Indirect Selection for Resistance to Locomotive Disorders in Dairy Cattle

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Abstract

Feet and leg problems are among the most important health concerns to Canadian dairy producers. Genetic variability in resistance to locomotive disorders exists and selection could be used to decrease susceptibility to lameness. Indirect selection using an index of conformation traits seems to be the most feasible approach. We have initiated a large scale research project to collect and analyze data on feet and leg disorders and associated conformation traits. Data on disorders will be collected in conjunction with producers, hoof trimmers, and veterinarians. Conformation traits will be evaluated by the Canadian Holstein Association. Records will be collected on approximately 10,000 cows. The resulting estimates of genetic and economic parameters will be used to devise a selection index for locomotive disorders, for inclusion in a total merit index. A pilot study analyzed records for an observed measure of clinical lameness on 1300 US Holstein cows. Heritability of clinical lameness was 0.10 and 0.22 based on linear and threshold models. Genetic correlations between clinical lameness and several conformation traits were greater than 0.60 in magnitude. Results from this pilot study suggest than conformation traits could be used to devise an index to select indirectly for increased resistance to locomotive disorders.

1. Introduction

Diseases of feet and legs of dairy cattle are a source of considerable economic loss for dairy producers. Esselmont (1990) estimated that lameness causes losses of $192 million (Canadian) in the United Kingdom, which is approximately $61 per cow. Losses accrue for several reasons. Most obvious are costs for treatment and prevention of locomotive disorders. Also, chronically or acutely lame cows are often culled involuntarily. Lameness is the third most common reason for involuntary culling, behind mastitis and reproductive failure. Lame cows also require more labor, produce less milk, and reproduce less efficiently than their healthy herdmates. Costs associated with lameness may increase in the future as the rate of genetic improvement for milk production per cow increases. Jones *et al*. (1994) found that health costs associated with locomotive disorders were about 50% greater for a genetic line of cows that was selected for high milk yield than for cows from a control line. Also, changes in housing systems for dairy cows from tie-stall barns to free-stall housing may increase the importance of functionality of feet and legs and the incidence of foot and leg disorders. Incidence of feet and leg problems increases as cows spend more time on concrete and are exposed to relatively moist environments (Frankena *et al*., 1992; Raven, 1992).

Cows spend much of their time standing and walking, so locomotive ability, the freedom from lameness in particular, is associated with longevity and profit. Feet and legs of cattle are subject to a number of different ailments (Greenough *et al*., 1981). Many of these diseases can be the result of a general condition called laminitis. Laminitis is irritation of and subsequent damage to the corium, the network of blood vessels and tissue that surrounds the bones of the foot and that is encased by the hoof. Cows with acute laminitis suffer from extreme pain and inflammation of the corium. The affected cells are responsible for production of the hoof, so laminitis often causes abnormal hoof growth. Typically, rate of hoof growth is increased and quality (hardness and durability) is compromised. The junction between the sole and outside walls of the hoof can be weakened, leading to a condition called "white line separation". The excess growth also tends to be uneven, upsetting the distribution of weight borne by the hooves. Ulcers can form when the bones of the foot exert continual pressure on specific areas of the sole. Erosion of the hoof near the heel can occur because the lower quality hoof is more subject to abrasive forces and because increased growth at the toe of the hoof causes disproportionate pressure on the posterior regions of the sole. Cracks and fissures in the claw may also result. Other foot diseases, such as foot rot and dermatitis, are caused by infectious organisms.

Approximately 90% of lameness in dairy cattle is associated with the claws (Shearer, 1996) but leg problems also affect locomotion. Cows may suffer from arthritis or other forms of inflammation of the joints. Some of these effects result from less than ideal conformation of the pelvic area and of the rear legs. Cows with poor rear leg structure often have awkward gaits and hence may be more apt to suffer from ailments that are associated with asymmetrical weight distribution on claws. For example, cows that stand and walk with their hocks close together and their rear feet pointed outward from the parallel plane of the body, place different amounts of weight on their lateral and medial claws. As a result, one sole wears more quickly while the other suffers from overgrowth.

Many of the factors that are associated with differences in incidence of lameness are of environmental origin (Enevoldsen *et al*., 1991), such as diet, housing, and management. However, a bulk of evidence indicates that genetic factors also play a significant role in predisposition of cows to foot and leg disorders. Reviews on genetic aspects of feet and leg traits were written by Distl *et al.* (1990), McDaniel (1995) and Ral *et al*. (1995). Estimates of heritability of specific claw disorders range from near zero to greater than 0.30 (Distl *et al*., 1990; Huang and Shanks, 1993), with most estimates around 0.15. Uribe *et al*. (1995) reported an estimate of 0.15 for heritability of culling for locomotive problems among Canadian Holsteins. These estimates suggest that genetic variation for foot diseases is sufficient to enable genetic selection as one of the means to reduce incidence of foot disorders.

Data pertaining to claw disorders are not widely available and have not been feasible to collect on a large enough scale in the field to allow effective selection against foot and leg problems based on genetic evaluations for sires and cows. Presently, selection for decreased locomotive disorders has been indirect, resulting from selection on feet and leg conformation traits. Feet and leg conformation traits can be scored more easily and less expensively than data on foot disorders. Cows enrolled in the Canadian Holstein Association type classification system are routinely evaluated for foot angle, curvature of the rear legs when viewed from the side, quality of the bone structure, and a subjective measure of overall feet and leg conformation. Several other conformation traits related to feet and legs are recorded in other countries, including diagonal length of the hoof, mobility, and curvature of the rear legs when viewed from the rear. Estimates of heritabilities of feet and leg conformation traits range from less than 0.10 to greater than 0.40 (Distl *et al*., 1990; Short and Lawlor, 1992; Choi and McDaniel, 1993). Heritabilities vary by trait and depend on definition of the trait and the precision with which it can be scored by trained classifiers. Absolute values of estimates of genetic correlations between claw disorders and traits such as foot angle and lengths of hoof diagonal and dorsal border have been quite high, with some exceeding 0.50 (Distl *et al.,* 1990).

If conformation traits are genetically correlated with disease traits, they can be used for indirect selection to decrease feet and leg problems. In theory, an index that includes several well defined conformation traits related to feet and legs can explain a significant amount of genetic variation associated with foot and leg disorders. Baumgartner *et al*. (as reported by Distl *et al*., 1990) concluded that the genetic response in decreased incidence of claw disorders that would result from using a selection index of four feet and leg conformation traits was 85% of the response possible with direct selection against claw disorders.

Indirect selection for decreased foot problems has several advantages over direct selection. First, heritabilities for feet and leg conformation traits are generally greater than for specific ailments (Distl *et al*., 1990). Also, conformation traits can be scored more easily, more consistently, and more frequently when they are evaluated by trained classifiers as part of routine type classification programs. Marginal costs of adding new traits to those already scored by classifiers will be limited, especially if the new traits replace less informative traits. Finally, conformation traits are measured in a cow's first lactation, which means that the information can be used earlier than information on foot diseases, for which most of the variance is expressed later in life.

We have recently initiated a research project in Canada, which is designed to improve the success of selection for decreased locomotive problems in dairy cattle. Objectives of the research are motivated by the importance of feet and leg disorders for efficient dairy production and animal welfare, and by the limited ability of current field recording programs to provide data to accurately measure and identify genetic differences in predisposition of animals to foot and leg disorders.

The long term objective of this work is to improve functionality and health of Canadian dairy cows, and to develop tools that can be used by breeders in the industry to decrease the incidence foot and leg problem and lameness. Specific objectives are: 1) to quantify genetic and phenotypic relationships among foot and leg conformation traits, locomotion, lameness, longevity, environmental factors, and economic efficiency in Canadian dairy cows; 2) To develop conformation traits for use in field recording programs that are reliable indicators of functionality of feet and legs and of foot and leg disorders; and 3) To design a selection index of new and existing foot and leg conformation traits and to incorporate this index into the Total Economic Value index for selection of sires for increased efficiency of production of Canadian dairy cattle.

2. Materials and Methods

2.1 Data collection

The first major step in addressing the first two objectives is the collection of data on a large number of Holstein cows in the field. Both data on foot and leg disorders and on foot and leg conformation measures will be required. These data will be obtained from two sources on a large number of dairy cows in herds across Canada.

Data on lameness and other foot and leg disorders will be collected in collaboration with professional hoof trimmers from herds in which most cows are trimmed on a regular basis. A total of approximately 10,000 cows from 150 herds will be scored during a period of 1.5 years. Professional hoof trimmers are skilled in detection, diagnosis, and treatment of common claw disorders. Data on both clinical and subclinical problems will be obtained. In addition, data on veterinary treated clinical lameness (**CL**) will be collected from these same herds by participating veterinarians.

At least five traits related to foot and leg disorders will be recorded at the time of trimming. Trimmers will evaluate cows for claw symmetry, hoof texture and hardness, hoof color, quality of sole, and quality of heel. Also, presence or absence of four specific hoof disorders (hoof rot, hairy hoof wart, corkscrew claw, and severe ulceration) will be recorded.

Data related to measures of foot and leg conformation traits will be obtained in conjunction with the Holstein Association type classification program. Feet and leg conformation traits will be obtained on over 40,000 cows that are scored as part of the regular type classification program. The principle aim will be to evaluate cows from herds that are also recording data for foot disorders, but data will also be recorded for cows in other herds.

Conformation traits of the hoof that will be measured include two measures of foot angle, angles of both the dorsal border and the hair line, and depth of heel. Leg traits scored will be rear leg structure viewed from both the side and rear, and leg bone quality. A measure of mobility is also under consideration. Certain defects in leg and rump structure will also be noted.

Although evaluation of genetic effects on feet and leg problems is the primary focus of this research, environmental effects will also be studied. Farms from which feet and leg disorder data will be collected will be from all major milk producing regions of Canada, hence effects of a variety of different climates can be quantified. Cows will be managed under a number of different production schemes, thus the effects of each scheme can be examined. To more adequately account for systematic environmental effects of different management, diets, and housing, questionnaire will be used, for completion by the herd owner. Similar data on herd characteristics will also be collected by the Holstein Association classifiers.

2.2 Statistical analyses

Heritabilities and genetic and phenotypic relationships among foot and leg conformation traits and foot and leg disorders will be quantified. Statistical models will account for systematic environmental effects such as herd, evaluator, season, age, etc. In addition, herd characteristics will be incorporated in statistical models to identify environmental factors that are associated with incidence of foot and leg disorders. Multiple trait models will be employed to estimate phenotypic and genetic relationships between foot and leg disorders, conformation traits, milk production, and longevity.

2.3 Foot and leg health index

To address the third objective related to the research on feet and legs, economic models will be developed and used to quantify the economic importance of genetic improvement of predisposition to the most important foot and leg disorders. Cost factors to be considered include the effects of foot and leg disorders on labor and treatment cost, productivity, longevity, and fertility. Economic values will consider changes in frequency of occurrence of disorders with age, using gene flow methods.

Using selection index methods, economic values and genetic parameters will be used to develop a genetic index of feet and leg conformation traits to predict most accurately sire differences in genetic predisposition to foot and leg problems and in functionality of feet and legs. The traits that will be chosen for inclusion in the index will be those with the ideal combination of greatest heritability and genetic correlation with differences in profit caused by foot problems. The ease and cost of accurately measuring traits will also be taken into consideration. The resulting feet and legs health index will be incorporated into an overall index for selection of sires for economic efficiency.

2.4 Pilot Study

A pilot study (Boettcher *et al., 1997*) to examine the potential magnitude of genetic relationships between visually scored CL and conformation traits has been completed. Data on **CL** on 1300 US Holstein cows were obtained from the original studies reported by Wells *et al.* (1993) and Warnick *et al*. (1995). Clinical lameness was scored on a 4-point ordered categorical scale developed by Wells *et al.* (1993) and assigned by observing cows walking (Table 1). Approximately 75% of the cows were scored 0; fewer than 10% scored 2 or greater, which Wells *et al.* (1993) defined as clinically lame.

Because data were recorded on an ordered categorical scale and were not Normally distributed, both linear and threshold models were used for analysis and results from the two models were compared. Factors in the models included the fixed effects of herd on the day of evaluation, evaluator, stage of lactation, and parity. Random effects were animal, to account for additive genetics; permanent environment, to account for repeated observations per cow; and residual. These models were used to estimate heritabilities and breeding values.

The relationships between this measure of CL and conformation traits evaluated by the US Holstein Association were also of interest. The REML procedure of Sigurdsson and Banos (1995) to estimate genetic correlations between two countries based on sire EBV was used to estimate genetic correlations between CL and the US Holstein Association conformation traits. The EBV for CL were considered EBV from one country and the ETA for conformation were considered EBV from a second country. The EBV from 77 bulls, each with at least 4 daughters with a CL evaluation were used for the analysis.

3. Results and Discussion

Effects on CL of herd-day, stage of lactation and parity were all significant ($P < 0.05$). Lameness was more common in early lactation and for cows in later parities. In early lactation, cows are fed high energy diets with relatively low proportions of roughage to concentrate. These diets can cause rumen acidosis, which often leads to laminitis and CL. Older cows are at a higher risk for CL because they have been subject to greater cumulative effects of lifetime wear and stress than their younger herdmates.

Estimates of heritability for CL were approximately 0.10 from the linear model and 0.22 from the threshold model. The correlation between EBV from the two models was 0.974. Permanent environmental effects accounted for 14% or 20% of the total variance, according to the linear or threshold models, respectively.

Estimates of genetic correlations between CL and conformation traits are in Table 2. Not surprisingly, the greatest correlations between conformation and CL were for several traits that described structure of the feet, legs, and rump. For both the linear and threshold models, the greatest (absolute value) correlation was between CL and foot angle. Estimates were -0.76 and -0.64 from the linear and threshold models respectively, indicating that decreased foot angle was genetically associated with increased CL. The genetic correlation of rear legs, rear view with CL was also quite substantial, -0.68 and -0.64 for the linear and threshold models respectively. These results indicate that cows that tend to walk or stand with their hocks pointing inward and toes pointing outward are genetically predisposed to CL.

Genetic correlations of rump width with CL were also greater than 0.60 for both models (Table 2), indicating that CL is more common among the daughters of bulls that transmit genes for wider rumps. Genetic correlations between feet and legs score (**FLS**) and CL were not as high as were the correlations between CL and the three previously mentioned traits. This was somewhat surprising, considering that CL and FLS are both general assessments of feet and leg form and function and because Holstein classifiers consider mobility, if possible, when evaluating cows for FLS (Connor, 1994).

Among the other type traits, genetic correlations between dairy form and CL were moderately high, especially for the linear model (Table 2). For the linear model, the correlation was 0.60, indicating that increased sharpness and decreased body condition was associated with increased CL. Manson and Leaver (14) also reported a phenotypic relationship between decreased body condition and increased CL. The causes and effects of this relationship are nebulous. Both body condition scores and CL may be indicators of susceptibility to metabolic disease. Cows in severe negative energy balance are likely to have less condition than healthy cows. Such cows are also more prone to laminitis.

Genetic correlations of body depth and strength with CL were moderately high and positive (Table 2). These correlations, and the high correlation of CL with rump width, indicate that sires with larger, wider, and possibly heavier daughters tended to be predisposed to CL. Genetic correlations between stature and CL were only about 0.10, however, suggesting that, genetically, increased body weight relative to frame size may be a more important risk factor for CL than absolute body weight.

Genetic correlations between CL and udder depth and udder cleft were moderately high, but negative (Table 2). Snugly attached udders were associated with decreased CL. This genetic relationship can not easily be explained. Phenotypically, cows may have to alter their gaits if their udders are deep and pendulous.

4. Conclusions

Heritabilities for CL were about 0.10 and 0.22 from the linear and threshold models, respectively. These results indicate that selection to decrease CL could be moderately successful. Genetic correlations between several conformation traits and CL were moderate to high. Greatest genetic correlations with CL were for feet and legs traits, foot angle and rear legs, rear view. However, several other traits, rump width and dairy form, in particular, had moderately high relationships with CL. The magnitudes of these correlations indicate that indirect selection for decreased CL by using conformation traits is feasible.

The results from this pilot study suggest that a selection index of conformation traits could be used to decrease the prevalence of CL in dairy cattle. However, prior to the development of such an index, additional research is needed to more precisely define the economic value of resistance to locomotive disorders and the genetic relationships between between common disorders and conformation traits. Our proposed research is designed to address these needs.

5. Acknowledgments

The authors thank the Cattle Breeders Research Council of Canada for financial support of this research and travel to the GIFT workshop in Uppsala, Sweden.

References

Boettcher, P.J., Dekkers, J.C.M., Warnick, L.D. and Wells, S.J. 1997. Genetic analysis of clinical lameness in dairy cattle. *J. Dairy Sci.* (submitted).

Choi, Y.S. and McDaniel, B.T. 1993. Heritabilities of measures of hooves and their relation to other traits of Holsteins. *J. Dairy Sci. 76,* 1989-1993.

Connor, J. 1994. Scoring your herd's frames, feet and legs. *Holstein World. 91,* 756.

Distl, O., Koorn, D.S., McDaniel, B.T., Peterse, D., Politiek, R.D. and Reurink, A. 1990. Claw traits in cattle breeding programs: Report of the E.A.A.P. working group "claw quality in cattle". *Livest. Prod. Sci. 25,* 1-13.

Enevoldsen, C., Grohn, Y.T. and Thysen. I. 1991. Heel erosion and other interdigital disorders in dairy cows: associations with season, cow characteristics, disease, and production. *J. Dairy Sci. 74,* 1299-1309.

Esselmont, R. 1990. The costs of lameness in dairy herds. *VIth International Symposium on Diseases of the Ruminant Digit.* Liverpool, England. July 16-20.

Frankena, K., Van Keulen, K.A.S., Noordhuizen, J.P., Noordhuizen-Stassen, E.N., Gundelach, J., DeJong, D. and Saedt, I. 1992. A cross-sectional study into prevalence and risk indicators of digital hemorrages in female dairy calves. *Prev. Vet. Med. 14,* 1-12.

Greenough, P.R., MacCallum, F.J. and Weaver, A.D. 1981. *Lameness in Cattle.* J.B. Lippincott, Toronto and Philadelphia.

Huang, Y.C. and Shanks, R.D. 1993. Within herd estimates of heritabilities of hoof characteristics. *J. Dairy Sci. 76 (Suppl. 1),* 148.

Jones, W.P., Hansen, L.B. and Chester-Jones, H. 1994. Response of health care to milk yield of dairy cattle. *J. Dairy Sci. 77*, 3137-3152.

McDaniel, B.T. 1995. Genetics and importance of feet and legs in dairy cattle. *46th Annual Meeting of the European Association for Animal Production.* Prague, Czech Republic.

Manson, F.J., and Leaver, J.D. 1989. The effect of concentrate: silage ratio and of hoof trimming on lameness in dairy cattle. *Anim. Prod. 49,* 15-22.

Ral, G., Berglund, B., Bergsten, C. and Darvelid, U. 1995. Genetic aspects of leg and hoof traits in cattle. *46th Annual Meeting of the European Association for Animal Production.* Prague, Czech Republic. September 4-7.

Raven, E.T. 1992. *Cattle footcare and claw trimming.* Farming Press Books. Ipswich, U. K.

Shearer, J.K. 1996. Lameness in dairy cattle: laminitis, claw disease, digitial dermatitis and foot rot. *J. Dairy Sci. 79 (Suppl. 1),* 189.

Short, T.H. and Lawlor, T.J. 1992. Genetic parameters of conformation traits, milk yield, and herd life in Holsteins. *J. Dairy Sci. 75,* 1987-1998.

Sigurdsson, A. and Banos, G. 1995. Estimation of genetic correlations between countries. *Proc. Interbull Open Meeting.* Prague, Czech Republic.

Uribe, H.A., Kennedy, B.W., Martin, S.W. and Kelton, D.F. 1995. Genetic parameters for common health disorders of Holstein cows. *J. Dairy Sci. 78,* 421-430.

Warnick, L.D., Pelzer, K.D., Meadows, A.W., diLorenzo, K.A. and Whittier, W.D. 1995. The relationship of clinical lameness with days in milk, lactation number and milk production in a sample of Virginia dairy herds. *J. Dairy Sci. 78 (Suppl.1),* 169. (Abstr.).

Wells, S.J., Trent, A.M., Marsh, W.E., and Robinson, R.A. 1993. Prevalence and severity of lameness in lactating dairy cows in a sample of Minnesota and Wisconsin herds. *J. Am. Vet. Med. Assoc. 202,* 78.

Table 1. The scoring system of Wells et al. (1993) for clinical lameness

Score	Gait Abnormality	Description
0	None	No visible gait abnormality or reluctance to walk
1	Mild	Mild variation from normal gait; including mild gait asymmetry or bilateral or quadrilateral restriction in free movement
2	Moderate	Moderate and consistent gait asymmetry or symmetric gait abnormality, but able to walk without continuous stimulation
3	Severe	Marked gait asymmetry or severe symmetric abnormality

Table 2. Estimated genetic correlations between conformation traits and clinical lameness according to estimated breeding values from the linear model and threshold model

	Model	
Conformation trait	Linear	Threshold
Stature	0.11	0.10
Strength	0.22	0.31
Body depth	0.42	0.43
Dairy form	0.60	0.31
Rump angle	-0.03	0.08
Rump width	0.63	0.62
Rear legs, side view	0.13	0.07
Rear legs, rear view	-0.68	-0.64
Foot angle	-0.76	-0.64
Feet and legs score	-0.45	-0.27
Fore udder attachment	-0.06	-0.02
Rear udder height	0.26	0.31
Rear udder width	0.40	0.35
Udder cleft	-0.46	-0.42
Udder depth	-0.44	-0.35
Front teat placement	-0.33	-0.29
Teat length	0.30	0.32