, production and functional traits were estimated by REML fitting a multi-trait linear animal model using the VCE 6.0 software (Groeneveld *et al.*, 2008). The models used were (levels are indicated between brackets):

- Claw health traits: The systematic effect considered were: lactation-calving age (31), days in milk at the moment of the trimming (grouped in 6 levels as follow: 0-60, 61-120, 121-180, 181-240, 241-305 and >305). The random effects considered were the comparison group herd-visit-trimmer (1679), the permanent environmental effect of the cow (35,337), and the random additive genetic effect (116,298).
- 305d production traits and days open: The systematic effects were age at calving (9), and the calving moth (12) .The random effects were the comparison group herd-year of calving (2852), and the animal additive genetic effect (116,298).
- LRCS: As systematic effect were included the age at calving (11), and calving moth (12), and as random effect were considered the effect of herd-year of calving (5062), and the animal additive genetic effect (116,298).
- Type traits: The model included the systematic effects age at calving (23), stage of lactation in the moment of type classification (11), and random effects herd-year of calving (5062), and animal additive genetic effect (116,298).

Results and discussion

Claw health disorders prevalence

Claw disease prevalence at cow level is shown in Table 1. Sole ulcer had the highest prevalence, whereas hyperplasia had the lowest. At least one disorder was shown in nearly 40% of cows in this study. Furthermore, the incidence of a severe lesion is very low in comparison with mild lesion. Incidences of claw disorders observed in our population were in a wide range, as it is reported in the literature (Van Der Waaij *et al.* 2005; Uggla *et al.* 2008).

Phenotypic effect of claw disorders on milk production and somatic cell score

The associated effects of DE, SU, WL and OCD on ECM and SCS at different intervals diagnosis date-control test-day, revealed from the mixed models, are shown in Table 2. The presence of claw disorders is associated with a significant decrease in milk production and an increase in SCS, especially SU, WL and OCD. The production loss caused by DE was low and statistically not significant. However, cows with SU and WL produce significantly less milk than the non-affected cows during 28 days before and after the diagnosis date. The production loss is larger before the trimming and the corresponding treatment, ranging from 0.94 to 1.27 kg / d for SU, from 0.94 to 0.88 kg / d for WL, and from

Table 1. Cow-level prevalence (%) of the claw disorders.

Claw disorders[1]	Total	Mild lesion	Severe lesion
DE	10.21	9.61	0.60
SU	14.71	13.09	1.62
WL	11.87	10.58	1.29
CL	2.96	2.68	0.28
IH	0.44	0.38	0.06
IP	1.00	0.74	0.26
OCD	37.6	33.77	3.83

[1]DE: Dermatitis, SU: Sole ulcer, WL: White line disease, CL: Chronic laminitis, IH: Interdigital hyperplasia, IP: Interdigital phlegmon, OCD: Overall claw disorder

Table 2. Phenotypic effect of claw disorders on the energy corrected daily milk production (ECM) and Somatic cell score (SCS).

	DE1		SU		WL		OCD	
Records affected cows	9582		14626		11138		33526	
Records non-affected cows	88473		83429		86917		61561	
Claw health level	β	SE	β	SE	β	SE	β	SE
ECM (Kg / d)								
Non-affected	0	…	0	…	0	…	0	…
-28 to -15 days	-0.06ns	0.16	-0.94***	0.12	-0.94***	0.13	-0.61***	0.08
-14 to test-day	-0.29ns	0.15	-1.27***	0.12	-0.88***	0.13	-0.81***	0.06
1 to 14 days	-0.35**	0.16	-0.88***	0.12	-0.53***	0.13	-0.49***	0.07
15 to 28 days	0.01ns	0.17	-0.76***	0.13	-0.03***	0.15	-0.38***	0.09
SCS								
Non-affected	0	…	0	…	0	…	0	…
-28 to -15 days	0.006ns	0.014	0.021ns	0.012	0.024ns	0.013	0.004ns	0.008
-14 to test-day	0.010ns	0.013	0.066***	0.011	0.038***	0.013	0.025**	0.006
1 to 14 days	0.026ns	0.016	0.016ns	0.012	0.038**	0.013	0.021**	0.007
15 to 28 days	0.009ns	0.015	0.024n	0.013	0.034*	0.015	0.019*	0.009

[1]DE: Dermatitis, SU: Sole ulcer, WL: White line disease, OCD: Overall claw disorder

ns: Not significant *$P<0.05$ **$P<0.01$ ***$P<0.0001$

0.61 to 0.81 kg / d for OCD. ECM yield began to decline 4 weeks before the diagnosis, and just after the trimmer visit showed a recovery until 4 weeks after. The SCS increase was more significant during the 14- d interval before and after the diagnosis date. Rajala-Schultz *et al.* (1999) reported more milk loss in Finnish Ayrshire dairy cows, whereas our results were more similar to estimates obtained by Warnick *et al.* (2001) in USA Holstein cows.

Phenotypic effect of claw disorders on fertility performance

The effect of claw disorders diagnosed within the first 100 days of lactation on calving-first service interval, calving-service conception interval, and number of services per conception are presented in Table 3. The presence of DE was associated with low and not significant effect on fertility performance. However, the presence of SU and WL was associated with an increase in the CFS and CSC intervals, mainly for severe lesions, varying from 4.83 to 17.43 days more than non-affected cows during the first 100 days of lactation. WL was associated with the highest deterioration of reproductive performance.

Claw disorders during the first 100 days postpartum showed negative effect but not highly significant on the number of services per conception. However, cows showing claw disorders during early postpartum period tended to have larger CFS and CSC intervals. It seems that cows were likely to become pregnant with fewer services per conception but to make this happen they need more time. Olechnowicz and Ja?kowski (2015) observed similar results in Polish Holstein-Friesian dairy cows, and Garbarino *et al.* (2004) reported that claw disorders have a detrimental effect on ovarian activity during the early lactation period, which support that claw disorders mask estrus expressions.

Table 3. Phenotypic effect of a claw disorders diagnosed within the first 100 days of lactation on fertility performance.

	DE[1]		SU		WL		OCD	
Cows with a mild lesion	985		848		842		2842	
Cow with a severe lesion	19		70		53		188	
Non-affected cows	12,129		12,129		12,129		12,129	
Claw health level	β	SE	β	SE	β	SE	β	SE
Calving-first service								
Non-affected	0	…	0	…	0	…	0	…
Mild lesion	1.97*	0.91	4.83***	0.99	4.94***	0.98	3.46***	0.58
Severe lesion	5.58^{ns}	7.16	8.00*	3.34	17.43***	3.94	10.24***	2.09
Calving-service conception								
No-affected	0	…	0	…	0	…	0	…
Mild lesion	0.48^{ns}	1.06	4.84**	1.08	3.51**	1.38	2.98**	0.72
Severe lesion	6.97^{ns}	6.82	8.96**	3.53	10.48**	5.51	8.05***	2.27
Services per conception								
No-affected	0	…	0	…	0	…	0	
Mild lesion	-0.047^{ns}	0.02	-0.058*	0.03	-0.032*	0.03	-0.054**	0.02
Severe lesion	0.187^{ns}	0.17	-0.025^{ns}	0.09	-0.172^{ns}	0.10	-0.112*	0.06

[1]DE: Dermatitis, SU: Sole ulcer, WL: White line disease, OCD: Overall claw disorder

^{ns}:Not significant $^{*}P<0.05$ $^{**}P<0.01$ $^{***}P<0.0001$

Genetic correlations

Genetic correlations for claw disorders and feet and legs, production, LRCS and days open in first lactation cows are shown in Table 4. The genetic correlation between claw disorders and feet and legs traits were, mostly negative, low to moderate, ranging from 0.25 to -0.64. The highest negative genetic correlations were found between F&L composite, RLRV, LOC and OCD, IH and IP. Our results are in accordance with other studies (Haggman and Juga, 2013; Larsen *et al.* 2009), reported that feet and legs conformation traits are not efficient as indicator traits for claw health selection.

The genetic correlations between claw disorders and 305-d first lactation production traits were positive, except between DE and fat yield, and low to moderate, ranged from -0.08 to 0.59. Koenig et al (2005) reported similar results. Positive genetic correlations between production traits and claw disorders indicate that intensive selection on production can have unfavorable increase of claw disorders incidence.

The genetic correlations obtained in our study between claw disorders and functional traits (LSCS and days open) were mainly positive, and ranged from -0.77 to 0.42. The highest unfavorable correlations were obtained for SU and OCD. Despite of the fact that correlations are low to moderate, it seems that there are genetic associations, as reported by Buch *et al.* (2011), between high SCS, and poor fertility with high incidence of claw disorders.

Conclusions

Claw disorders affected milk production and SCS during the 4 weeks before and after diagnosis date. SU and WL were the biggest cause of production loss and somatic cell increase. Mild and severe SU and WL lesions during the early period of lactation were associated with largest CFS and CSC intervals. Some feet and legs traits seemed to be more genetically correlated to specific disorders, such as LOC, RLRV and F&L composite with DE, SU, IH and IP. In general, cows with a good locomotion score are less likely to

Table 4. Genetic correlations between claw health disorders and feet and legs, yield, and functional traits for first lactation cows.

	DE[1]	SU	WL	CL	IH	IP	OCD
F&L	-0.26	-0.24	-0.01	-0.08	-0.46	-0.62	-0.29
FA	0.05	0.03	0.25	0.25	-0.17	-0.42	0.16
BQ	-0.06	-0.03	-0.27	-0.10	-0.35	-0.40	-0.21
RLSV	0.12	0.20	-0.01	0.12	-0.01	0.38	0.18
RLRV	-0.28	-0.04	0.24	0.15	-0.38	-0.64	-0.07
LOC	-0.38	-0.27	-0.02	-0.15	-0.43	-0.53	-0.35
F&L	-0.26	-0.24	-0.01	-0.08	-0.46	-0.62	-0.29
305-d yield							
Milk	0.05	0.13	0.19	0.32	0.12	0.41	0.20
Fat	-0.08	0.11	0.02	0.16	0.02	0.59	0.10
Protein	0.02	0.07	0.11	0.23	0.12	0.59	0.14
Functional traits							
LSCS	0.08	0.21	-0.07	0.09	0.09	-0.01	0.14
Days open	0.13	0.42	0.18	0.38	-0.07	-0.77	0.40

[1]DE: Dermatitis, SU: Sole ulcer, WL: White line disease, CL: Chronic laminitis, IH: Interdigital hyperplasia, IP: Interdigital phlegmon, OCD: Overall claw disorder.

F&L: Feet and leg composite, FA: Foot angle, BQ: Bone quality, RLSV: Rear leg side view, RLRV: Rear leg rear view, LOC: Locomotion, LSCS: Lactation somatic cell score

claw lesions. As expected, high yielding cows were more prone to claw disorders, especially to CL. Our results showed a positive relationship between claw health problems and poor fertility, as well as with higher SCS in animals affected by SU.

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