THESIS

SURVEY OF THE PREVALENCE OF CONFORMATIONAL DEFECTS IN FEEDLOT RECEIVING CATTLE IN THE UNITED STATES

Submitted by

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ABSTRACT

SURVEY OF THE PREVALENCE OF CONFORMATIONAL DEFECTS IN FEEDLOT RECEIVING CATTLE IN THE UNITED STATES

A survey was conducted on large beef cattle feedlots in Colorado and Texas between March and July 2015, to assess the current status of conformational defects in U.S. fed steers and heifers. The objectives were to: 1) determine the prevalence of conformational defects in feedlot receiving cattle in a population across multiple regions within the United States; and 2) increase industry awareness of the structural problems found in the current cattle population to help ultimately improve a practical selection focus. Conformational traits of front and rear claw, front and rear feet angles, rear leg side view, and rear leg hind view were evaluated on a scale of 1-9 with scores 4-6 serving as the most desirable. Overall soundness was evaluated from 0-100 with 66-100 serving as optimal soundness. A new scoring tool was developed and added to assess conformational problems in cattle shoulder and hip structure. Data from 2,886 head of feedlot cattle was used to evaluate the frequency of these conformational defects. Phenotypic evaluation revealed the highest prevalence of conformational issues in the shoulder, hip, and rear leg covering multiple relationships with demographic characteristics. Of the entire sample, 49.97% had a less than ideal shoulder structure, 53.33% had a less than ideal hip structure, and 29.97% displayed a less than ideal hock structure when viewed from the side. Heavier weight cattle showed a significantly higher (P<0.0001) prevalence of front claw scissor type abnormalities (7-9) and an increase (P<0.0001) in impaired mobility scores (group 2). Northern cattle exhibited a significant (P<0.0001) increase in front claw defects of scissor claw type abnormalities (7-9).

Lastly, *Bos Indicus* cattle displayed a higher prevalence ($P<0.0001$) of round hip structures (7-9) and an increase ($P<0.0001$) of impaired mobility scores (group 2). The remaining traits had significantly higher proportions in the desirable (normal) group, and thus, the industry has shown positive developments in rear claw set and front and rear feet angles. Additionally, 85.85% of our total sample demonstrated overall comprehensive soundness scores for sound and flexible mobility (group 3). These findings will be useful to the beef industry in creating a benchmark for the conformational status of the current cattle herd to ultimately improve skeletal structure for improved welfare and performance in feedlot cattle.

Key Words: beef cattle, conformation, defects, feedlot, survey

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OVERVIEW

Bovine Anatomy

The bovine skeleton is a complex array of internal bone work, which serves as the primary foundation for the attachment of muscle tissues and provides a means for locomotory mechanisms. It is paramount to understand the dynamic relationship of all the skeletal connections. If one area suffers, another area has to overcompensate for the deficiency of the other. Vermunt and Greenough (1995) explain there is an "optimum angle" for the joints of dairy cattle and accurate measurements should be evaluated in precise units such as degrees. If we examine the cattle in terms of form (skeleton) to function (locomotion), an optimum angle for each joint makes sense for the most effective means of functionality.

For evaluative purposes, structural flaws in the skeleton are best examined starting at the hooves then assessing the connecting structures to the rest of the body cavity. There are numerous factors affecting claw shape in cattle: genetics, breeds, age, body weight, environment, ground type, floor type, changes in management, and diet type. While simply looking at genetic impacts and claw anatomy, a figure from Vermunt and Greenough (1995) summarize the major components of claw conformation.

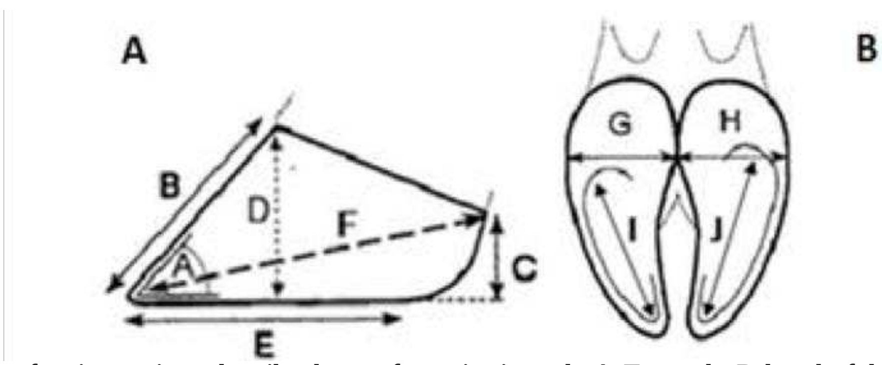


Figure 1.1 Illustration of various traits to describe claw conformation in cattle. A, Toe angle; B, length of the dorsal border; C, heel height; D, toe height; E, claw length; F, diagonal length; G, width of the lateral claw; H, width of the medial claw. (Vermunt and Greenough, 1995)

The most common traits to describe the claw are as follows (Reference Figures 1.1 and 1.2):

- Dorsal angle (toe angle, claw angle-A). The slope of the dorsal border of the claw with respect to the floor surface.
- Length of the dorsal border (toe length-B). The distance from the dorsal skin-horn junction (periople) to the apex of the claw.
- Heel height (heel depth-C). The vertical distance from the floor surface to the skin-horn junction at the extreme plantar or palmar margin of the bulb of the hind or front claw, respectively.
- Claw width (G-H). The often subjectively selected, largest distance between the abaxial and axial wall of the claw and the sole-bulb junction.
- Claw length (sole length-E). The length of the abaxial wall and bulb that are in contact with the floor surface.
- Toe: heel ratio (D/C). The ratio is calculated by dividing the height of the toe, being the vertical distance from the dorsal skin-horn junction to the floor surface, by heel height.
- Diagonal length (F). The distance from the apex of the toe to the skin-horn junction at the heel.
- Sole area (area of ground surface-E*(G-H)). Methods to reproduce the sole area include the use of claw imprints of tracings of the claw on paper. The area is calculated by multiplying claw length with claw width (Vermunt and Greenough, 1995).

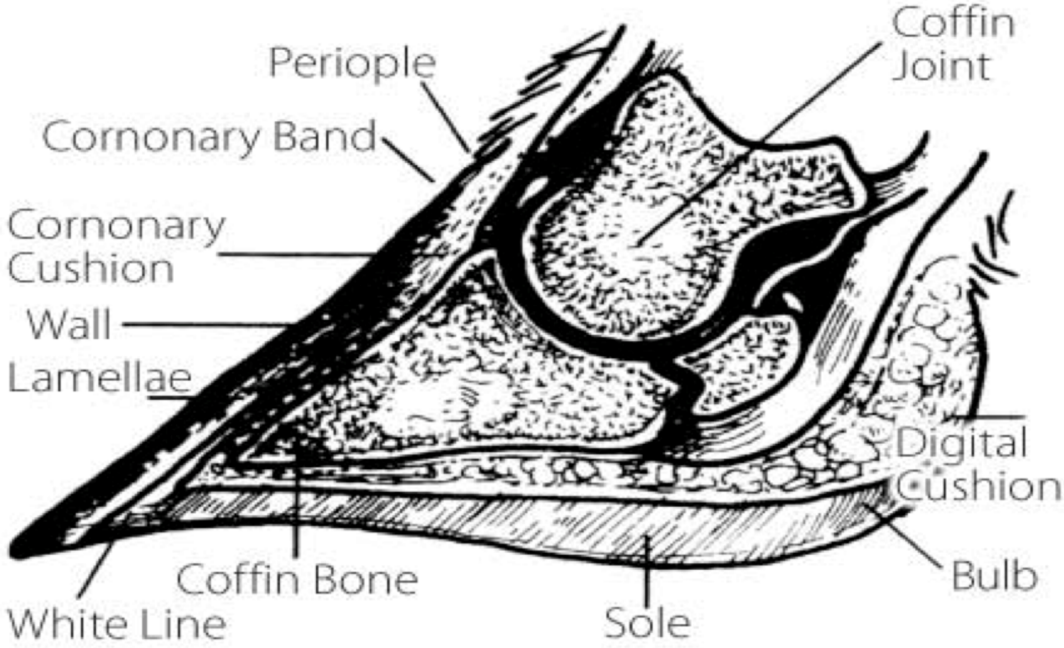


Figure 1.2 Anatomy of the hoof. (Ashwood, 2011)

Some of the most severe claw defects include scissor claw and crooked toe (Reference Figure 1.3), which impact animal comfort, uneven weight distribution on the other toes and hooves, damage to hoof walls, and an increased predisposing factor for lameness.

Figure 1.3 Hoof defects. (Ashwood, 2011)

Overall, Vermunt and Greenough (1995) reported the ideal dorsal angle for both front and rear hooves should encompass the 50°-55° range. Any deviations on either side of this range typically indicate a structural problem further up the skeleton in the pastern, knee, or hock regions.

The most common areas to note in the metacarpal (lower leg/pastern) regions of the bovine skeleton are as follows (Reference Figure 1.4) (Budras and Habel, 2011):

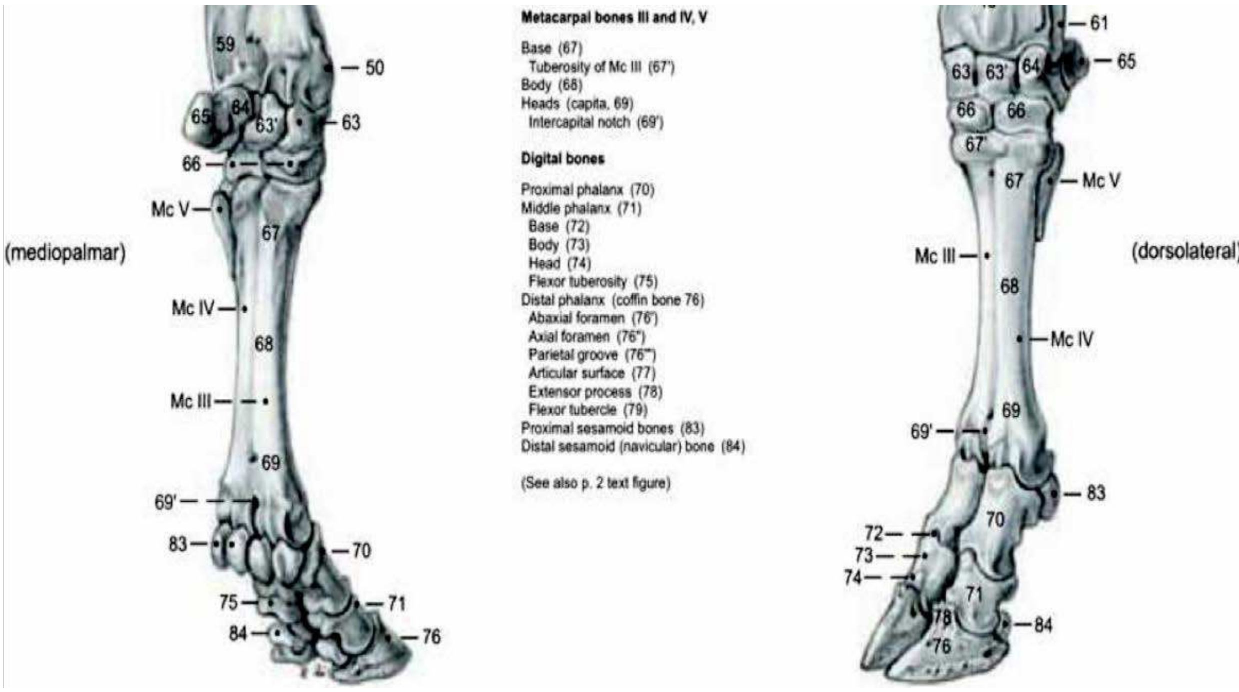


Figure 1.4 Anatomy of the thoracic metacarpal region. (Budras and Habel, 2011)

- Third metacarpal body (cannon bone-68). Main weight bearing column extending from the center of the knee to the intercapital notch above the fetlock joint.
- Metacarpophalangeal joint (fetlock-between 70 and 83). Composite hinge joint responsible for flexion and extension. Their dorsal walls are fibrocartilaginous sesamoid bodies (dewclaws).
- Proximal interphalangeal joints (pastern-between 70 and 71). Incompletely fused bony structures responsible for flexion, extension and small lateral and rotational movements.
- Proximal sesamoid bones (dewclaws-83). Lack the proximal phalanx (70) and attach to the digits by ligaments.
- Distal phalanx (coffin bone-76). Middle and distal phalanges responsible for some flexion and rotational movements (Budras and Habel, 2011).

In beef cattle, a figure by Ashwood (2011) from the Australian Brahman Breeders' Association exhibits the defects for both extremes in regards to pastern anatomy. Too much of a pastern angle (b) can result in longer toe (claw) lengths. This defect is commonly referred to as weak pasterned and is oftentimes accompanied by bruised and irritated dewclaws that are more susceptible to infection. On the other hand, a straight angled pastern (c) produces smaller, shorter toes, regularly indicative of tight pastern joints, straight shoulders, or post-legged defects. As mentioned before, these types of defects can negatively impact the claw conformation and some studies have shown that straight pastern angles are also more susceptible to heel horn erosion (Haggman and Juga, 2013).

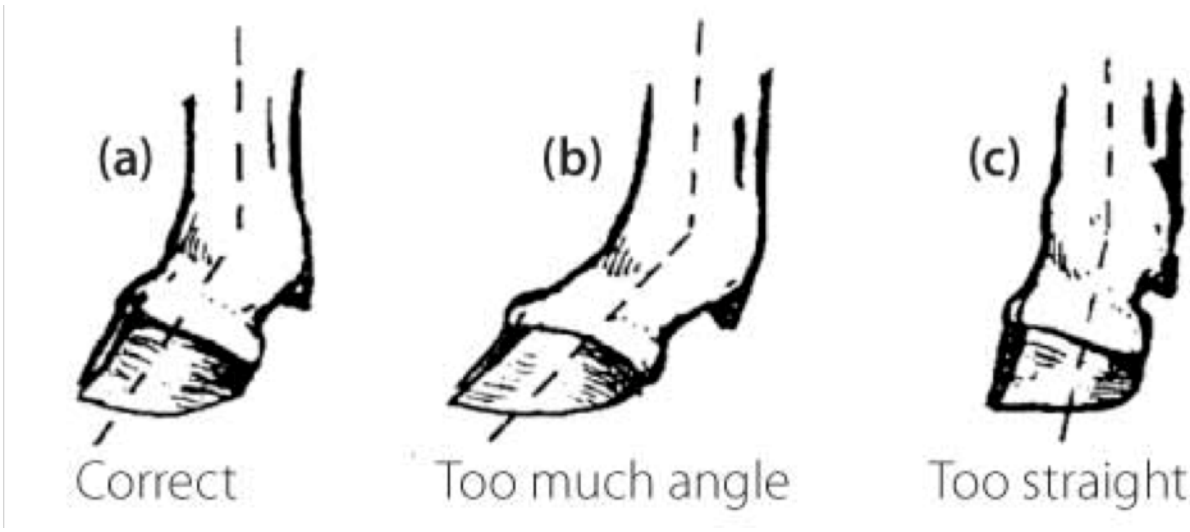
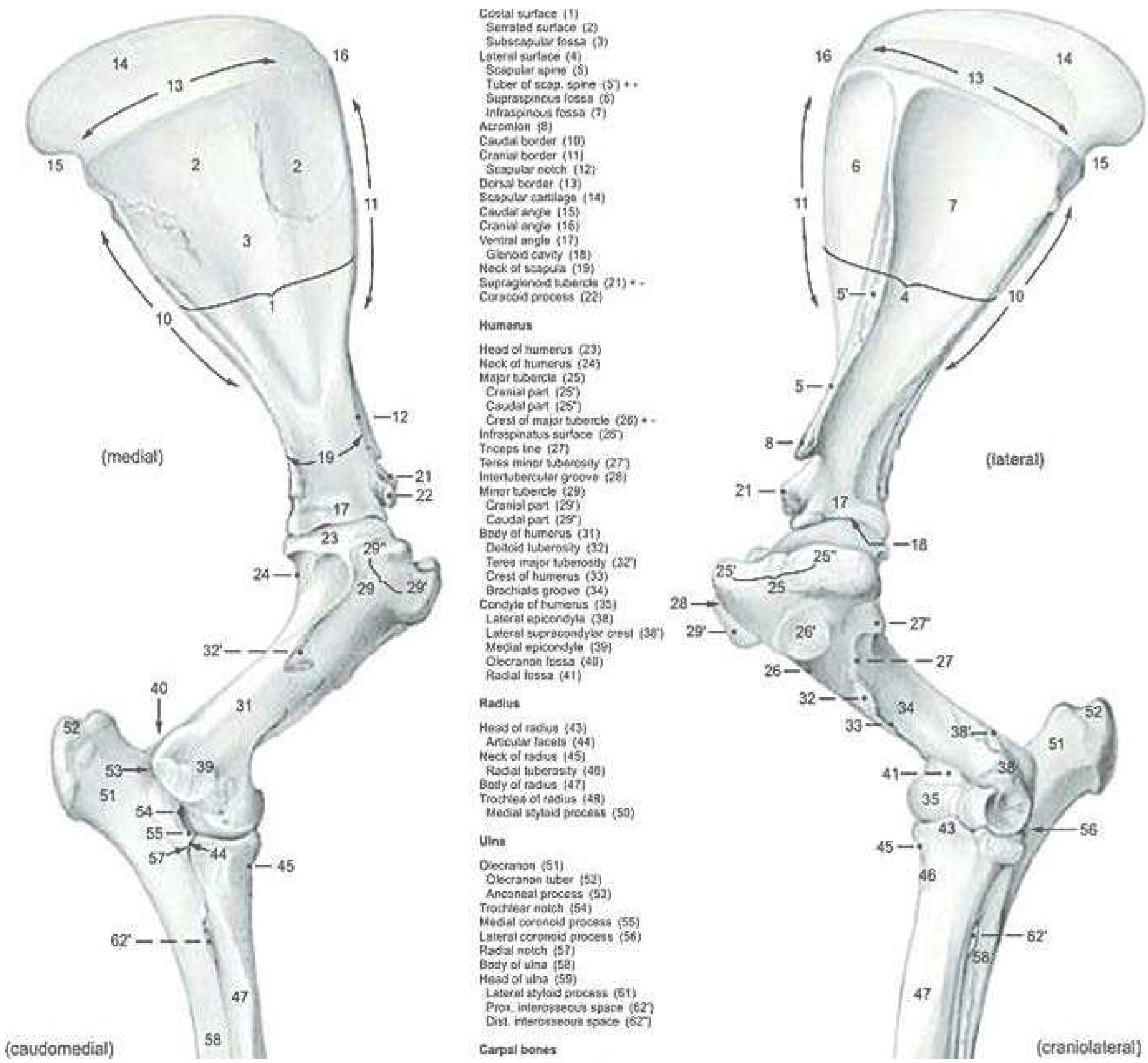


Figure 1.5 Pastern defects. (Ashwood, 2011)

Similar to horse conformation (Beeman, 2002), correct angulation between the shoulder blade (scapula) and humerus is beneficial for shock absorption in the bovine skeleton. The forelimb serves as the main support beam for at least half of the total body weight of the cattle; therefore, more desirable angulation equates to an increased overall animal comfort while traveling. The most common areas to mention of the thoracic (fore) limb are as follows



(Reference Figure 1.6):

Figure 1.6 Anatomy of the thoracic limb. (Budras and Habel, 2011)

- Scapula (shoulder blade-1-22). Contains half moon-shaped scapular cartilage (14) and scapular spine (5). Responsible for main support and flexion in the upper shoulder.
- Shoulder joint. Simple spheroidal joint connecting the glenoid cavity of the scapula (18) and the head of humerus (23). Restricted to flexion and extension in the shoulder, acting as contractile ligaments for movement.
- Elbow joint. Simple hinge composite joint for flexion or extension connecting condyle of humerus (35) to the head of the radius (43).
- Radius (47) and ulna (58). Relatively short, flat bones that are often fused together. The area where the extensor muscles of the elbow joint attach (Budras and Habel, 2011)

Figure 1.7 exhibits the deviations found in the thoracic limb for beef cattle. Beeman (2002) suggests that lameness will start to occur more rapidly for straight legs due to the fact that a straighter shoulder equates to a shortened gait; therefore, the animal will have to plant its leg more times into the ground to cover the desired distance. For the most comfort and cushion for the lower joints, an ideal angle for the scapula blade should be 45°.

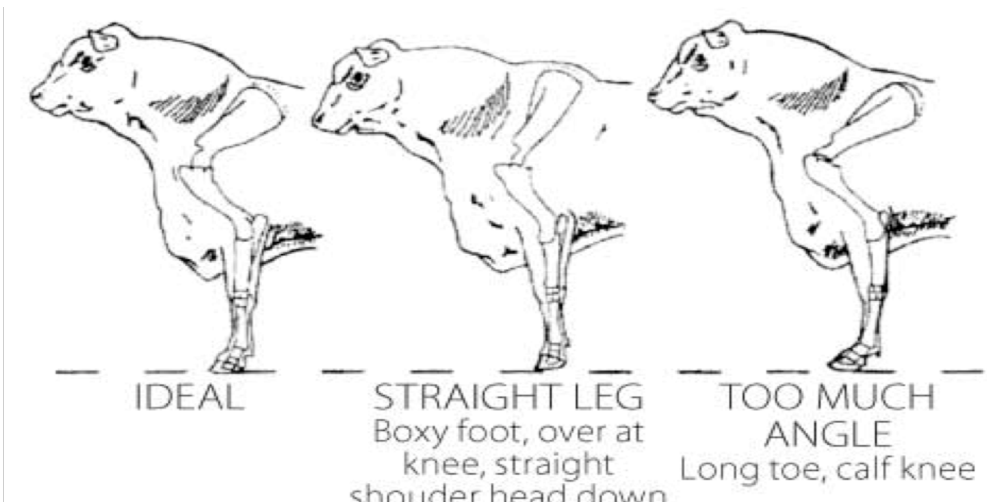


Figure 1.7 Shoulder angle defects. (Ashwood, 2011)

Little research has been done to extensively look into deviations in the hip structures. For brevity, hip angles and structures are usually termed in reference to the slope from hooks to pins. The angle of the hip can expose many other deviations in the skeleton in regards to loin, spine, and hock structure, as well as pastern issues.

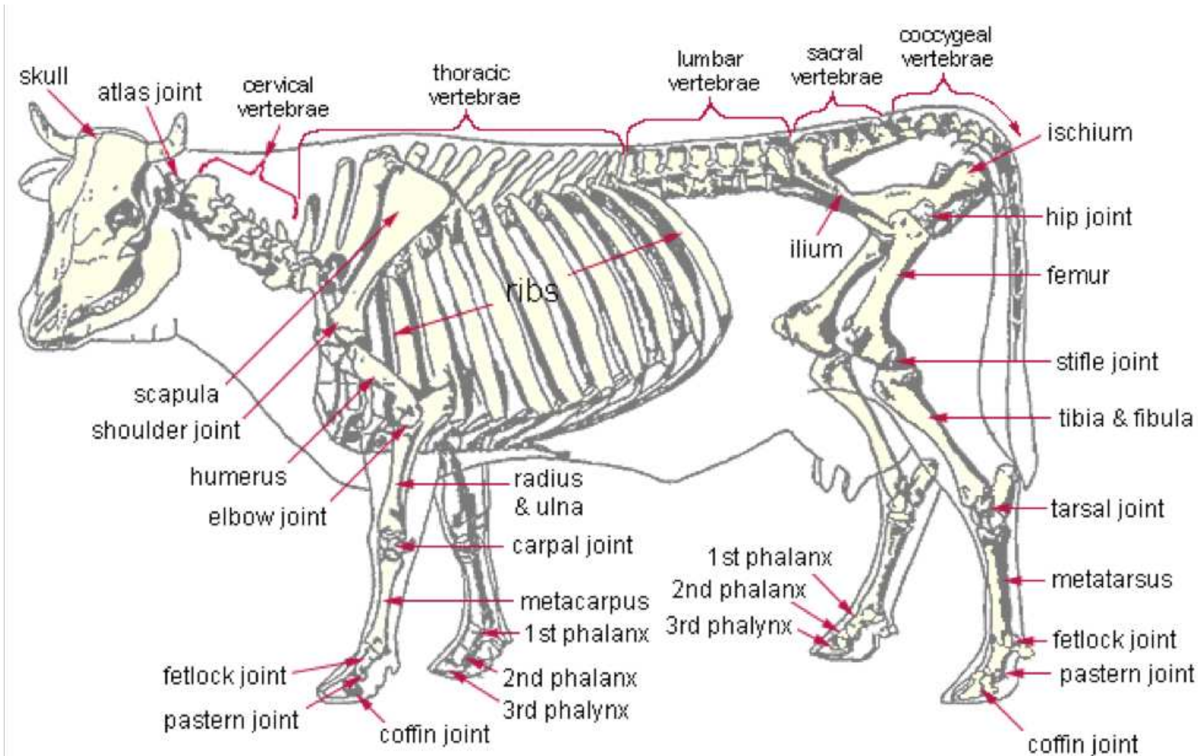


Figure 1.8 Bovine skeleton. (UniserveScience, 2012)

The areas of interest in the pelvic limb for the hip region include (Reference Figures 1.8 and 1.9):

- Hook bones. The anterior curve of the ililum on the point of the pelvis that situates on either side of the spine between the lumbar and sacral connecting regions.
- Pin bones. The posterior end of the ischium by the tail (coccygeal vertebrae).
- Hip joint. Connects the proximal head of the femur with the acetabulum (hip socket) on the distal end of the ilium.

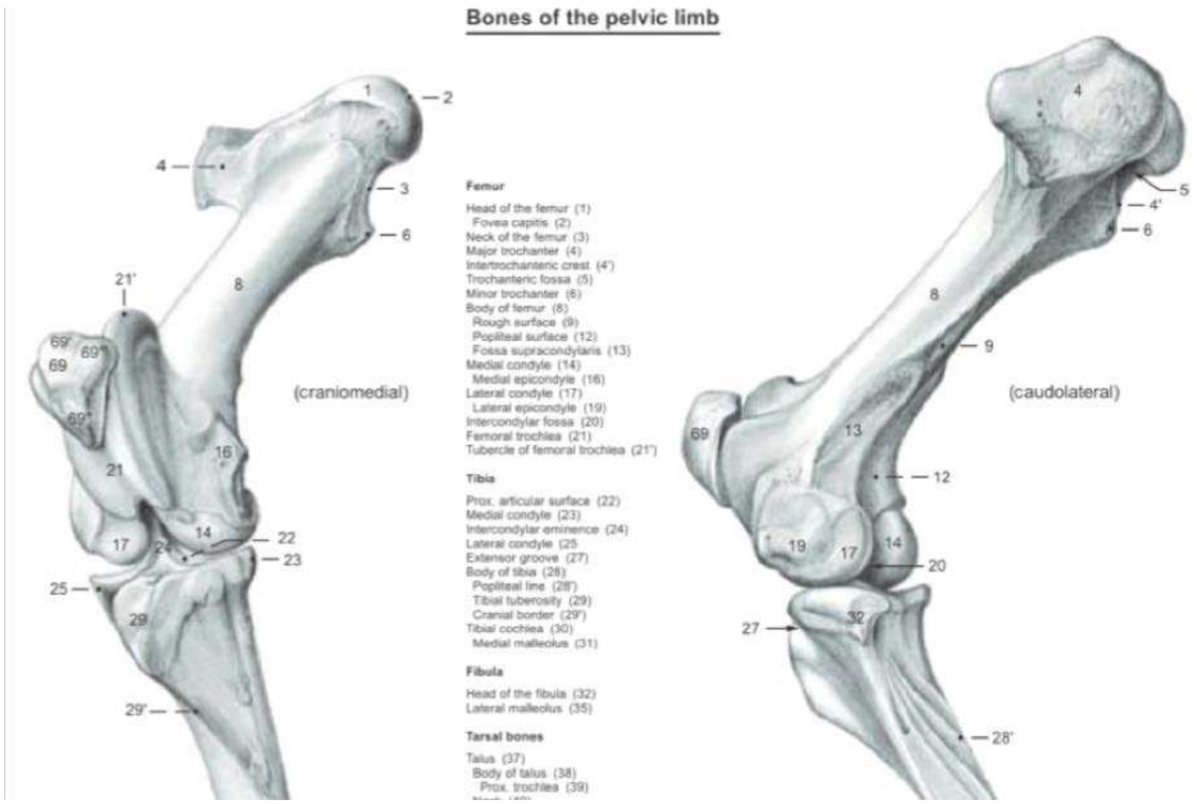


Figure 1.9 Anatomy of the pelvic limb. (Budras and Habel, 2011)

- Femur (8). Straight, cylindrical beam serving as the main foundation for the hip. The head of the femur (1) presents a condyloid lateral extension.
- Stifle joint (femorotibial joint-between 17 and 25). Simple condylar connecting the tibia to the femur. Responsible for flexion and extension restricted by ligaments.
- Medial condyle (23). Part of the tibia that is laterally extended to the lateral condyle (25). Works in hand with the extensor groove (27) for flexion and extension (Budras and Habel, 2011).

While the ideal hip structure should show evidence of moderate slope from hooks to pins, there are two major extremes in regards to hip structure. The first deviation is usually termed steep hipped or round hipped, when the angle from hooks to pins is too distinct and it begins to negatively impact hock and pastern structure. The second defect includes an inverted angle from hooks to pins where the pins are significantly higher than the hook bones. The animal will appear to have a high tailhead, when it's actually the bone structure deviating from normal.

The lower rear skeleton becomes very similar to the forelimb in regards to bone structure. Other areas to note in the lower pelvic limb include (Budras and Habel, 2011):

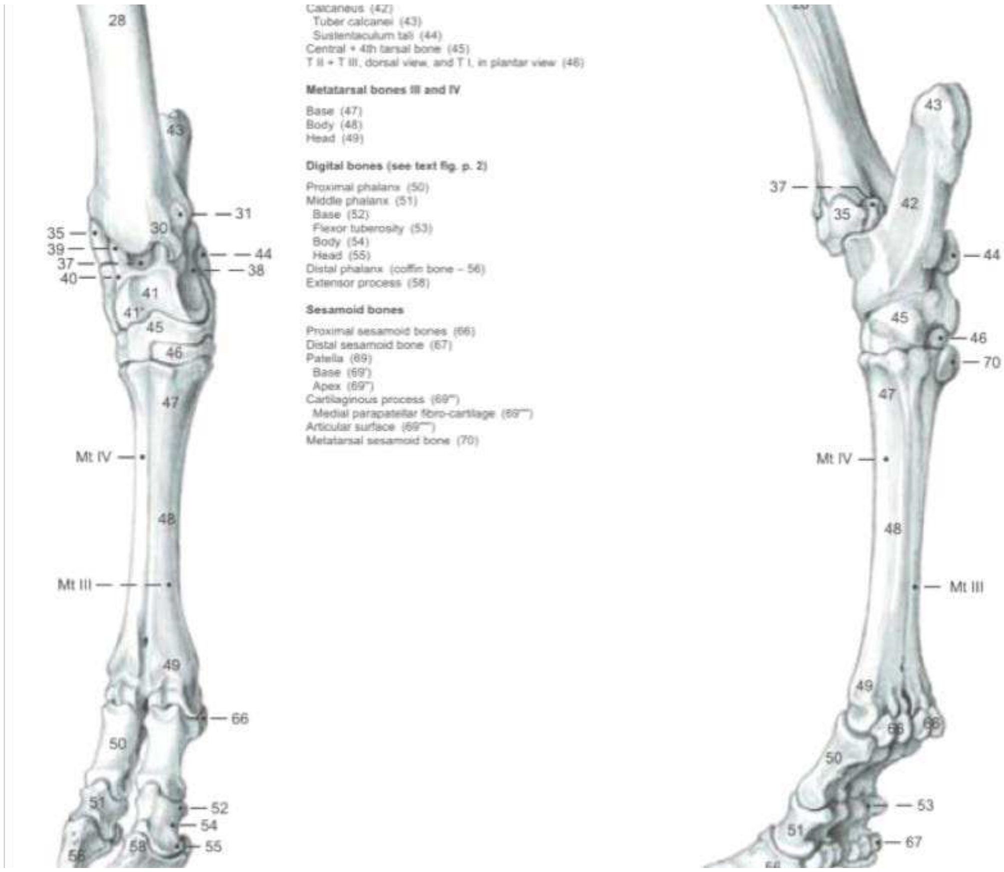


Figure 1.10 Anatomy of the pelvic metacarpal region. (Budras and Habel, 2011)

- Tarsal joint (hock). Composite joint responsible for flexion and extension. Also serves as a snap joint with long plantar ligaments, divided into medial branches blended with fibrous capsules.
- Third metacarpal body (cannon bone-48). Main weight bearing column extending from the tarsal region (45) to the proximal phalanx (50).

- Proximal interphalangeal joints (pastern-between 50 and 51). Incompletely fused bony structures responsible for flexion, extension and small lateral and rotational movements.
- Proximal sesamoid bones (dewclaws-66). Lack the proximal phalanx (50) and attach to the digits by ligaments (Budras and Habel, 2011).

Vermunt and Greenough (1996) reported that cattle hocks were considered “straight” if the angle exceeded 170°, but Fehér et al. (1968) reported that AI bulls with hocks greater than 155° were considered straight. Forabosco et al. (2004) presented that beef animals raised in the pastures will have a harder time walking with post-legged problems because the cattle adopt a stilted gait. As a consequence, the weight-bearing portion of the claw migrates to a more dorsal position, resulting in increased toe abrasion (Vermunt and Greenough, 1996). These angles are important to watch, especially in breeding stock, because of the strain put on the hind limbs during breeding season in both service and dismount.

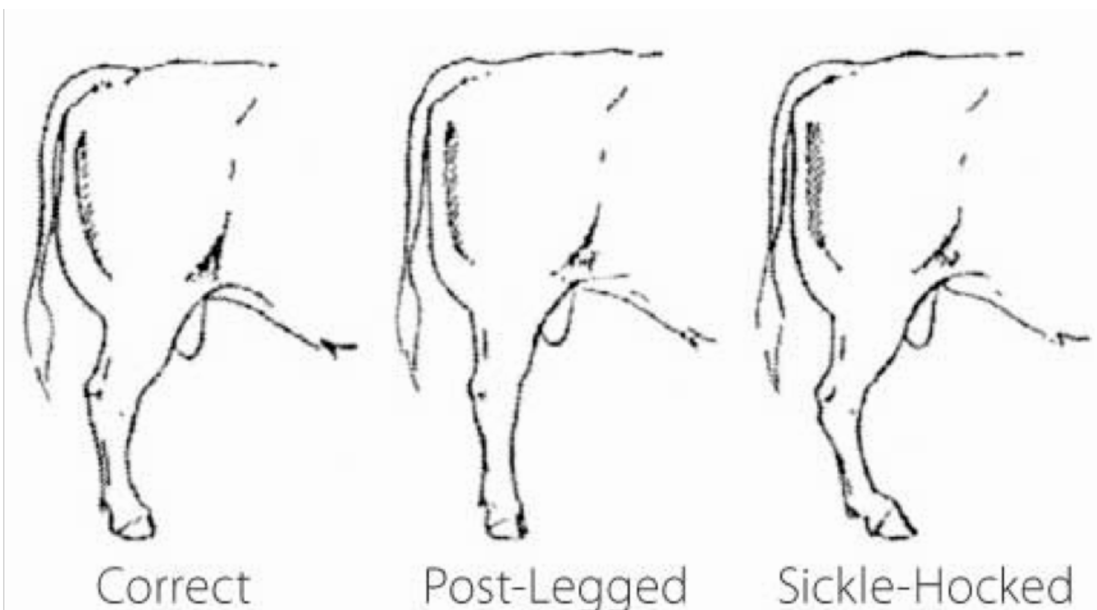


Figure 1.11 Hock defects side view. (Ashwood, 2011)

Vermunt and Greenough (1996) also reported that Fehér et al. (1968) found 20% of animals with hock angles exceeding 155° became lame with increased age. As an average, acceptable hock angles should be in the 145° to 150° range. Figure 1.12 shows severe hock deviations when viewed from the rear profile. Bow legged (b) cattle tend to walk on the outer walls of their hooves with their toes pointing inward, shifting their weight to the outer portions of their skeletons. Cow hocked (c) animals show deviations of rotated hooves to the outside. Oftentimes the hocks rub together while the animal is in motion, but both sets of rotations put harsh strains on the ligaments in the leg, frequently followed by a higher incidence of lameness.

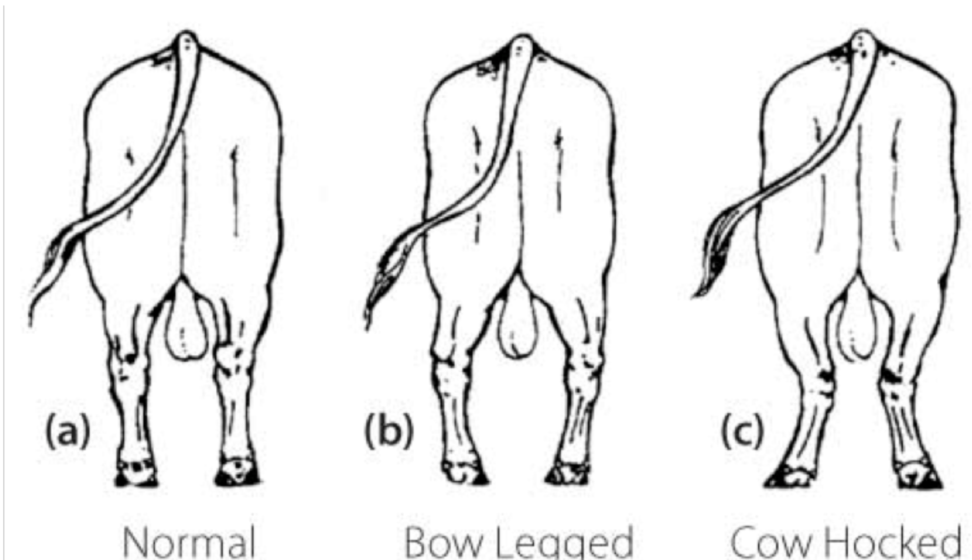


Figure 1.12 Hock defects rear view. (Ashwood, 2011)

It is challenging to identify one particular defect that is the most detrimental in regards to overall cattle structure and movement. Beeman (2002) suggests that the toed out defect is the most concerning for horses due to the extra pressure exerted on the knee and coronet bands rubbing together while on the travel. All in all, both upright and collapsed joints on either the fore or hind limbs of the bovine skeleton demonstrate altered locomotion. Structural problems may convey a predisposition to cattle lameness and reducing the incidence of these defects will bring an improvement in animal care and welfare.

Effects of Lameness

Lameness is described as an evaluation of an animal's ability to move efficiently or the lack thereof. Conformational defects in the bovine skeleton only encompass one branch of predisposing factors contributing to the onset of lameness. Aside from the genetic component that includes skeletal flaws, other factors that inherently impact lameness fall under the general scopes concerning environment and management.

Van Dorp et al. (2004) mentioned that environmental effects might worsen the stance of a cow and increase the need to select for cows with optimal conformation. The living environment of the animal plays a pivotal role on the skeletal adaptations to those conditions. There are many challenges in regards to temperature extremes and the concern with cattle adaptations to the mitigation of heat or cold stress (Lyles and Calvo-Lorenzo, 2014). Understandably, climate effects are unpredictable; however, it is the producer's responsibility to be prepared to meet these types of challenges and minimize the impact of these events. Proper housing and pen layouts can help divert some of the issues with unexpected weather and pen conditions with consideration to proper drainage, waste removal, and a minimal exposure to the elements by means of protective housing. Ground surface and pen condition can negatively impact the feet and leg condition during wet periods, and the constant exposure to moisture on the feet can soften the hoof walls and make the surrounding skin more vulnerable to irritation, infection, and lesions, all predisposing factors to an early onset of lameness (Ashwood, 2011).

Vermunt and Greenough (1995) divulge the changes in the structural characteristics in the bovine claw. The nature of the ground or floor surface indicates the influences of rate of wear. They demonstrated that rate of horn growth was greater in confinement housing vs. pasture raised dairy cows with almost 35% more wear on abrasive concrete floors.

Consequently, claws on confined floors shift the weight to the sole, whereas lateral walls become wider on cattle housed outside on earthen surfaces (Vermunt and Greenough, 1995). Lameness is one of the most reliable signs in diagnosing pain and discomfort originating from limb disorders (Boelling and Pollott, 1998).

Any changes in management may predispose cattle to claw disorders, lesions, and lameness. Disease prevention is a management issue that works simultaneously with environmental impact on hoof care. Claw diseases and disorders contributing to lameness have shown to rank third in total dairy losses after mastitis and fertility problems (Enting et al., 1997). There is a moral obligation on the producer end to maintain the proper care of the animals. Any digression in fixing these concerns, from a management perspective, can prove to have severe consequences not only in animal health but economically as well.

Nutritional factors have demonstrated a significant role on cattle lameness, particularly laminitis. Laminitis is a multifactorial disease that often presents with hemorrhages in the sole or abnormalities in the claw horn, thus impacting cattle locomotion and an earlier onset of lameness. Extensive research has looked into the impacts of laminitis, and one particular association with rumenal acidosis (Greenough et al., 1990; Donovan et al., 1998). Acute laminitis has shown to be associated with high levels of rumen soluble carbohydrates, starches, or proteins in cattle rations (Donovan et al., 1998). Modified rations that have an increase in soluble carbohydrates and a lower effective fiber often induce a significantly higher rate of rumen acidosis. In a study by Greenough et al. (1990), intensively fed beef calves and yearlings showed increased prevalence of heel hemorrhages when fed a higher energy ration. Additionally, rations with higher levels of protein indicated a thinner sole at slaughter than those fed a lower level of protein. It is important for cattle to receive a nutritionally balanced diet, formulated specifically for each stage of life, with enough fiber to stimulate the biological need for chewing cud and creating enough saliva to act as a buffer in the digestive process to deter the effects of acidosis. Adverse problems associated with poor metabolism could unintentionally predispose cattle to issues with hoof quality and lameness. Overall the livestock keeper needs to be aware of hoof health and control the problems for the long term through proper hoof care and management of nutritional and environmental components (Haggman and Juga, 2013).

Economics also come into play for the producer to increase income by reducing costs. In the hog industry, Kadarmideen et al. (2004) records leg weakness as a high economic, health and welfare concern to countries with intensive pig production where leg weakness was reported to be unfavorably correlated to growth rate and lean meat content. Laenoi et al. (2011) also explained that leg weakness in hogs has a significant impact on fitness and longevity, which affects the welfare, production and reproductive performance in pigs. Likewise, economic losses due to conformational defects have been found in the dairy industry (Enting et al., 1997). Attributed costs go into multiple categories for cost of veterinary treatment, labor, weight loss, changes in production, and even culling and replacement losses totaling an average of $42.90 per cow (Harris et al., 1988).

Alterations in soundness and predisposing factors to lameness are often associated with skeletal structure abnormalities. With lameness causing discomfort, it is considered an indicator for suffering and pain (Boelling and Pollott, 1998). Ultimately, pain mitigation for livestock and animal welfare should rise to the forefront as top priorities for producers. Boelling and Pollott (1998) describe locomotion as the easiness of movement; this reflects a normal gait as well as any impaired locomotion, caused by a disorder. With environment, management, and genetics playing the roles of predisposing factors to lameness and negatively influencing cattle locomotion, the skeletal component of minimizing lameness can be substantially improved by phenotypic selection of proper conformation traits.

Need for Evaluation

While there are multiple research endeavors for both the swine and dairy industries in regards to skeletal conformation defects, the beef industry seems to be deficient in this particular area. The interest in animal welfare has risen to be a top concern for many consumers. While beef cattle structural integrity research is rather novel, the issue itself has advanced into highly important territory after the debate over whether cattle lameness and the use of beta agonists in feedlot cattle is inherently linked (Thomson et al., 2015). There are a number of factors known to influence the development of leg weakness, such as nutrition imbalance, high body weight, rapid growth rate, bone and joint diseases, bad body and leg structure, and mechanical stress (Laenoi et al., 2011). Without a doubt, these many aspects of management and environment have profound effects on lameness and need to be taken into account. There is little literature associated with evaluating the basic skeletal structure of cattle and its impacts on conformation solely from a genetic standpoint. By removing other variables including management, environment, and diet differences, genetic factors impacting skeletal defects can be more readily evaluated.

Evaluating conformational defects has been done with several different approaches for both the hog and dairy industries. Van Steenbergen (1989) and Thompson et al. (1981) mention the idea of scoring traits individually rather than combining them, so that the degree of the trait is scored rather than the desirability. Thompson et al. (1981) indicate some advantages of a linear scoring system including:

- Scores cover the biological range
- Traits are scored individually
- Wide ranges of numerical scores allow for analysis on a continuous scale
- Heritabilities for scored traits are comparable to corresponding traits in relation to an ideal
- Linear scoring permits interpretation of biological relationships amongst exterior traits.

In the hog industry, Van Steenbergen (1989) used a linear scoring system of 0-9 with 0.5 increment categories to evaluate exterior conformation traits in relation to reproduction and longevity, where 4.5 exhibited normal. Aasmundstad et al. (2014) utilized a 7-point linear scale for leg confirmation traits with 4 used as optimum and a 4-point linear scale (4-7) for locomotion, with 4 used as optimum, to investigate the heritabilities and genetic correlations between conformation traits and longevity. Laenoi et al. (2011) used an optimum intermediate (3) on a scale of 1-5 to analyze the impacts of leg weakness on fitness and longevity. They transformed the data to also include a desirability scale using the absolute value of the original scores (ie. the extreme scores 1 and 5 become 'poor leg scores (2)', while 2 and 4 become 'moderate leg scores (1)', and 3 becomes the 'optimum leg score (0)'.)

For the cattle industry, Thompson et al. (1981) utilized a 50-point linear scale with 25 as the average for evaluating genetic heritabilities of Holstein cattle dairy character traits. Forabosco et al. (2004) used an intermediate optimum with a linear scale of 1-5 to investigate the phenotypic relationship of type traits (production, muscle development, body size, leg structure, and refinement) on longevity in Chianina cows. The most recent cattle research from Jeyaruban et al. (2012) utilized a linear scale of 1-9, with 5 and 6 serving as the most desirable scores for evaluating feet and leg traits. Like Laenoi et al. (2011), they too, categorized the data into three groups to separate the most desirable group (5-6) from the less desirable groups (1-4) and (7-9). Though the methods used to sample conformation defects tend to differ, it was important to assess the traits with an established scoring system and incorporate new tools to better depict the current conformation of the U.S. beef cattle herd.

Research conducted to quantify the presence of conformational defects is scarce, and we found no recent publications exhausting the topic at hand. It is imperative that structural integrity in cattle must not be sacrificed with high priorities of growth and carcass merit. In the words of Jim Williams, owner of the V8 ranch, "The day may come when the art of breeding cattle can be automated, but today, the eye of the master still plays an important role in pedigreed livestock." The skill in phenotypic evaluation holds incredible value in deciphering the impacts of genetics on skeletal defects. With so many variables impacting lameness, it's time to utilize that expertise in our selection of beef cattle and merge improving husbandry practices with more accurate consumer perceptions of the beef industry.

CHAPTER II: SURVEY OF THE PREVALENCE OF CONFORMATIONAL DEFECTS IN FEEDLOT RECEIVING CATTLE IN THE UNITED STATES

SUMMARY

A survey was conducted on large beef cattle feedlots in Colorado and Texas between March and July 2015, to assess the current status of conformational defects in U.S. fed steers and heifers. The objectives were to: 1) determine the prevalence of conformational defects in feedlot receiving cattle in a population across multiple regions within the United States; and 2) increase industry awareness of the structural problems found in the current cattle population to help ultimately improve a practical selection focus. Conformational traits of front and rear claw, front and rear feet angles, rear leg side view, and rear leg hind view were evaluated on a scale of 1-9 with scores 4-6 serving as the most desirable. Overall soundness was evaluated from 0-100 with 66-100 serving as optimal soundness. A new scoring tool was developed and added to assess conformational problems in cattle shoulder and hip structure. Data from 2,886 head of feedlot cattle was used to evaluate the frequency of these conformational defects. Phenotypic evaluation revealed the highest prevalence of conformational issues in the shoulder, hip, and rear leg covering multiple relationships with demographic characteristics. Of the entire sample, 49.97% had a less than ideal shoulder structure, 53.33% had a less than ideal hip structure, and 29.97% displayed a less than ideal hock structure when viewed from the side. Heavier weight cattle showed a significantly higher (P<0.0001) prevalence of front claw scissor type abnormalities (7-9) and an increase (P<0.0001) in impaired mobility scores (group 2). Northern cattle exhibited a significant (P<0.0001) increase in front claw defects of scissor claw type abnormalities (7-9). Lastly, *Bos Indicus* cattle displayed a higher prevalence (P<0.0001) of round hip structures (7-9) and an increase (P<0.0001) of impaired mobility scores (group 2). The remaining traits had significantly higher proportions in the desirable (normal) group, and thus, the industry has shown positive developments in rear claw set and front and rear feet angles. Additionally, 85.85% of our total sample demonstrated overall comprehensive soundness scores for sound and flexible mobility (group 3). These findings will be useful to the beef industry in creating a benchmark for the conformational status of the current cattle herd to ultimately improve skeletal structure for improved welfare and performance in feedlot cattle.

Key Words: beef cattle, conformation, defects, feedlot, survey

INTRODUCTION

As animals are continually bred and selected for performance driven traits, anecdotal evidence has suggested that conformational soundness is too often sacrificed. August 2013 brought forth many apprehensions with animal well-being as Tyson Fresh Meats expressed concerns related to cattle exhibiting stiff joints, lethargic movements, and difficulty walking into the plants. Health experts suggested one potential link to the use of the feed supplement Zilmax, and thus, Tyson would not be accepting any more cattle fed this supplement. Since the specific variable of the problems is difficult to distinguish, it makes sense to revert back to the basic foundation prior to feeding, supplements, and housing differences, i.e. the animal skeleton and the genetics that create that animal before all other variables come into play. Herein, perhaps, lies an even bigger issue than the Zilmax product itself. As pounds of muscle are rapidly added to an already compromised structural skeleton, conformational problems are amplified affecting the structural integrity, animal comfort, and overall animal performance in the feedlots.

Outside of economic losses associated with decreased average daily gain (ADG), live weight, treatment costs, and labor (Harris et al., 1988; Enting et al., 1997) due to lameness issues, the increased public concern for animal welfare puts the beef cattle industry in the spotlight. A contemporary survey for conformational defects has not been conducted, and this study will create a benchmark for structural deficiencies. One aim of the study is to determine the prevalence of conformational defects in feedlot receiving cattle across multiple regions in the United States; the second is to increase industry awareness of these conformational issues to hopefully form the basis for increased studies relating structural soundness to areas including animal welfare, cattle comfort, and overall productivity in the feedlots.

MATERIALS AND METHODS

Prior to the initiation of the experiment, care, handling, and sampling of the animals was approved by the Colorado State University Animal Care and Use Committee. Data collection took place during routine processing of feedlot cattle in JBS Five Rivers feedyards.

General Overview

Five large feedlots in Colorado and Texas were surveyed between March and July 2015 for a total of seven days to represent cattle origins in various regions across the United States. Feedlots were surveyed based on maximizing travel and time efficiency and optimizing the proportion of cattle numbers at each visit. During feedlot visits, cattle demographic information was collected and processing sheets were reviewed prior to phenotypic scoring. Lot information on sex class, regional cattle origin, source origin, and average lot live weight was requested from each feedlot for randomly chosen lots of cattle just arriving at the feedlot. Conformational defects were split between the two observers to eliminate a single evaluator bias amongst total sampling. The conformation traits were evaluated on a 1-9 scale on the basis of an intermediate optimum (4-6) and comprehensive soundness was evaluated on a continuous scale of 0-100 with score 100 serving as the desired optimum.

Every third animal processed through the chute was scored for conformational defects by two trained observers. Observer one collected the following traits for all sampling: front feet claw set, front feet angle, rear feet claw set, rear feet angle, comprehensive soundness, and hide color description. Observer one was positioned 3-4 meters in front of the squeeze chute to effectively evaluate claw set and then rotated on the side profile of the animal to score the remaining traits on the walk. Observer two collected the remaining traits: *Bos indicus* breed type and an estimated percent *Bos indicus*, cattle sex, shoulder angle side view, hip angle side view, rear leg side view, and rear leg hind view. This evaluator was professionally trained as a Certified Brahman judge by the American Brahman Association to properly assess *Bos indicus* breed type. Observer two was positioned 4-5 meters away from the cattle side profile as they entered the sorting pens to score the side view traits. Once those scores were collected, observer two rotated around the cattle in order to score the remaining hind view traits. The same evaluator observed the same defects throughout the entire experiment to ensure consistency of observations during data collection. Prior to the beginning of this study, a standardized collection process was held to ensure consistency of measurements and observations during data collection. Surveys were designed using Qualtrics Software Version 2009 (Qualtrics, Provo, UT).

Conformational Defects

Front and rear feet angles, front and rear feet claw set, rear leg side view, and rear leg hind view defects were evaluated based on the linear 1-9 scoring system from (Jeyaruban et al., 2012) for Australian Angus cattle (See Figure 2.1). The conformation of the front and rear feet claw set was evaluated from the front profile in regards to the shape (primary curl) and evenness of the claw set (Smith, 2011). Categories 1-3 were evaluated as open divergent, 4-6 as normal (good), and 7-9 as extreme scissor claw. The conformation of the front and rear feet angles was evaluated from the side profile for strength of pastern, depth of heel and length of foot (Smith, 2011). Categories 1-3 were evaluated as steep toe, 4-6 as normal (good), and 7-9 as shallow heel.

The conformation of the rear leg was evaluated from both the side [rear leg side view], as the angle measured at the front of the hock (Smith, 2011), and from behind [rear leg rear view], as the direction of the feet when viewed from the rear (Smith, 2011), after the cattle had settled into the sorting pens following chute processing. From the side, categories 1-3 were evaluated as post legged (straight), 4-6 as normal (good), and 7-9 as sickle hocked. From behind categories 1-3 were evaluated as bow legged, 4-6 as normal (good), 7-9 as cow hocked. Much like the work of Boelling and Pollott (1998), traits scored were representative of both legs, both claws, etc.

Two new indicator traits were developed and added to the survey to better encompass the conformational problems found in the beef industry: shoulder angle side view and hip angle side view (See Figure 2.2). Shoulder angles were examined on the side profile based on the angle measurement of the scapula blade to the shoulder joint. Categories 1-3 were evaluated as straight, 4-6 as normal (good), and 7-9 as relaxed. Hip angles were evaluated on the side profile based on the incline from hook bones to pin bones. Categories 1-3 were evaluated as inverted, 4-6 as normal (good), and 7-9 as round hipped. Summary statistics of the conformational defects can be found in Table 2.1. While the majority of the means suggest that the traits fall within the optimum range, the industry should be cautiously aware of the structural problems that were still observed, without the animals being supplemented beta agonists nor feed additives. Defects in the shoulder, hip, and hock are of primary concern based on the frequencies outside of the normal range. The occurrences of all defects can be found in Table 2.2.

Overall Comprehensive Soundness

While individual conformational defects play an important role in contributing to the soundness of the animal, the overall comprehensive soundness trait was developed and added to provide an all-encompassing score for comprehensive soundness as a stand-alone score. Early in the sampling process, the observers detected that some cattle, regardless of individual trait scores, were fully capable of achieving more than acceptable mobility and soundness. The observers utilized this score on the basis of 0-100 to rank how easily the cattle moved despite their individual trait scoring. The overall comprehensive soundness score was based on a linear 0-100 scoring system, where optimum soundness and flexibility is ranked 100. For statistical evaluation, scores were then collapsed into three groups: severely impaired mobility (scores <33), impaired mobility (≥33 and <66), and sound and flexible mobility (≥66). Because this score was added later, it features 2,036 total head of cattle out of the total 2,886 head sampled. Summary statistics of overall composition can be found in Table 2.3.

Statistical Analysis

All analyses were performed using SAS (SAS Inst. Inc.; Cary, NC). Mean, standard deviations, and minimum and maximum values for each trait were generated using PROC MEANS. Frequency distributions were analyzed using PROC FREQ. Initially, all demographic traits were analyzed simultaneously against individual conformational defects. Non-significant traits were removed to allow for further analysis of significant traits.

RESULTS AND DISCUSSION

General Overview

Because of the large sample size, a great majority of the characteristics showed a statistical significance ($P<0.05$). Following evaluations similar to Jeyaruban et al. (2012) and Laenoi et al. (2011), conformation scores were collapsed into three categories, which facilitated the comparison amongst the most desirable scores (4-6) from the less desirable scores (1-3) and (7-9). Much like Jeyaruban et al. (2012), the lack of extreme scoring on either end of the scale resulted in some low standard deviations for front feet claw set, rear feet claw set, and front feet angle.

Lot Average Live Weight

The average lot live weight from all 2,886 head was reported at 357.3 kg. Summary statistics can be found in Table 2.4. The weight range of the sampled cattle was 238.6 kg to 454.5 kg. For analysis by defect, live weight was divided into lightweight (<357.3 kg) and heavyweight groups (≥357.3 kg) with 48.96% of our total population in the lightweight group and 51.04% in the heavyweight group.

Breed Types

Estimated breed types (Table 2.4) consisted of native-type *Bos taurus* (93.4% of total sample) and *Bos indicus* (6.6% of total sample). For evaluative purposes, an estimate of percent *Bos indicus* was completed. One of the observers was professionally trained as a Certified Brahman Judge and had the credentials to assess the breakdown in fractions of 1/8. Groups were, however, condensed down for analysis into Brahman influenced or None.

Sex Classes

Table 2.4 shows that 89% of the cattle surveyed were steers and 11% were heifers. Our percentages differed from the National Beef Quality Audits since our sample comprised solely of feedlot steers and heifers rather than the 63.5% steers, 36.5% heifers, 0.1% cows, and 0.03% bullocks reported by Moore et al. (2012). This unbalance could be attributed to the current rebuilding of the cow-herd in the United States.

Hide Color Assessment

Hide color assessment has been included in National Beef Quality Audits (McKenna et al., 2002; Garcia et al., 2008; Moore et al., 2012) since hide color is used in many of the USDA-certified beef branded programs. Hide color distributions can be found in Table 2.4. We found a slightly higher frequency of black hided cattle (61.3%) than the 61.1% reported by Moore et al. (2012). The distinguishable prevalence of black hided cattle was not surprising since numerous branded beef programs highlight Angus genetics for an increase in black hided cattle entering the programs for increased premiums.

Regional Cattle Origin

Regional cattle origin was collected as a demographic trait to compare the relationship with conformational defects. Twelve states were represented in the U.S., as well as Canada, totaling 13 various regions of cattle origin prior to arrival at the feedlot. After adding up cattle percentages for each location, we separated origins into a northern region and a southern region to balance the percentages to get the most even amount possible for both categories in order to compare. Total breakdown of regional cattle origin can be found in Figure 2.3.

Source Origin

Source origin of the cattle attests to the type of environment the cattle were purchased from prior to entering the feedlot for processing. Growyards contributed to the highest frequency of cattle (37%), but this type of purchase option was solely confounded to the northern feedlot location (Colorado), along with cattle backgrounded on wheat pasture (4.9%). Likewise, the sale barn option was confounded to the southern feedlot location (Texas). This finding may be attributed to northern feedlots sourcing directly from producers and contractors rather than purchasing from sale barns. Similarly, the southern feedlots were more closely located to sale barns, thus purchasing a higher number of sale barn cattle in contrast to the northern feedlots. See Table 2.5 for summary of source origin types.

Front Claw

The data showed that 93.66% of the cattle surveyed had an optimum (4-6) front claw structure (See Table 2.2). Lot average live weight was significant (P<0.0001) for front claw defects. We found that 97.95% of the lightweight cattle (<357.3 kg) exhibited a normal front claw structure (4-6). Of the heavy weight group (≥357.3 kg), 10.25% of the cattle had scissor claw (7-9) type abnormalities. This finding aligns similarly with Vermunt and Greenough (1995) where increased body weight influences a higher prevalence of this type of claw abnormality. Breed type proved to be significant (P=0.0203) where 93.25% of the native type *Bos Taurus* cattle had an optimal front claw, in addition to 99.47% of all *Bos Indicus* cattle also showing a normal (4-6) front claw. Regional cattle origin was significant (P<0.0001) where 10.26% of all northern cattle exhibited scissor claw type abnormalities (7-9). On the other hand, 97.42% of all southern cattle fell into the optimum (4-6) category. Source origin proved to be significant (P<0.0001) where 11.70% of all cattle coming from growyards had scissor claw type abnormalities (7-9). However, all other source categories exhibited a normal front claw (4-6): backgrounded on wheat (93.62%), native grass (95.42%), sale barn (98.79%), and wheat pasture (99.03%). Reference Table 2.6 for all summary statistics of defect frequencies and group percentages by demographic comparisons.

Front Feet Angle

We found that 96.47% of all cattle showed an optimum (4-6) front feet angle. Lot average live weight proved to be significant (*P*=0.0013) where 97.66% of all lightweight cattle had a normal front feet angle (4-6). Of the heavy weight cattle, 95.32% also showed a normal front feet angle (4-6). Breed type was significant (*P*=0.0035) for both breed groups. Of the native type *Bos Taurus* cattle, 96.59% had a normal (4-6) front feet angle and 94.74% of all *Bos Indicus* cattle also showed a normal (4-6) front feet angle. Regional cattle origin also proved to be significant (*P*<0.0001). Both northern and southern cattle had a significant distribution in the optimal group (4-6) with 94.69% of all northern cattle having a normal foot angle and 98.08% of all southern cattle also showing a normal angle. Source origin proved to be significant (*P*<0.0001) where all source categories exhibited a normal front feet angle (4-6): backgrounded on wheat (97.16%), growyard (93.82%), native grass (98.51%), sale barn (97.17%), and wheat pasture (98.38%). Reference Table 2.6 for all summary statistics of defect frequencies and group percentages by demographic comparisons.

Shoulder

The data revealed that 49.97% of the total sample had a less than ideal shoulder structure. Lot average live weight proved to be significant (*P*<0.0001) for both weight groups. Of the lightweight cattle, 54.92% exhibited a straight-shouldered defect (1-3). Similarly, 36.93% of the heavyweight cattle also displayed the straight-shouldered defect (1-3). Breed type was significant for both breed groups. 43.40% of all native type *Bos Taurus* cattle had a straight-shouldered defect (1-3). Likewise, 78.95% of all *Bos Indicus* cattle also showed a straight-shouldered defect (1-3). Regional cattle origin was also significant (*P*<0.0001). Of all northern cattle, 37.92% exhibited a straight-shouldered defect (1-3). Likewise, 52.84% of all southern cattle also had a straight-shouldered defect (1-3). Source origin proved to be significant (P<0.0001) for all groups. Of the cattle backgrounded on wheat, 15.60% exhibited a relaxed shoulder (7-9) and 11.35% showed the straight shouldered defect (1-3). Similarly, 41.76% of all cattle sourced in growyards, 46.34% of all cattle raised on native grass, 47.77% of all sale barn cattle, and 70.23% of all cattle on wheat pasture all displayed a straight shoulder. Due to this distribution, we suspect that shoulder problems are becoming increasingly prevalent amongst all cattle entering the feedyards, no matter what source they originate from. Reference Table 2.6 for all summary statistics of defect frequencies and group percentages by demographic comparisons.

Hip

Data showed that 53.33% of total cattle numbers had a less than ideal hip structure with 51.59% landing in the round-hipped group (7-9). Lot average live weight proved to be significant (P<0.0001). Of the lightweight cattle, 55.70% displayed a round hip structure (7-9). Likewise, 47.66% of the heavy weight cattle also came from the round-hipped group (7-9). Breed type was significant (P<0.0001) for both groups. Of the native type *Bos Taurus* cattle, 49% had a round hip structure (7-9) and 88.42% of all *Bos Indicus* cattle also showed a round hip structure (7-9). Regional cattle origin proved to be significant (P<0.0001) where 45.92% of all northern cattle landed in the round hipped group (7-9). Likewise, 51.59% of all southern cattle also showed a round hip structure (7-9). Source origin was also significant (P<0.0001) for all groups. 55.32% of all cattle backgrounded on wheat, 39.89% of all cattle sourced in growyards, 52.63% of all cattle raised on native grass, 54.66% of all sale barn cattle, and 82.52% of cattle on wheat pasture all displayed the round hipped defect (7-9). Due to this high distribution of round-hipped cattle, we suspect that hip problems are also becoming increasingly prevalent amongst all cattle entering the feedyards, no matter what source they originate from. Reference Table 2.6 for all summary statistics of defect frequencies and group percentages by demographic comparisons.

Rear Leg Side View

Of the total sample, 70.03% demonstrated a normal hock structure. Lot average live weight was significant (*P*<0.0001), where 25.55% of all lightweight cattle showed the straight, post-legged defect (1-3). On the other hand, 13.10% of all heavy weight cattle displayed sickled hocks (7-9). Breed type proved to be significant (*P*=0.0055) for both breed groups. Of the native type *Bos Taurus* cattle, 19.44% had a straight, post-legged defect (1-3) and 30.53% of all *Bos Indicus* cattle also showed a straight, post-legged defect (1-3). Regional cattle origin was significant (*P*<0.0001) with 17.61% of all northern cattle showing a post-legged defect, as well 22.49% of all southern cattle also having post-legged defect (1-3). Source origin also proved to be significant (*P*<0.0001) for all groups. Of the cattle sourced in growyards, 16.29% exhibited a straight, post-legged defect (1-3) and 13.39% showed sickled hocks (7-9). Similarly, 26.24% of all cattle backgrounded on wheat displayed sickled hocks (7-9). Finally, 19.11% of all cattle raised on native grass, 12.96% of all sale barn cattle, and 53.07% of all cattle on wheat pasture all displayed a straight, post-legged defect (1-3). Because of this distribution, numerous hock deviations continue to be prevalent amongst all cattle entering the feedyards, no matter what source they originate from. Reference Table 2.6 for all summary statistics of defect frequencies and group percentages by demographic comparisons.

Rear Leg Rear View

The sample showed that 83.19% of the cattle exhibited a normal hock structure when viewed from behind. While not statistically significant (P=0.1404), it is important to note that 15.80% of all the cattle tended to display a cow-hocked defect (7-9). Regional cattle origin proved to be significant (P=0.0026) with 15.50% of all northern cattle exhibiting a cow-hocked defect (7-9) and also 16.07% of all southern cattle having a cow-hocked defect (7-9). Source origin was also significant (P<0.0001) for all groups. 31.21% of all cattle backgrounded on wheat, 11.33% of all cattle sourced in growyards, 12.93% of all cattle raised on native grass, 22.87% of all sale barn cattle, and 21.04% of cattle on wheat pasture all displayed the cow-hocked defect (7-9). Reference Table 2.6 for all summary statistics of defect frequencies and group percentages by demographic comparisons.

Rear Feet Angle

The data indicated that 88.25% of all cattle had a normal rear feet angle (4-6). Lot average live weight was significant (P<0.0001) for both groups where 86.08% of the heavy weight cattle had a normal rear feet angle and 90.52% of all lightweight cattle also had a normal rear feet angle (4-6). Breed type proved to be significant (P<0.0001) for both groups. Of the native type *Bos Taurus* cattle, 88.69% had a normal rear feet angle, whereas 17.89% of all *Bos Indicus* cattle showed a shallow heel or weak pastern (7-9). Regional cattle origin was also significant for both groups (P<0.0001) with 11.06% of all northern cattle showing a steep toe or upright pastern (1-3), but 91.20% of all southern cattle fell into the optimum category (4-6). Source origin proved to be significant (P<0.0001) where 13.39% of all cattle in growyards displayed a steep toe or upright pastern (1-3). However, all source categories exhibited a normal rear feet angle (4-6): backgrounded on wheat (91.49%), native grass (90.96%), sale barn (92.11%), and wheat pasture (91.26%). Reference Table 2.6 for all summary statistics of defect frequencies and group percentages by demographic comparisons.

Rear Claw

Of the total sample, 99.72% of all cattle had an optimum (4-6) rear claw. Lot average live weight was significant (P=0.0213) for both groups where 100% of all lightweight cattle exhibited a normal rear claw and 99.46% of all heavy weight cattle also exhibited a normal rear claw structure. Regional cattle origin proved to be significant (P=0.0121) with 99.42% of all northern cattle exhibiting an optimum claw and 100% of all southern cattle also having an optimum rear claw (4-6). Source origin proved to be significant (P=0.0411) where all source categories exhibited a normal rear claw (4-6): backgrounded on wheat (98.58%), growyard (99.44%), native grass (100%), sale barn (100%), and wheat pasture (100%). Reference Table 2.6 for all summary statistics of defect frequencies and group percentages by demographic comparisons.

Overall Comprehensive Soundness

The sample concluded that 85.85% of our sample landed in the group with sound flexible mobility (3). Lot average live weight was significant (P<0.0001) with 89.14% of all lightweight cattle showing sound and flexible mobility (3). At the same time, 20.80% of all heavyweight cattle landed in group 2 (impaired mobility). A higher prevalence of cattle with impaired mobility was expected from the heavyweight group since added pounds of muscle tend to have a negative effect on joint flexibility and soundness for feedlot cattle. As cattle get heavier and approach their processing dates, they are more inclined to have more difficulty moving. Breed type also proved to be significant (P<0.0001). Of the native type *Bos Taurus* cattle, 87.32% showed sound and flexible mobility (3). On the other hand 71.58% of all *Bos Indicus* cattle fell into group 2 (impaired mobility). Regional cattle origin was significant (P<0.0001) where 100% of all northern cattle showed sound and flexible mobility (3). Of the southern cattle, 17.59% landed in group 2 (impaired mobility). Source origin proved to be significant (P<0.0001) where 14.19% of all cattle sourced on native grass and 28.95% of all sale barn cattle showed impaired mobility (group 2). The other source categories exhibited sound and flexible mobility (group 3): growyard (100%) and wheat pasture (100%). Reference Table 2.6 for all summary statistics of defect frequencies and group percentages by demographic comparisons.

Recommendations

Sampling improvements may be accomplished by evaluating skeletal structure defects and locomotion concurrently with a third observer exclusively evaluating comprehensive overall soundness to eliminate any potential observer bias by evaluating individual defects simultaneously with the comprehensive score.

CONCLUSION

With the investigation of phenotypic relationships between different structure traits, we found the most notable relationships associated between individual traits with weight, region, breed type, and source. By sampling the cattle at receiving, many external influences were eliminated, while still capturing a similar age and weight range among samples. With supplements like Zilmax off the market at the time of sampling, we were able to effectively capture the natural occurrences of all conformational defects in our sample population. Van Dorp et al. (2004) suggested that factors like age and management tend to have a high influence on feet and leg traits in cattle. Because our sample collection occurred at the processing stage of receiving and the cattle had lower body weights, we may not have been able to decipher the full variability of conformational defects that are present in the entire feedlot population. Overall, this sample did not encompass the full variability of weight and age but served as a blank starting point prior to alternative feeding techniques, technologies, and other external variables. Ultimately, future studies would benefit from following the biological changes that occur in the skeleton from receiving cattle all the way to their finishing slaughter weight.

The most noticeable conformational issues were found in the shoulder (straight/upright), hip (round hipped), and hock (post-legged and cow hocked) deviations from normal (4-6) with high frequencies encompassing multiple demographic characteristics. As stated, 49.97% of our entire sample had a less than ideal shoulder structure, 53.33% had a less than ideal hip structure, and 29.97% displayed a less than ideal hock structure when viewed from the side. On the whole, these demographics showed a significant difference in conformational traits: heavier weight cattle showed a higher influence of front foot scissor claw type abnormalities (7-9) and an increase in impaired mobility scores (group 2), northern region cattle exhibited more front claw defects of scissor claw type abnormalities (7-9), and *Bos Indicus* cattle displayed a higher prevalence of round hip structures (7-9) and impaired mobility scores (group 2).

While considering the positives, the industry has clearly made substantial developments in rear claw set and front and rear pastern angles. Additionally, 85.85% of our total sample population demonstrated overall comprehensive soundness scores for sound and flexible mobility (group 3). Thus, we achieved our goals of determining the prevalence of conformational defects in feedlot receiving cattle from multiple regions in the United States and hope this serves to provide industry awareness of some of the problems found in the current beef cattle population. We intend for this basis to direct the industry toward a route with a more practical genetic focus on improved skeletal structure to ultimately prevent poor structure from worsening in the future.

There is a definitive link between improving individual parts and improving overall soundness as a whole. In a practical sense, phenotypically evaluating younger, lighter cattle can reveal their potential abilities to maintain correct structural integrity throughout the course of their lives as we add extra weight and muscle tissue to their skeletons in the finishing stages. It is important to note that gains in muscle, performance, and carcass driven traits are high priorities for feedlot cattle. At the same time, cattle welfare is of high importance in the beef industry, and a balance should be reached in regards to sound conformation and high feeding efficiency to reach the desired finishing stage in feedlot cattle. In the long term, genetic advancement through phenotypic selection of conformational traits may play an important role in maintaining structural integrity for beef cattle in our feedlots. After all, understanding the skeletal components of the animals from a genetic standpoint may be the ticket in warranting the use of progressive technologies back into the industry to help us become the most efficient feeders possible.

Table 2.1. Summary statistics and description[1] of conformational traits for feedlot cattle (N=2886).

Defect	Mean	Std. Dev.	Min	Max	Description: Score 1	Description: Score 9
Front Claw	5.4	0.7	3.0	9.0	Open divergent	Extreme scissor claw
Front Feet Angle	5.2	0.8	2.0	8.0	Steep toe	Shallow heel
Shoulder	3.8	1.3	1.0	8.0	Straight	Relaxed
Hip	6.5	1.1	2.0	9.0	Inverted	Round hipped
Side View	4.9	1.4	2.0	8.0	Post legged (straight)	Sickle hocked
Rear View	5.5	1.1	3.0	8.0	Bow legged	Cow hocked
Rear Feet Angle	5.2	1.1	1.0	8.0	Steep toe	Shallow heel
Rear Claw	5.0	0.3	3.0	9.0	Open divergent	Extreme scissor claw

[1]Based on an assessment scale of 1-9 with the optimum score range of 4-6 (normal/good)

Table 2.2. Distribution of cattle conformational traits (N=2886).

Defect		Statistics	
		Frequency[1]	Total Percent
	Score 1-3	3	0.10
Front Claw[2]	Score 4-6	2703	93.66
	Score 7-9	180	6.24
	Score 1-3	44	1.52
Front Angle[3]	Score 4-6	2784	96.47
	Score 7-9	58	2.01
	Score 1-3	1320	45.74
Shoulder[4]	Score 4-6	1444	50.03
	Score 7-9	122	4.23
	Score 1-3	50	1.73
Hip[5]	Score 4-6	1347	46.67
	Score 7-9	1489	51.59
	Score 1-3	582	20.17
Side View[6]	Score 4-6	2021	70.03
	Score 7-9	283	9.81
	Score 1-3	29	1.00
Rear View[7]	Score 4-6	2401	83.19
	Score 7-9	456	15.80
	Score 1-3	165	5.72
Rear Feet Angle[8]	Score 4-6	2547	88.25
	Score 7-9	174	6.03
	Score 1-3	1	0.03
Rear Claw[9]	Score 4-6	2878	99.72
	Score 7-9	7	0.24

[1]Represents occurrence out of 2886 total head
[2]Open divergent (1-3), optimum/good (4-6), extreme scissor claw (7-9)
[3]Steep toe (1-3), optimum/good (4-6), shallow heel (7-9)
[4]Straight (1-3), optimum/good (4-6), relaxed (7-9)
[5]Inverted (1-3), optimum/good (4-6), round hipped (7-9)
[6]Post legged/Straight (1-3), optimum/good (4-6), sickle hocked (7-9)
[7]Bow legged (1-3), optimum/good (4-6), cow hocked (7-9)
[8]Steep toe (1-3), optimum/good (4-6), shallow heel (7-9)
[9]Open divergent (1-3), optimum/good (4-6), extreme scissor claw (7-9)

Table 2.3. Summary statistics and description of overall comprehensive soundness for feedlot cattle (N=2036).

Trait	Statistics							
	Mean	Std Dev	Min	Max	Optimum	Score	Frequency[1]	Total Percent
Overall Comp.	81.3	14.1	13.0	100.0	100	Score <33[2]	22	1.08
						Score ≥33[3] and<66)	240	11.79
						Score ≥66[4]	1774	87.13

[1]Represents occurrence out of 2036 total head
[2] Severely impaired mobility (Score <33)
[3]Impaired mobility (Score ≥33 and<66)
[4]Sound and flexible mobility (Score ≥66)

Table 2.4. Distribution of cattle demographic characteristics (N=2886).

Characteristic		Statistics	
		Frequency[1]	Total Percent
Lot Average Live Weight	Lightweight	1413	48.96
	Heavyweight	1473	51.04
Breed Type	*Bos Taurus*	2696	93.4
	Bos Indicus	190	6.6
Sex Class	Steers	2569	89
	Heifers	317	11
Hide Color	Black	1769	61.3
	Brindle	113	3.9
	Red	502	17.4
	Roan	23	0.80
	Smoke	115	4.00
	Yellow	90	3.10
	White	274	9.5

[1]Represents occurrence out of 2886 total head

Table 2.5. Percentage distribution and description of cattle source origin[1]

Source Origin	Percentages	Description
Backgrounded Wheat Pasture	4.9	Pasture type setting, grazed on wheat with low-energy, grain supplementation
Growyard	37.0	Feedlot type setting, fed a low-energy, grain diet
Native Grass	30.3	Pasture type setting, grazed on native grass
Sale Barn	17.1	Cattle bought from an auction barn
Wheat Pasture	10.7	Pasture type setting, grazed on wheat

[1]Cattle environment prior to entering the feedlot for processing

Table 2.6 Summary statistics of defect frequencies and group percentages by demographic comparisons.

Defect	Score	Weight: Light (<357.3 kg)	Weight: Heavy (≥357.3 kg)	Weight: p-value	Breed Type: *Bos T.*	Breed Type: *Bos I.*	Breed Type: p-value	Region: N	Region: S	Region: p-value	Source[1]: BW	Source[1]: GY	Source[1]: NG	Source[1]: SB	Source[1]: WP	Source[1]: p-value
Front Claw	1-3	0[2] 0.00[3]	3 0.20		3 0.11	0 0.00		3 0.22	0 0.00		0 0.00	0 0.00	0 0.00	0 0.00	3 0.97	
	4-6	1384 97.95	1319 89.55	<.0001	2514 93.25	189 99.47	0.0203	1230 89.52	1473 97.42	<.0001	132 93.62	943 88.3	834 95.42	488 98.79	306 99.03	<.0001
	7-9	29 2.05	151 10.25		179 6.64	1 0.53		141 10.26	39 2.58		9 6.38	125 11.7	40 4.58	6 1.21	0 0.00	
Front Angle	1-3	11 0.78	33 2.24		44 1.63	0 0.00		44 3.20	0 0.00		2 1.42	40 3.75	0 0.00	0 0.00	2 0.65	
	4-6	1380 97.66	1404 95.32	.0013	2604 96.59	180 94.74	.0035	1301 94.69	1483 98.08	<.0001	137 97.16	1002 93.82	861 98.51	480 97.17	304 98.38	<.0001
	7-9	22 1.56	36 2.44		48 1.78	10 5.26		29 2.11	29 1.92		2 1.42	26 2.43	13 1.49	14 2.83	3 0.97	
Shoulder	1-3	776 54.92	544 36.93	<.0001	1170 43.40	150 78.95	<.0001	521 37.92	799 52.84	<.0001	16 11.35	446 41.76	405 46.34	236 47.77	217 70.23	<.0001
	4-6	604 42.75	840 57.03		1409	35		763	681		103	569	449	243	80 25.89	

Table 2.6 Summary statistics of defect frequencies and group percentages by demographic comparisons.

Defect	Score	Weight: Light (<357.3 kg)	Weight: Heavy (≥357.3 kg)	Weight: p-value	Breed Type: *Bos T.*	Breed Type: *Bos I.*	Breed Type: p-value	Region: N	Region: S	Region: p-value	Source[1]: BW	Source[1]: GY	Source[1]: NG	Source[1]: SB	Source[1]: WP	Source[1]: p-value
					52.26	18.42		55.53	45.04		73.05	53.28	51.37	49.19		
	7-9	33 2.34	89 6.04		117 4.34	5 2.63		90 6.55	32 2.12		22 15.60	53 4.96	20 2.29	15 3.04	12 3.88	
Hip	1-3	21 1.49	29 1.97		49 1.82	1 0.53		28 2.04	22 1.46		7 4.96	22 2.06	14 1.60	5 1.01	2 0.65	
	4-6	605 42.82	742 50.37	<.0001	1326 49.18	21 11.05	<.0001	715 52.04	632 41.80	<.0001	56 39.72	620 58.05	400 45.77	219 44.33	52 16.83	<.0001
	7-9	787 55.70	702 47.66		1321 49.00	168 88.42		631 45.92	858 56.75		78 55.32	426 39.89	460 52.63	270 54.66	270 54.66	
Side View	1-3	361 25.55	221 15.00		524 19.44	58 30.53		242 17.61	340 22.49		13 9.22	174 16.29	167 19.11	64 12.96	164 53.07	
	4-6	962 68.08	1059 71.89	<.0001	1906 70.70	115 60.53		931 67.76	1090 72.09	<.0001	91 64.54	751 70.32	657 75.17	401 81.17	121 39.16	<.0001
	7-9	90	193		266	17	.0055	201	82		37	143	50	29	24	

Table 2.6 Summary statistics of defect frequencies and group percentages by demographic comparisons.

Defect	Score	Weight: Light (<357.3 kg)	Weight: Heavy (≥357.3 kg)	Weight: p-value	Breed Type: *Bos T.*	Breed Type: *Bos I.*	Breed Type: p-value	Region: N	Region: S	Region: p-value	Source[1]: BW	Source[1]: GY	Source[1]: NG	Source[1]: SB	Source[1]: WP	Source[1]: p-value
		6.37	13.10		9.87	8.95		14.63	5.42		26.24	13.39	5.72	5.87	7.77	
Rear View	1-3	9 0.64	20 1.36	.1404	29 1.08	0 0.00	.5267	23 1.67	6 0.40	.0026	8 5.67	11 1.03	4 0.46	1 0.20	5 1.62	<.0001
	4-6	1176 83.23	1225 83.16		2246 83.31	155 81.58		1138 82.82	1263 83.53		89 63.12	936 87.64	757 86.61	380 76.92	239 77.35	
	7-9	228 16.14	228 15.48		421 15.62	35 18.42		213 15.50	243 16.07		44 31.21	121 11.33	113 12.93	113 22.87	65 21.04	
Rear Angle	1-3	53 3.75	112 7.60	<.0001	165 6.12	0 0.00	<.0001	152 11.06	13 0.86	<.0001	3 2.13	143 13.39	5 0.57	0 0.00	14 4.53	<.0001
	4-6	1279 90.52	1268 86.08		2391 88.69	156 82.11		1168 85.01	1379 91.20		129 91.49	886 82.96	795 90.96	455 92.11	282 91.26	
	7-9	81 5.73	93 6.31		140 5.19	34 17.89		54 3.93	120 7.94		9 6.38	39 3.65	74 8.47	39 7.89	13 4.21	
Rear Claw	1-3	0 0.00	1 0.06	.0213	1 0.40	0 0.00	.9668	1 0.07	0 0.00	.0121	0 0.00	1 0.09	0 0.00	0 0.00	0 0.00	.0411

Table 2.6 Summary statistics of defect frequencies and group percentages by demographic comparisons.

Defect		Demographics														
		Weight			Breed Type			Region			Source[1]					
	Score	Light (<357.3 kg)	Heavy (≥357.3 kg)	p-value	*Bos T.*	*Bos I.*	p-value	N	S	p-value	BW	GY	NG	SB	WP	p-value
	4-6	1413 100	1465 99.46		2688 99.70	190 100		1366 99.42	1512 100		139 98.58	1062 99.44	874 100	494 100	309 100	
	7-9	0 0.00	7 .48		7 0.26	0 0.00		7 0.51	0 0.00		2 1.42	5 0.47	0 0.00	0 0.00	0 0.00	
Overall Comp.	<33	22 1.08	0 0.00		22 1.19	0 0.00		0 0.00	22 1.46		0 0.00	0 0.00	0 0.00	22 4.45	0 0.00	
	≥33 <66	126 9.24	140 20.80	<.0001	212 11.48	136 71.58	<.0001	0 0.00	266 17.59	<.0001	0 0.00	0 0.00	123 14.19	143 28.95	0 0.00	<.0001
	≥66	1215 89.14	533 79.20		1612 87.32	54 28.42		524 100	1224 80.95		0 0.00	436 100.00	744 85.81	329 66.60	239 100.00	

[1]Source: Cattle environment prior to entering the feedlot for processing; BW = Backgrounded Wheat Pasture, GY = Growyard, NG = Native Grass, SB = Sale Barn, WP = Wheat Pasture
[2]Top number in each cell refers to the defect frequency distribution of each column group
[3]Bottom number in each cell refers to the defect percentage distribution of each column group

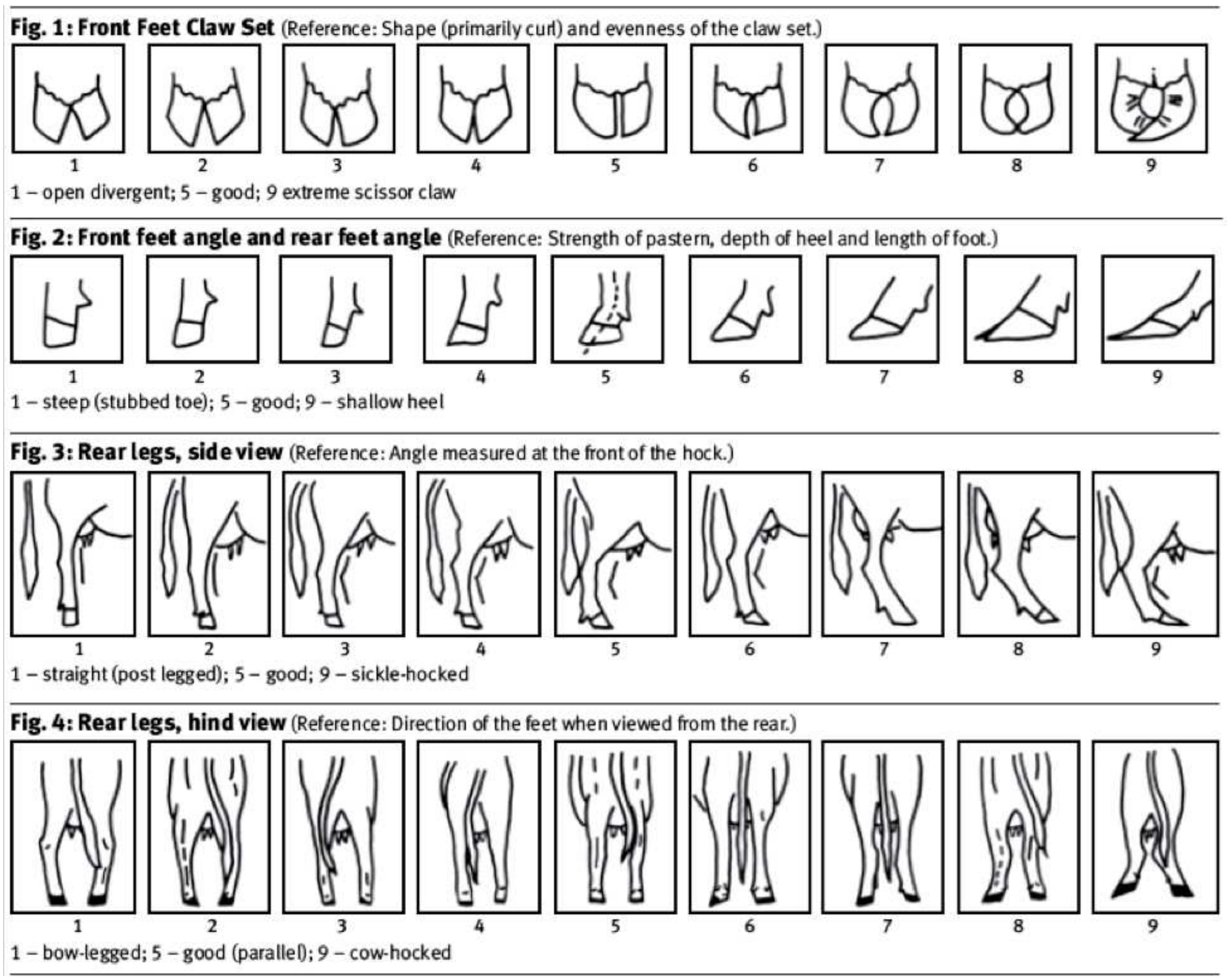


Figure 2.1 Feet and Leg Trait Scoring System (Jeyaruban et al., 2012) and Definitions (Smith, 2011)

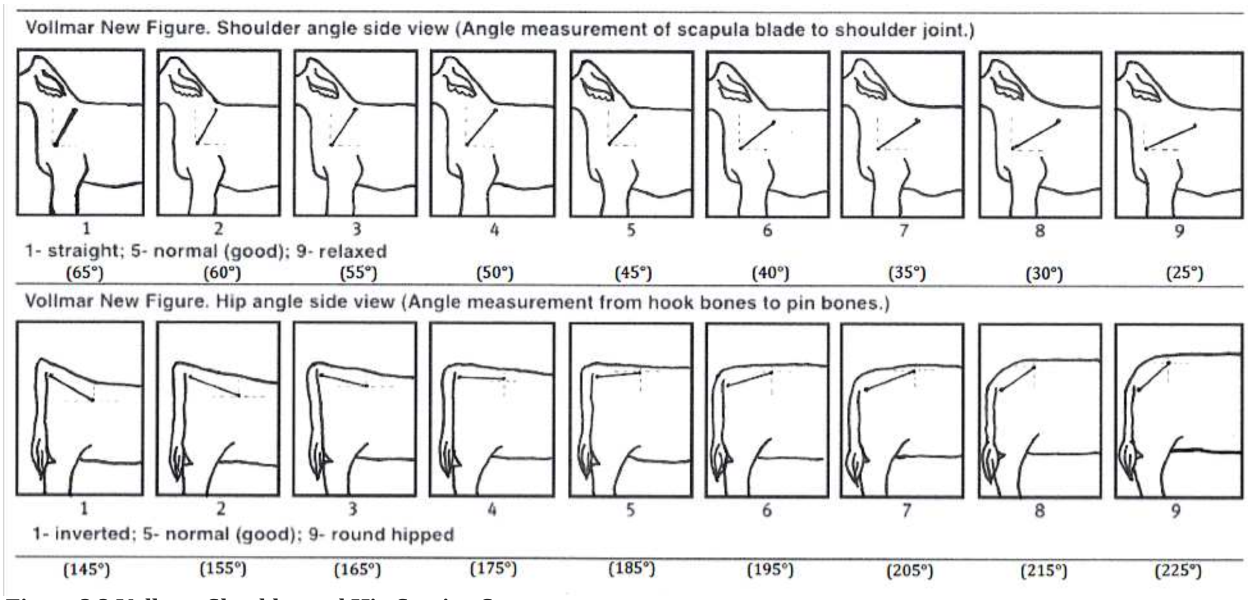


Figure 2.2 Vollmar Shoulder and Hip Scoring System

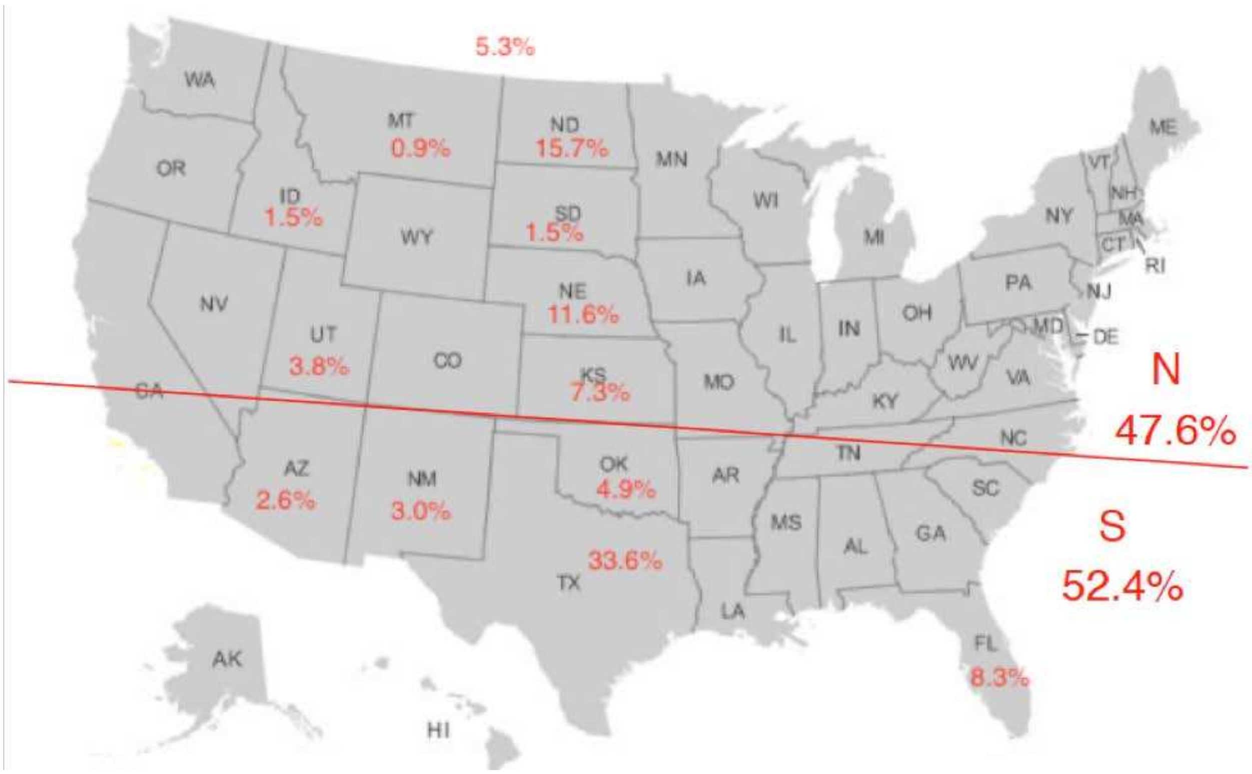


Figure 2.3 Breakdown of Regional Cattle Origin

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