Breeding Programs to Reduce Foot and Leg Problems

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Abstract

The incidence of foot and leg problems and their direct and indirect consequences can be reduced by selection. The most promising approach is to select on an index that includes at least linear scores for foot angle or diagonal, rear legs rear view, and a locomotion score. Desirable are high foot angles, shorter diagonals, straighter rear legs from the rear with little to no closeness at the hocks, and locomotion scores that reflect easier walking. In some populations legs straighter than average at the hocks as observed from the side may have value. Low frequencies of direct observation of actual foot and leg problems limit their usefulness in selection decisions, but they might improve estimates of Breeding Value if used when they are available. Because the heritabilities of the foot and leg traits are low when based on the phenotype of individual animals, selection will be many times more effective when based on animal model estimates of progeny average breeding values. Antagonistic genetic correlations apparently exist between yields of protein, milk, and fat of first lactations and incidence of foot and leg problems. These indicate that the index used for feet and legs be a subindex or only part of the overall index used for selection of parents of future generations of dairy cattle.

1. Introduction

Foot and leg problems and other locomotor disorders are the most important reason for involuntary culling after reproduction and mastitis. Also, part of the culling for poor reproduction may actually be due to foot and leg problems through cows not showing estrus. Even part of the culling for "low production" is likely to be really due to such problems. In addition foot problems and lameness cause much pain to cattle and reduce animal welfare. The main purpose of this paper is to review and interpret research of genetic influences on problems of feet, legs, locomotion, and lameness and their importance. A second goal is to identify how genetic differences in feet and legs affect resistance to foot and leg problems and lameness. The third goal is to recommend how genetic variation may be best used in breeding programs to reduce foot and leg problems and increase the efficiency of cattle production. For earlier reviews of the topic see Politiek et al. (1986), Distl et al. (1990), McDaniel (1995), Ral et al. (1995), and Boelling and Pollott (1997). The latter contains a particularly detailed and complete list of the heritabilities of and genetic correlations among foot and leg traits and problems.

2. Pathways of genetic resistance

The two main pathways by which genetics affects resistance to foot and leg problems are (1) metabolic, mostly internal to an animal, and (2) by structural differences in body parts. Obviously, metabolic differences are difficult to measure but structural differences can be directly observed externally.

Little is known about the underlying metabolic factors affecting foot and leg problems except that some, such as those leading to laminitis, are extremely important. Until practical tests are developed that can easily and accurately predict which animals are most susceptible to metabolically-induced lameness, direct measurement of metabolic differences will be of limited use in breeding for improved locomotion or resistance to foot and leg problems.

Body structural characteristics that can be observed in early lactations and that predict resistance

to problems will be of most use in breeding for resistance in the next decade. Those easily scored or measured and most predictive of future lameness will be of most use. Until much more is learned about genetic factors underlying lameness, most improvement in resistance to lameness will come from selecting to improve the body structures that enable animals to resist foot problems because they are many times more often to be the cause of poor locomotion.

Why not base all selection only on actual incidence of foot problems and lameness? One reason this is probably less effective than indirect selection is that generally clinical foot foot and leg problems are of low frequency, especially in young cows, and subclinical cases are not easy to identify accurately. Recording lameness accurately requires the training of a large number of farmers and veterinarians to obtain and record observations daily. Yet, only a few carefully trained observers are needed to score claws, feet, legs and other desired body structures once or twice on the large number of young cows necessary for effective selection. When widely available, incidence of foot problems and lameness should be a useful tool but not the main component of selection decisions.

3. Genetic basis of claw disorders

Proven levels of genetic differences in lameness and foot diseases include breeds, as well as sire progeny groups and cows within breeds. Several studies have found less lameness in Jerseys than in Friesians or Holsteins and other breeds within the same herd (Ral et al., 1993). Individual estimates of within breed heritabilities for a large number of foot and leg traits are detailed in Boelling and Pollott (1997).

Genetic differences between and within breeds have been found in laminitis, bulb or heel erosion, "foot rot", sole ulcer, various interdigital diseases and white line abnormalities as well as claw and leg traits. All of these diseases have been associated with foot problems and lameness to some degree.

Laminitis appears to be the underlying cause of many foot problems. Yet, the metabolic factors that make animals susceptible to laminitis are still not well understood. Probably it is affected by many genes as well as environmental and nutritional factors. A complication is that it has a positive genetic correlation with milk and protein yields of .25 to .35. My interpretation of this correlation is that it means that susceptibility to foot problems will increase with continued selection for higher yields unless resistance factors are included as a criteria of selection, probably in the selection index used.

Genetic correlations between claw measurements and claw disorders have been moderate (see Boelling and Pollott, 1997, and Distl et al., 1990, for reviews). As angle of the dorsal wall (foot angle) increased, laminitis, dermatitis digitalis, and sole contusion decreased. Cows with steeper foot angles had less clinical lameness in Boettcher et al. (1997). Similar associations have been observed for claw length and diagonal. Correlations of foot angle with heel horn erosion and hyperplasia interdigitalis were low but positive. Selection for higher angles and shorter diagonals should reduce incidence of foot problems.

Genetic differences have been found in the following structural traits and have been associated with lameness: claw angles, lengths, and diagonal; leg set, both side and rear views; bulb or heel height; and locomotion score. Results have been generally similar from both actual measures and scores. Systems of scoring feet and legs have been developed that are accurate enough to identify genetic variation yet simple and inexpensive so that large numbers of breeding animals can be evaluated. Genetic evaluations on eye-scored measures of foot angle and legs side view are available on most progeny tested dairy bulls in AI. Legs rear view is used in some countries and foot diagonal is scored in Holland. Although research has shown value for length of claws when measured (Choi and McDaniel, 1993; Distl et al, 1990) breeding organizations have been reluctant to score claw length because of the potential bias from trimming.

Incidences of locomotive disorders are repeatable from lactation to lactation within cows. Lyons et al. (1991) found the repeatability of locomotive disorders (.55) to be higher than those of all other health problems (.09 to .33). Others have reported similar results (Distl and Schmid, 1993; Enevoldsen et al., 1991a and 1991b).

4. Heritabilities of foot and leg traits

Heritability estimates for a single eye-scored foot angle average about 0.10 with few values higher than .15 and is even lower for length. Ranges for leg scores are similar with one as high as .22 (Visscher and Goddard, 1995). Claw diagonal seems to be more

heritable with scores having a heritability of .19 (Groen et al., 1994) and actual measures even higher ones (.23 to .41, McDaniel and Wilk, 1995, unpublished). This means that single scores of most foot or leg traits on an individual cow are not a reliable measure of her genetic merit for the trait. Yet, a heritability of 0.10 is adequate to obtain a reliable estimate of the breeding value of a bull when scores on many of his offspring are available.

The underlying genetic differences among cows for leg traits, especially when scored from the rear, seem to be larger than those observed by even trained evaluators. The major contributor to low heritabilities for leg traits appears to be variation in the stance of a cow when she is scored. Scores or even actual measures on individual cows often show large changes when they are observed after the cow moves a few steps (unpublished; Te Plate and McDaniel, 1990; Van Aubel, McDaniel, and Brown, 1996). Thus, the low heritabilities of leg traits may be more a consequence of measurement errors rather than lack of genetic variation.

Practically all scoring for conformation of claw and leg traits is based only on the rear. Characteristics of front legs and claws are generally ignored because variation in them is not considered to be a cause of many locomotive disorders. Genetic variation in front claws seems as large as that in back claws (Hahn et al., 1984; Baumgartner and Distl, 1990). Heritabilities based on actual measurements of front claws have been higher than those based on measurements of rear claws of the same cows. Judgments of front legs were also more heritable than those of rear legs in the one study where they were scored (Baumgartner and Distl, 1990). In the latter research four of the six front leg or claw traits were more heritable than their rear counterpart. Their scores, when considered together with those for rear claws, might make it easier to recognize genetic differences, particularly among individual cows.

If and when it is important to have more accurate breeding values for claw traits for individual cows, they may be obtained by combining the cow values based on two or more observations of each with those for their sires and other relatives. Actually, data on other related animals should contribute to the more accurate breeding values. Use of an "animal model" method of genetic evaluation that includes the genetic relationships among all animals evaluated will provide more reliable genetic values for individual females as well as bulls. Even with the extra information provided by relatives, the reliability of the information on an individual cow's claws and legs is of limited value to predict what she will transmit to her offspring. However, cow values are unbiased when computed with an animal model and often may be all that are available.

5. Relation of linear traits to foot problems and survival

Foot and leg problems are one cause of remature culling. Uribe et al. (1995) found the heritability of "culled for leg problems" to be .15. This is a particularly high value for a trait with low frequency as it was identified as responsible for only 3.5% of the cullings. This may mean only a few genes were involved. Actually, locomotion problems may have been a contributing cause for many of the cows reported as culled for low production or reproduction.

Another approach has been to determine the association of culling percentage (de Jong, 1995; Reurink and Van Arendonk, 1987) or survival to a fixed parity (Visscher and Goddard, 1995) and traits of feet-legs. Correlations of length of productive life with foot and leg traits have been used as an indicator of the importance of individual characteristics.

Progeny tests of bulls for conformation for feet and legs have been favorably associated with longevity of daughters in both North America and Europe. Correlations of genetic values of sires for claw angles were more closely related to survival than those of leg traits in earlier research but the opposite has been true in recent reports (McDaniel and Wilk, 1995, unpublished; Visscher and Goddard, 1995). It is imperative that values for feet and leg traits be computed as accurately as possible on bulls by use of a proper animal model. Because such breeding values are unbiased measures of a bull's true genetic value, they should be used in the selection criteria rather than the actual progeny averages so often used.

The most extensive studies of the relations of foot and leg linear scores with survival are those of Boldman et al. (1992); Brotherstone and Hill (1991a and 1991b); Burke and Funk (1993); Dekkers et al. (1994); Foster et al. (1989); Rogers et al. (1989) ; McDaniel et al. (1993); Short and Lawlor (1992); de Jong (1994). Sire evaluations for survival and those for linear traits of claws and legs were in the desirable direction in all but one study.

Although survival rates were defined somewhat differently in each of the investigations, most showed higher claw angles were positively correlated with increased survival. This was especially true when milk was included as a covariate to remove the effects of early culling of low yielding first lactation cows. Much of the value of claw angle seems to be advantage in survival of cows with intermediate to high, but not the highest, angles (Foster et al., 1989; McDaniel and Wilk, 1995, unpublished).

Results of many analyses have indicated that legs straighter from the side -higher hock angles- than considered optimum by the various agencies doing the scoring were associated with longer lives. In most the degree of straightness that predicted the longest lives still were legs with some set to the hock. Variation in legs side view has been less than half as useful as claw angles to predict longevity.

Generally scores of rear legs rear view have been more highly correlated with survival than those of rear legs side in the few studies where they were compared (Brotherstone et al., 1991a and b; McDaniel et al., 1993; Lawlor and McDaniel, unpublished, 1995; Boettcher et al., 1997). Sire evaluations of bulls transmitting straighter legs from the rear view that were plumb (i.e., at right angles to the ground surface with less "hocking in"), were positively associated with higher survival rates. In the analyses legs rear view has been nearly as useful as claw angle for predicting survival and was additive to it.

Only Burke and Funk (1993) addressed the relative importance of feet and legs to predict survival for different housing types and foot trimming routines. They found that the regression of herdlife on foot angle was higher in tie stalls than in free stalls or loose housing.

All investigators except McDaniel et al. (1993) found that sire breeding values for udder traits were slightly more highly correlated with survival than were claw and leg traits. In our study claw angle was the best predictor of survival rate. The data of McDaniel et al. (1993) were based on 389,000 cow lifetimes in the Southeastern U.S.A., an area where most cows are housed in free stalls or outside on dirt lots for much of the year.

Studies of relationships of measured claw traits and survival have given similar results as those of scores even though they were based on much smaller samples of data. The genetic correlation of average claw angle and age at culling was .87 in the research of Choi and McDaniel (1993). Findings of Reurink and Van Arendonk (1987) were in the same direction but smaller. In all investigations first lactation cows with shorter claws lived longer.

Only a few studies have correlated measured claw diagonals with survival or culling rates. One based on measured claw diagonals of 1600 first lactation cows showed it to be more highly related to length of productive life than any other claw trait or combination of claw traits (McDaniel and Wilk, 1996). In fact, it was as highly correlated with PTAs for length of life on paternal half-sisters as was milk yield. Average length of life of daughters increased linearly with shorter diagonals. In Dutch Friesians the difference in survival to third calving of first lactation cows in the quartile for the shortest measured claw diagonal and those in the highest was over 8% (Reurink and Van Arendonk, 1987). In contrast, differences in survival of cows in the highest and lowest quartiles for claw angle only were 3% while those for claw length differed by only 2%.

The relation of scored claw diagonal with survival has been determined in only one study (de Jong, 1994). In this research based on about 500,000 cows, those having the longest diagonals were culled fastest. The least culling was in those with intermediate to shorter diagonals. Culling rates of cows with the shortest diagonals were higher than in those with intermediate values. Additional research is needed to determine the value of scored claw diagonal to predict survival rates in other environments.

6. Foot-leg indexes

Some form of an index is now used in Canada, Holland, and the United States and perhaps others. Dekkers et al. (1994) have shown the Canadian index is significantly correlated with length of productive life. The Dutch feet-leg index is strongly related with percentage culled by the third calving (de Jong, 1994), with the culling rate decreasing from 56% for the lowest indexed decile to only 24% for the highest decile.

The feet-leg composite implemented January 1, 1996. by the US Holstein Association is favorably correlated with transmitting value for productive life (r = .26; Lawlor and McDaniel, 1995, unpublished).

The US Holstein Foot-Leg Composite is computed as follows:

0.5(.48*PTA foot angle +.37*PTA rear legs rear view
-.15*PTA rear legs side)
+0.5 (PTA foot-leg score)

Locomotion or mobility score accounts for at least 60 % of the variation in the Feet-Leg Score assigned by a Holstein Association classifier. These results show that indexes effective for predicting length of productive life can be developed from observations of the feet, legs and when available, locomotion scores.

7. Genetic correlations of foot and leg traits with yields

Breeding values for foot traits scored or measured in first lactation have generally been negatively correlated with those for milk production (see review of Boelling and Pollott, 1997). These results indicate that lameness will increase as a consequence of selection for increased yields unless foot and leg traits are also considered in selection decisions.

Additional evidence on the unfavorable genetic association of yield and locomotion problems comes from the finding that costs for treating foot and leg disorders were higher in a line selected for increased yield than in controls (Jones et al., 1994) and were responsible for 20 % of the differences in health costs between the lines. Uribe et al. (1995) found that the genetic correlations of production with "culling for leg problems" ranged from .20 to .27 and indicated that long term selection for yields probably would increase culling for impaired legs. Feet and leg disorders were genetically correlated with milk yield in both US (Lyons et al., 1991, r = .48) and Dutch (Groen et al., 1994, r = .26) data. The antagonism between yields and locomotion means that positive selection pressure must be placed on foot and leg traits or they will deteriorate when selection is strong for milk or protein yields.

8. Breeding for resistance to foot and leg problems and lameness

Selection will be most effective when based on BLUP Animal Model measures of Breeding Value. These are based on all information available on an animal: itself, ancestors, relatives and progeny. Use of all of the genetic information simultaneously is necessary because of the low heritabilities of foot, leg and other traits that predispose an animal to lameness.

The minimum set of foot and leg traits needed in an effective selection program include scores or measures of one or more claw characteristics and scores of leg traits. A combination of angle, length and diagonal of rear claws seem to be the best for ease and accuracy of scoring or measurement and predictive value for lameness of the foot traits. Actually, some data suggest that claw diagonal alone is an adequate foot measure (Reurink and Van Arendonk, 1987; Boelling, 1994; McDaniel and Wilk, 1996). Which rear leg traits that should be included is not as well established. Most programs have used rear leg set from the side view, which primarily reflects hock angle. Boelling (1994) found it to be more highly correlated with locomotion scores than claw measures. Other data indicate that the rear view of rear legs is more informative for predicting survival (McDaniel et al., 1993; Lawlor and McDaniel, 1995, unpublished) although less heritable than side view. When available, locomotion scores seem to be useful predictors. Actual lameness incidence should be included when present, but no studies have actually compared its value relative to that of indirect selection based on feet and leg characteristics and locomotion scores.

The potential genetic impact of MOET herds and bull mothers justifies obtaining detailed information on susceptibility and incidence of foot problems and lameness in them. Detailed observations on claws and feet, legs, incidence of laminitis, and locomotion are indicated. Perhaps even sophisticated and expensive procedures such as measures of metabolism and force plates to determine the distribution of forces on the bottom of claws as cows walk are justified. Distl and Mair (1993) and Distl and Hubert (1994) have demonstrated a method of measuring the latter.

Recent findings in Holland (de Jong, 1994) and the USA (Lawlor and McDaniel, 1995, unpublished) indicate locomotion can be useful in selection for resistance, at least as part of an overall foot-leg score. Clearly, it is more difficult to obtain locomotion scores accurately than those on claws and legs, so increased costs of scoring would likely occur.

Use of genetic information on feet, legs, and locomotion as part of a selection index will be more effective than using it as an independent selection criteria. The reason for this statement is that research indicates genetically high yielding cows are more subject to locomotion problems, so yields and feet-

legs must be balanced against each other when selecting. Otherwise, locomotion may improve but yields may be reduced enough to make the animals less profitable.

Another justification for use of an index is evidence for intermediate optimums in several foot and leg traits. Usually the optimum is closer to one extreme than the other. Using an index should prevent moving beyond the optimal point because of the low heritabilities and antagonistic genetic correlations with yield traits.

Eventually it should be possible to identify genes and alleles that have large effects on claws. Particularly, this should be true for those causing defective claws. Distl (1994) suggested that epidermal growth factor and its receptor may be good candidate genes. Distl (personal communication) has also suggested the keratin gene as a candidate.

9. Conclusions and recommendations

Genetic improvements in foot and leg traits are not likely to prevent all foot and leg problems and lameness, but selection for high claw angles, shorter claw diagonals, straighter legs from the side and especially the rear, and improved locomotion can reduce their incidence within herds.

Selection to improve foot angle has been widely used successfully to improve feet but improved methods are needed. The best candidates to supplement or replace foot angle seem to be claw diagonal, rear legs rear view, and locomotion score. The most practical way to improve locomotion in dairy cattle, based on current research, seems to be use of a foot-leg index that includes claw diagonal if available and foot angle if it is not, leg score (especially from the rear), and a locomotion score. This does not mean that foot angle needs to be discarded but that other measures be used to supplement and possibly replace it. Until the scores on the additional traits are widely available, foot angle may be the primary selection criteria for feet with some lesser emphasis on legs. Breeding values on foot angle are widely available on bulls in AI, and research in several countries shows that daughters of bulls siring steeper foot angle live longer. This is after considering effects of other physical traits and yields.

Data on the effects of genetic variation in leg structure are not as consistent but do suggest an impact on longevity. Legs that are straighter than average seem the best. Selection for an intermediate optimum is difficult, but research suggests that mating to maintain an intermediate to straight leg is worthwhile. Although not as easily or widely scored, research has suggested that leg structure from the rear is more useful than legs scored from the side. Additional research to identify the optimum leg structure is needed.

Research in some countries suggests that scores for feet and legs can be combined effectively into a single index that may be used to improve locomotion. Inconsistency of results indicates more research is needed on how best to combine traits into an index.

Additional traits of feet and legs do show substantial amounts of genetic variation. Because of the time and expense necessary for obtaining accurate measures of these traits on large numbers of dairy cattle, they are unlikely to be of practical value in the near future.

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