Using Conformational Anatomy to Identify Functionality in Dairy Cows

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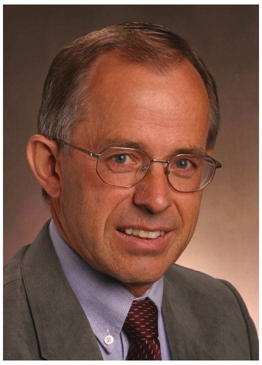


Today's dairy cow deals with some of the greatest challenges ever faced in the history of the dairy industry. Some of these challenges include the stresses associated with unprecedented levels of production, the expectation for superior reproductive performance, high energy rations, being housed on concrete, and constant exposure to all stresses of modern confinement management. The length of a cow's productive life in a herd directly affects profitability of dairy production; longer herd life reduces replacement costs and increases the proportion of lactations from higher yielding, mature animals. Therefore, it is paramount that we increase the cow's chance of surviving longer in the herd.

Dairy cow survival is influenced by many genetic and non-genetic factors. Non-genetic factors include stall size and barn design, bedding type, milk quota restrictions, and the availability and affordability of replacement heifers. Genetic factors include the genetic capability for high production and desirable milk components, calving without assistance, normal cycling, ease of conception, maintaining adequate body condition, resisting metabolic disorders and mastitis pathogens and the ability to move with sound locomotion while requiring minimal foot trimming

A functional cow that is able to meet the demands of modern dairy production will only reach the desired goals if she is provided with the environment, care and housing that is necessary to achieve the full expression of her genetic potential. Many cows fail to attain the above genetic and non-genetic requirements and as a result leave their herds prematurely. These animals are either genetically inadequate or live in an environment that compromises the expression of their genetic potential.

Traditionally, the primary focus of the classification system was the overall Final Class. Great importance was placed on whether an animal scored Good Plus, Very Good or Excellent, and not as much emphasis was placed on the detailed appraisal of individual traits that identify strengths and weaknesses. Classification was historically used to establish livestock dollar value and provide elite breeders with an official stamp that proved an animal was worthy of becoming future breeding stock. In the past, little effort was made to use conformation to improve profitability in more commercial herds.

The past decade has seen a dramatic shift in the use of classification as a herd improvement tool. Final Class still carries huge importance and prestige in herds that have a long-standing investment in dairy cattle type improvement. The classification program today, however, focuses on a comprehensive set of descriptive traits that describe the animal's strengths and weaknesses, and collectively depicts their overall functionality.

Although the heritability of milk production and associated milk components is moderate to high (Muir et al., 2004), conformation traits have a wide range of heritability (Kistemaker and Huapaya, 2006) from 0.08 to 0.53, with Final Score having a heritability of 0.26. However, even with this variable heritability, if we review the superior cows of the breed over the past 100 years, it is very evident that incredible genetic progress has been made in body conformation.

Today's dairy businesses are more commercially oriented (i.e., many larger dairy herds) and less focused on the individual animal. Generating interest in breed improvement programs, especially classification, can be difficult, mainly because these traits have never been shown to increase profitability directly. The most imminent challenge facing breed associations is to clearly demonstrate a relationship between functional type and longevity, generate an incentive for breeding functional type characteristics that increase longevity, and therefore build on the genetic improvement already achieved.

If one likens a dairy cow to a piece of machinery in a factory, increased output in a stressful environment places more wear and tear on the parts. Environment and machine operation can be upgraded, however the optimal solution might be to build a better machine that is more resilient and lasts longer. Advances in management, housing, nutrition and genetics have raised the bar on expectations of dairy cows. A constant challenge is to genetically improve the structure (conformation) of the animal to be more resilient and functional in order to improve profitability in modern confinement systems so that maximum output (production and reproduction) with minimal input (feed, veterinary treatment and replacement costs) can be sustained over a long lifetime.

Initial attempts to increase dairy cow longevity through type trait selection began in the 1970's when breed associations first developed linear type appraisal programs. For the next two

decades type and longevity were considered synonymous. Since then numerous studies have addressed the genetic relationships between linear type traits and longevity (Caraviello et al., 2004; Sewalem et al, 2004; Larroque and Ducrocq, 2001)

Despite the consistent improvement in physical conformation, a significant proportion of genetic variation in longevity remains unexplained by existing type or production traits. Some bulls that transmitted outstanding production and type still had daughters that tended to leave the herd prematurely. Therefore, type traits can be used as an indirect indicator of expected longevity of a bull's daughters but actual culling and fertility data are needed to explain the rest of the story. We must recognize that daughter fertility and survival are important profitability traits. These are dependent not only on conformation and productivity traits but also on the general health and physiology of the cow, as well as the cow's resiliency to the stress of high production and confinement housing

More recently, emphasis on tall and large frames has been directed more to a focus on an angular, open and well-sprung rib accompanied by a wide chest and sufficient depth of body to provide the functionality necessary to consistently produce large amounts of milk. Sufficient stature is still required to achieve the necessary balance with a desirable skeletal frame that provides the strength to support a strong loin and a properly sloped rump. The rump represents the prominences of the pelvis and its importance in feet and leg structure, udder width and attachment, as well as calving ease cannot be over estimated. A strongly attached and well-balanced udder with fine texture will support high and persistent production over the cow's lifetime. All of these attributes have been incorporated into the Canadian classification system with the objective to build a more functional cow. The focus of this paper will be on identifying the most important conformation characteristics with known relationships to functional survival, including:

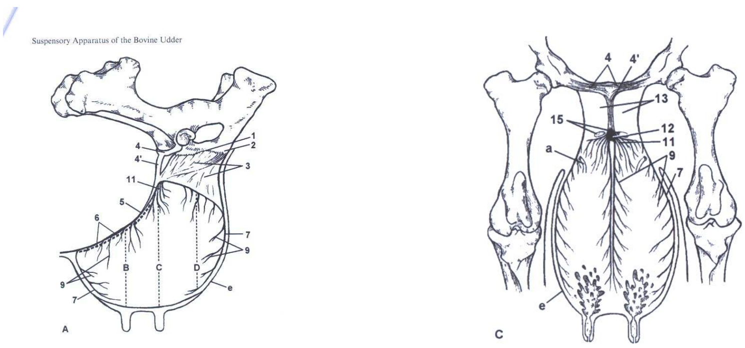
- udder conformation,
- feet and leg conformation,
- thoracic and abdominal body conformation, and
- rump and loin structure

Udder Conformation

Evaluation of udder conformation and the relative importance placed on each trait has been modified over the years. Any discussion of udder conformation should include a detailed description of the udder's suspensory apparatus since this attachment to the ventral abdominal wall and the pelvic floor is fundamental to udder health and longevity.

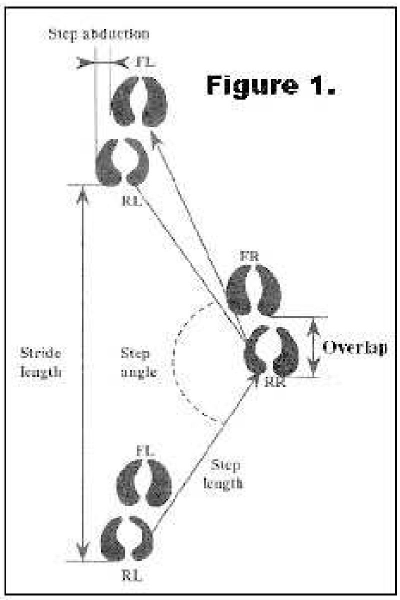
The udder's exterior form and location depend on the development and strength of its suspensory apparatus which is responsible for the attachment of the udder to the ventral abdominal wall and the pelvic floor. Many of the undesirable changes in the udder's exterior characteristics and location can be attributed to a weakness of the suspensory apparatus and these changes are usually irreversible. Normal maturity will cause the suspensory ligament to stretch and excessive stretching or tearing can cause pendulous udders, which are more prone to injury and infection.

Historically, the udder was located in a more anterior position and was attached only to the abdominal wall much the same as with deer or elk. Udder shape, location, and strength of attachments are hereditary. Heritability of udder traits were estimated to be between 0.14 to 0.42 (Kistemaker and Huapaya, 2006). Therefore genetic selection has the ability to alter anatomical structure of the cow's udder. Selection for increased production has caused the udder to increase in size and mass. As a result the udder's centre of gravity has shifted caudal or posterior and the suspensory apparatus of the udder has been supplemented with additional support tissue that attaches to the pelvic floor by means of the symphysial tendon (represented by "3" in the diagram below). Evaluating fundamental anatomical characteristics such as udder depth and suspensory udder strength has facilitated the development of a functionally sound udder to accommodate the stress of high production.



(Jalakas et al., 1999)

Several researchers have shown a consistent relationship between udder conformation and udder health and longevity. VanDorp et al., (1998) showed that cows with longer teats were genetically predisposed to a higher incidence of mastitis. In addition, cows may alter their gait if udders are deep and pendulous. Udder traits (especially the height of the udder above the hock) were found to positively influence the length of productive life. Udder depth and milking ease accounted for 84% of the total contribution of type traits to functional longevity (Larroque and Ducrocq, 2001). Recent Canadian data reported that rear teat placement, udder depth, and udder texture were udder traits that had a significant influence on functional survival (Sewalem et al., 2004).



<u>Feet and Leg Conformation</u>

Locomotion is a qualitative observation of a cow's ability to walk normally. It should evaluate the cow's conformation and motion biomechanics, her freedom from lameness, and the desirability of the surface upon which she walks. Scoring locomotion directly is the most accurate determination of a cow's feet and leg soundness.

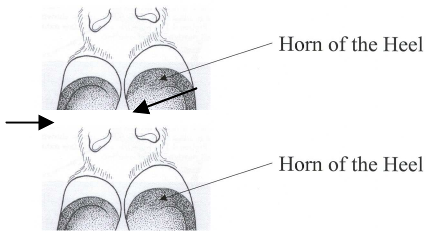
In addition to evaluating the magnitude of lameness, locomotion scoring has been initiated in several countries as part of the type classification system. In Canada, locomotion is being evaluated as a research trait in free stall herds. Locomotion evaluation involves observing a cow while walking and identifying important step parameters including foot placement and length of stride. Normal locomotion is characterized by a long fluid stride where the rear foot falls into the position vacated by the front foot on the same side (no abduction or overlap). Undesirable locomotion may result in the rear foot being placed outside the imprint of the front foot as well as a reduction in the stride length, and a decrease in step angle and walking speed.

(Telezhenko, 2003)

In the past, scoring of actual locomotion on a large population in Canada has not been practiced since many cows are still housed in tie stall barns. Instead, a selection index for locomotion was developed using scored feet and leg traits and genetic and phenotypic relationships between these traits and locomotion. The phenotypic correlation between feet and leg traits and locomotion was estimated using recent data collected in free-stall herds. Correlations ranged from 0.21 with Bone Quality to 0.59 for Rear Legs Rear View. A prediction using all feet and leg traits explained 41% of the total variation in locomotion. Among the traits in the prediction, Rear Legs Rear View and Foot Angle were the most influential traits explaining 55% and 16% of that variation, respectively (Muir 2006, personal communication). The most heavily weighted trait in the index was Rear Leg Rear View (Boettcher and Fatehi, 2001).

Since the locomotion index was developed, Holstein Canada has initiated scoring actual locomotion (as a research trait) in free-stall herds in an effort to provide data to validate and further refine the locomotion index. It is anticipated that in the future a selection index for locomotion could be incorporated into the Canadian Lifetime Profit Index.

Studies have shown that 86% of all lameness involves the hind foot and that 85% of all hind leg lameness involves the lateral claw (Blowey, R.W. 1998). The hind legs are connected to the pelvis by a fixed and relatively inflexible ball and socket joint. While standing, the weight should be distributed equally on each hind leg and equally on each claw assuming good level trimming. During motion, the centre of gravity shifts from side to side and the weight bearing by each hind foot varies with the movement (Raven, 1989). The outer hind claw carries more weight and is more heavily stressed and this is consistent with the much greater incidence of lameness associated with the outer claw of the hind feet. The cow has responded to this by developing an outside claw that is larger and thicker in the sole and heel than the inside claw. Even with these adaptations, the increased stress on the outside claw still results in a significantly greater incidence of lameness.



(Blowey, R.W. 1998)

Several researchers have shown relationships between feet and leg traits and clinical lameness. Wells et al. (1993) showed that a 10-degree drop in foot angle resulted in an odds ratio of 2.4 to develop clinical lameness. The estimated heritability of feet and leg traits is low, ranging from 0.08 to 0.30 (Kistemaker and Huapaya, 2006), however, the most influential type trait on profit, after adjusting for production, was shown to be Feet and Legs (Perez-Cabal and Alenda, 2002).

This association can be attributed to the positive influence that sound feet and legs can have on reproduction and longevity. A favourable genetic correlation was estimated between Feet and Legs and non-return rate, suggesting that cows with good feet and legs were less likely to return to service (Wall 2005). Melendez (2003) explained that cows having foot and leg problems were less likely to show signs of estrous. (Sewalem et al. 2004) reported that cows having extremely course bones, extremely shallow heels, low foot angle, and extremely straight or curved legs from the side view had decreased functional longevity.

Thoracic and Abdominal Body Conformation

The Canadian Holstein has long been recognized around the world for her capacity, made possible by well sprung, open ribs, and for the unique combination of chest width and body depth that give rise to her characteristic angularity. Although extreme height and size in the show ring has been preferred historically, stature and size have been shown to have negligible effects on longevity (Sewalem et al., 2004). The classification system in Canada has progressed alongside knowledge of relationships between body traits and longevity. As a result size is no longer evaluated and stature does not receive as much emphasis, contributing less than 3% to the Final Score. In Canada, a cow having an angular, open and well-sprung rib with a wide chest and sufficient depth of body is desired to support the ability to produce large amounts of milk

Studies have demonstrated the relationships between body shape and survival in dairy cows. Cows that were extremely short, small, and narrow-chested had a higher risk of being culled compared to cows intermediate for these traits. A clear relationship between angularity and longevity was observed, indicating that extremely non-angular cows (score of 1) were 2.47 times more likely to be culled than those with intermediate angularity (score of 5). Additionally, extremely angular cows (score of 9) had a 1.28 times better chance of surviving than cows that scored 5 (Sewalem et al., 2004).

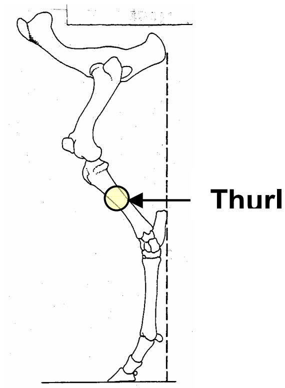
Holstein Canada recently introduced Body Condition Score (BCS) as a research trait. Although this trait currently does not contribute to Final Score, evaluation of daughters will enable calculation of sire proofs for body condition loss and perhaps predict future daughter reproductive performance by incorporating BCS into the daughter fertility index. In addition, the scoring of body condition helps to establish the principle that dairy strength is a functional trait that should be evaluated independent of body condition score. Cows should not receive high scores for dairyness just because they are thin

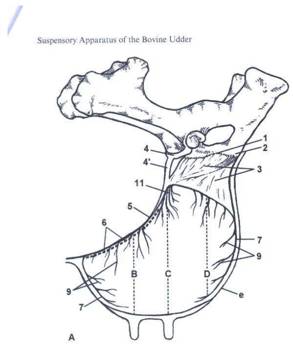
Relationships between body condition and reproductive performance are well documented. Cows with high genetic merit for BCS lost less body condition in early lactation, and therefore experienced less severe negative energy balance (Dechow et al., 2002). In addition, Dechow et al. (2002) reported that the genetic correlation between body condition loss and days to first service was 0.68 in first lactation and 0.44 in second lactation, indicating that as body condition loss became more severe, days to first service increased. Kadarmideen and Wegmann (2003) found similar favourable genetic correlations between fertility (days to first service and non-return rate) and BCS. Dechow et al. (2002) noted that selection for yield appears to increase body condition loss by lowering postpartum BCS. Cows that were thinner (lower body condition) had longer calving intervals (Pryce 2000).

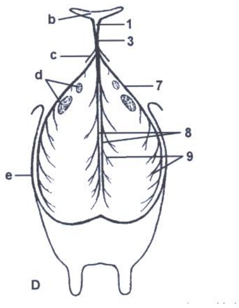
Thoracic and abdominal capacity along with dairyness and femininity (angularity) are desirable attributes to facilitate the dairy cow’s ability to process large volumes of roughage and sustain high production and desirable reproductive performance.

Rump and Loin Structure

A dairy cow’s rump connects several other anatomical structures of significance through the pelvic region. The hind legs articulate with the pelvis at the thurls, the udder attaches to the abdominal wall by way of the prepubic tendon (represented by “4” in the diagrams below) and to the pelvis floor by way of the suspensory ligaments (represented by “7” and “8” in the diagrams below:







To complete the link, the loin is directly attached to the pelvis at the lumbo-sacral junction. Essentially, the rump and loin structures fasten the cow’s abdominal and lumbar regions to her feet and legs and mammary system. Without adequate strength in this area, the productive life of a cow will be seriously compromised

The position of the hook and pin bones define the allowable width of the pelvis to accommodate a desirably high and wide rear udder. A wide, correctly sloped rump is characteristic of pelvic structure that allows for easier passage for the calf at birth and necessary drainage of post-calving fluids in order to prevent metritis infections and fertility related problems. Ali and Schaeffer (1984) described the ideal rump phenotype for ease of calving as one having pin bones that are slightly lower than hook bones, a vulva almost vertical when viewed from the side, collectively displaying a long and wide rump with a well-defined pelvic arch. Finally, absence of abnormalities such as advanced anus, advanced tailhead, and recessed tailhead are desired so that fertility is not negatively affected.

Higher pin bones are associated with an undesirable tilt to the vaginal canal causing it to lie at an inward sloping angle rather than lying flat. With this type of angle, the reproductive tract is more prone to infection because the vagina is unable to drain effectively (Astis 2002). During parturition, the natural exit path for a calf is at a downward angle. Higher pins have a genetic association with inefficient longer calving intervals (Wall 2005). Research shows that animals with higher pin bones and narrower rumps are more likely to have difficult calvings (Cue 1990). In addition, cows with high and narrow pin bones had an increased genetic predisposition to retained placentas (VanDorp et al., 1998). (VanDorp et al., 1998) showed
that cows with lower scoring rumps were genetically prone to a higher incidence of lameness.
In addition to its positive affect on reproduction, researchers have reported a strong link between a sloped wide rump structure and increased longevity. Animals with intermediate rump angles (slope of 1-2 inches from hook to pin) had a longer productive life (lower rate of culling) than animals with extremely low or extremely high pin bones in relation to hip bones (Pérez-Cabal and Alenda, 2002).   Sewalem et al. (2004) showed that the relative risk of involuntary culling was lowest at intermediate rump angles.

Conclusion

The dairy industry faces a unique challenge to constantly improve functionality of the dairy cow to meet the needs of future production and reproduction demands. This report has attempted to identify important conformation characteristics that can be evaluated to predict and improve future daughter survival

Today's classification program focuses on a comprehensive set of descriptive traits that describe the animal's strengths and weaknesses and that collectively depict overall functionality. Since conformation traits are heritable and have been shown to be linked with functionality, selection for conformational traits is an effective tool to facilitate genetic improvement in functionality. In their efforts to continue genetic improvement, breed associations must continue to clarify the relationship between functional type and longevity and promote breeding programs emphasizing the functional type characteristics that increase longevity.

We are equipped with more accurate selection and evaluation tools than at any time in the past. However, sound decision-making is still dependent on superior cow sense and good common sense. These are the qualities that the dedicated breeders of the past have utilized to achieve the tremendous genetic progress that has been accomplished over the past hundred years. We must ensure that we apply our genetic tools wisely as we strive to achieve continued genetic progress that maximizes functionality in the dairy cow in an environment of modern confinement management.

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