A comprehensive analysis of pelvic measurements in beef cattle
by Barry Roger Cook

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Animal Science
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Abstract:
Three experiments were performed to evaluate differences in pelvic measurements, and evaluate the effects of selection for pelvic measurements on dystocia in beef cattle. Experiment 1 involved the evaluation of pelvic measurements in bulls and analyzed the relationship with scrotal circumference (SC) , birth weight (BW), 365-d weight (WT365) and age (AGE). Eight hundred and six test station bulls representing three breeds that had completed the 1990 or 1991 performance test at the Midland Bull Test Center were included in the analyses. Breed effects were evaluated for pelvic height (PH), pelvic width (PW), pelvic area (PA; product of PH and PW), hip height (HH) and scrotal circumference (SC). Breed and linear effects of AGE, HH and WT365 were significant (P<.05) for PA. Salers were the tallest and had the largest PA when adjusted for AGE or WT365 (P<.01). Pooled linear regressions of PA on age and WT3 65 were .201 cm^2/ d and .045 cm^2/ kg. Phenotypic correlations (rp) between pelvic dimensions and HH were high (P<.01) while rp of pelvic measurements with WT365 and SC were low to moderate. Experiment 2 analyzed the relationship of PA, PH, PW, BW, WT3 65, and pelvic shape (WHRAT; PH/PW) with dystocia in 317 primiparous heifers representing four herds (HERD) of predominantly Salers and British breeding. Dystocia scores (CDS) of 1-5 were assigned at parturition to determine the severity (INTENSE) and incidence (DIFF) of dystocia. The base model included HERD, SIRE (HERD) and SEX. HERD was significant (P<.01) for both INTENSE and DIFF. Herd 1 had the highest least squares mean for INTENSE (2.54) while Herd 4 had the lowest (1.04). BW was significant (P<.Ol) in the analyses of both INTENSE and DIFF, yet PA failed to affect (P>.10) the INTENSE or DIFF analyses of dystocia. The standardized partial regression coefficients (b') were .07 and -.007 for BW and PA, respectively. Experiment 3 was a two-phase stochastic computer simulation analysis involving five replications (REP) that analyzed different selection strategies based on heifer PA (PBRD) and sire BW (SEPD), and different combinations (TRT) of calf (FC) and dam heterosis (FD) on yearling pelvic area (YRLGPA), calving pelvic area (CLVGPA), CDS, DIFF, BW and CLVGPA/BW ratio (RATIO). Simulated data were analyzed as observations and as weighted REP means. In both analyses the main effect of SEPD was significant (P<.Ol) for BW, CDS, DIFF and RATIO while PBRD was significant (P<.Ol) for YRLGA and CLVGPA. Weighted means analysis found all quadratic and interaction effects of SEPD and PBRD non-significant (P>.10). Analyses of observations found TRT to affect (P<.Ol) CDS, DIFF, BW, RATIO, YRLGPA and CLVGPA. Chi-square results showed that DIFF and CDS frequency responded more to changes in SEPD. Conclusions are that differences in PA exist in bulls between breeds, but, selection for greater PA cannot overcome the effects of calf BW on dystocia.

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ABSTRACT

Three experiments were performed to evaluate differences in pelvic measurements, and evaluate the effects of selection for pelvic measurements on dystocia in beef cattle. Experiment 1 involved the evaluation of pelvic measurements in bulls and analyzed the relationship with scrotal circumference (SC), birth weight (BW), 365-d weight (WT365) and age (AGE). Eight hundred and six test station bulls representing three breeds that had completed the 1990 or 1991 performance test at the Midland Bull Test Center were included in the analyses. Breed effects were evaluated for pelvic height (PH), pelvic width (PW), pelvic area (PA; product of PH and PW), hip height (HH) and scrotal circumference (SC). Breed and linear effects of AGE, HH and WT365 were significant (P<.05) for PA. Salers were the tallest and had the largest PA when adjusted for AGE or WT365 (P<.01). Pooled linear regressions of PA on age and WT365 were .201 cm^2/ d and .045 cm^2/ kg. Phenotypic correlations (r_p) between pelvic dimensions and HH were high (P<.01) while r_p of pelvic measurements with WT365 and SC were low to moderate. Experiment 2 analyzed the relationship of PA, PH, PW, BW, WT365, and pelvic shape (WHRAT; PH/PW) with dystocia in 317 primiparous heifers representing four herds (HERD) of predominantly Salers and British breeding. Dystocia scores (CDS) of 1-5 were assigned at parturition to determine the severity (INTENSE) and incidence (DIFF) of dystocia. The base model included HERD, SIRE(HERD) and SEX. HERD was significant (P<.01) for both INTENSE and DIFF. Herd 1 had the highest least squares mean for INTENSE (2.54) while Herd 4 had the lowest (1.04). BW was significant (P<.01) in the analyses of both INTENSE and DIFF, yet PA failed to affect (P>.10) the INTENSE or DIFF analyses of dystocia. The standardized partial regression coefficients (b') were .07 and -.007 for BW and PA, respectively. Experiment 3 was a two-phase stochastic computer simulation analysis involving five replications (REP) that analyzed different selection strategies based on heifer PA (PBRD) and sire BW (SEPD), and different combinations (TRT) of calf (FC) and dam heterosis (FD) on yearling pelvic area (YRLGPA), calving pelvic area (CLVGPA), CDS, DIFF, BW and CLVGPA/BW ratio (RATIO). Simulated data were analyzed as observations and as weighted REP means. In both analyses the main effect of SEPD was significant (P<.01) for BW, CDS, DIFF and RATIO while PBRD was significant (P<.01) for YRLGA and CLVGPA. Weighted means analysis found all quadratic and interaction effects of SEPD and PBRD non-significant (P>.10). Analyses of observations found TRT to affect (P<.01) CDS, DIFF, BW, RATIO, YRLGPA and CLVGPA. Chi-square results showed that DIFF and CDS frequency responded more to changes in SEPD. Conclusions are that differences in PA exist in bulls between breeds, but, selection for greater PA cannot overcome the effects of calf BW on dystocia.

INTRODUCTION

Efficient utilization of time, labor and available resources is essential for successful production of beef cattle. Maximization of the proportion of calves weaned per cow exposed will markedly increase efficiency. However, post-natal calf loss is a recurring problem for many producers that results in a tremendous economic loss.

Environment, management and the genetic predisposition of cattle all interact to determine whether calves live or die. Thus, immediate solutions to reducing calf loss are not readily available. Since most calf losses occur as a result of dystocia, defined as difficulty at parturition, a viable starting point to reducing calf loss must integrate the factors that cause calving difficulty. Factors that have been attributed to dystocia include traits of the calf and dam.

The two main traits that have been shown to be related to dystocia include birth weight of the calf and the pelvic area of the dam. When these two traits interact in a negative fashion the affect at parturition can be disastrous. As a result, the effect of selection for dam pelvic area has received considerable attention in determining options to reduce dystocia. Additionally, calf birth weight has been scrutinized in attempts to derive solutions to reduce dystocia. However. one problem has been the inability to predict the actual birth weight of the calf at parturition.

Objectives

The objectives of this study were to:

1) Evaluate the relationship of pelvic area to calving difficulty in heifers.

2) Determine the effect of varying levels of percentage Salers breeding on dystocia.

3) Evaluate pelvic measurements in bulls and their association with other traits.

4) Conduct a stochastic computer simulation study to determine the effects of different selection strategies involving pelvic area and sire birth weight on the reduction of dystocia.

5) Evaluate the effects of different combinations of calf and dam heterosis on the incidence of dystocia.

LITERATURE REVIEW

Dystocia, defined as difficult or delayed birth, is the primary cause of post natal mortality in calves (Anderson and Bellows, 1967; Koger et al., 1967; Laster and Gregory, 1973; Smith et al., 1976). Resulting economic loss is not restricted to loss of the calf or decreased postnatal performance, each time a cow needs assistance calving there is an added cost of labor attributed to the calf.

A comprehensive study by Rahnefeld et al. (1990) reported four major consequences which can result from dystocia; calf mortality, cow mortality, diminished cow reproduction and decreased calf performance. Calf survival was lowest for those calves that required assistance at calving. An additional reduction in calf survival was observed for calves that required minimal assistance. Smith et al. (1976) reported calf death losses to be 3.7 times greater for calves that suffered dystocia. Anderson and Bellows (1967) found that 79% of the calves lost at birth were anatomically normal, but injuries from parturition were the main cause of death.

Cow death loss can also result from dystocia. Rahnefeld et al.(1990) analyzed 10 yr of cow mortality records and reported that 46.2% of the cows that died between 0 and 35 d post-partum had experienced dystocia. Of the 46.2%, approximately 38.5% of the cows had a difficult delivery. Foulley et al. (1976) reported that when calving assistance was given and the cow was lost the economic impact was great.

Dystocia can have a significant effect on subsequent female reproductive performance. Rahnefeld et al. (1990) showed the post-partum anestrus period increased as the level of difficulty increased. Laster (1973) showed a decrease of 14.4% of cows in estrus during the 45 d breeding season. When pooled over all ages the overall conception rate decreased by 15.9% from dystocia. Brinks et al. (1973) reported that heifers that experienced dystocia as 2 yr-olds weaned 11% fewer calves the first year and 14% less calves per cow exposed the second year when compared to herd mates that experienced no difficulty at parturition. Philipsson also (1976e) reported that heifers who endure calving stress have a lower rate of conception and required a greater number of inseminations per service period.

When dystocia appears imminent, obstetrical assistance can be administered in an attempt to reduce calf loss, maintain viable reproductive performance and reduce the overall economic impact of dystocia. Doornbos et al. (1984) analyzed the effect of early versus late obstetrical assistance at parturition and reported that more cows from the early assisted group were in estrus at the start of the breeding season. They concluded that prolonged labor as a result of dystocia had an inhibitory effect on post-partum reproductive performance.

The economic effect of dystocia was reflected in a study by Brinks et al. (1973). Three-year-old cows that suffered dystocia as 2 yr-olds had calves that were born 13 d later and weighed 21 kg less at weaning when compared to contemporaries that had no difficulty at parturition.

Cause of Dystocia

As a result of the large effects of dystocia on herd performance and economic returns, the need exists to delineate the causes of dystocia. Past research has determined that dystocia can be partitioned into a calf effect, maternal effect and a calf by maternal interaction (Bellows et al., 1971 a,b; Laster, 1973; Nazzie et al., 1989).

A study by Bellows et al. (1971b) of 198 Angus and Hereford primiparous heifers was conducted at the U.S. Range Livestock Experiment Station in Miles City, Montana to evaluate the relationships associated with dystocia and factors attributed to the dam or calf. Calf factors analyzed were sex, birth weight and gestation length. Male calves required more assistance than female calves at parturition. Calf birth weight was significant for dystocia and ranked first in importance of the factors associated with the calf or dam. A review paper by Price and Wiltbank (1977) used calf birth weight to represent calf size and reported the correlation of calf birth weight and dystocia to be .44. In an analysis of calving records of 1889 Hereford and Angus cows by Laster et al. (1973), dystocia increased 2.3% ± .21% for each 1 kg increase in birth weight. Smith et al. (1976) reported a similar increase of 1.63% ± .20% in dystocia score of calves sired by British and Continental breeds. Nevins et al. (1986) reported that dystocia score increased .05 units for each 1 kg increase in birth weight in a closed line of Hereford cattle.

Recent research by Naazie et al. (1989) involved the analysis of 547 2-yr-old heifers. The full model included dam pelvic measures, calf birth weight, sire birth weight and some relative measures of ratios of calf birth weight and dam weight at calving on dystocia. The full model accounted for 32.5% of the variation in dystocia. Calf birth weight was reported to be the most important variable and accounted for 17.8% of the variation in dystocia.

Rutter et al. (1983) evaluated 476 purebred Charolais heifers and reported a significant difference between male and female calves for dystocia. The difference between sexes was significant at both the first and second calvings. They reported that heifer calves were not a significant source of variation for dystocia at first parturition until calf weight reached 50 kg. At second parturition heifer calves failed to influence calving difficulty.

Burfening et al. (1978a) analyzed 5578 progeny records sired by 178 purebred Simmental bulls. Gestation length, when analyzed as a covariate, significantly affected calf birth weight and calving ease score. An increase of .70% assisted births was reported for each day increase in gestation length. When birth weight was included with gestation length as covariates, gestation length was no longer significant for dystocia or percent assisted births. They concluded that the influence of gestation length was through its affect on birth weight. Bellows et al. (1971b) reported gestation length to have a positive effect on calf birth weight in Hereford and Angus dams. Lawlor, Jr. et al. (1984) analyzed performance data on 543 3-yr-old Angus, Hereford and Simmental crossbred calf groups and reported fifty percent Simmental calves had the longest gestation length. They also had the heaviest birth weight and had the most trouble calving. Price and Wiltbank (1978) found the correlation between gestation length and birth weight, from 21 different studies, to be .296. They reported that a relationship does exist between gestation length, sex of calf and calf birth weight. Male calves were 2.7 kg heavier at birth and required more assistance.

Breed of sire has been shown to have a significant effect on dystocia (Sagebiel et al., 1969; O'Mary et al., 1972; Singleton et al., 1973 and Lawlor, Jr. et al., 1984). The incidence of dystocia has been reported to be higher in Hereford and Angus cows when calves were sired by Charolais, Simmental, Limousin or South Devon bulls, as compared to Angus, Hereford or Jersey bulls (Laster et al., 1973). Bos indicus sired calves have been shown to be heavier at birth and have more difficulty at parturition. A higher rate of dystocia has been found to exist in crossbred heifer calves, versus straightbred heifer calves (Sagebiel, 1973).

Maternal Effects

Pelvic area of the dam is the most important maternal effect related to the incidence of dystocia (Bellows, 1971b; Deutscher, 1978; Johnson et al., 1988). Short et al. (1979) evaluated 592 crossbred 2-yr-old heifers for causes of dystocia. Dam pelvic area ranked second, behind calf birth weight, in the order of importance for calving difficulty. They attempted to overcome the two dimensional non-linear nature of pelvic area by analyzing the square root of pelvic area and the cubed root of birth weight but failed to account for additional variation in dystocia.

Price and Wiltbank (1978) reported that 69% of 2-yr-old Hereford heifers that had a pelvic area <200 cm^2 experienced dystocia, whereas heifers with a pelvic area between 200-229 and 230-269 cm^2 had dystocia rates of 30 and 25%, respectively. Belcher and Frahm (1979) analyzed data on 900 heifers and found that heifers who calved without assistance had 7.4 cm^2 greater pelvic area, as compared to heifers that required assistance at parturition. An Australian study by Axelson et al. (1981) showed that females experiencing dystocia had 14 cm^2 smaller pelvic area, when compared to heifers who calved unassisted. Breed differences have been shown to exist in the order of importance of pelvic area on dystocia.

Bellows et al. (1971b) reported pelvic area to rank first in the order of importance for maternal effects in Hereford females and second in Angus.

The role of independent pelvic dimensions has been studied to determine if pelvic height or pelvic width would account for more variation in dystocia. Philipsson (1976d) showed differences in pelvic area to be more a function of pelvic height than width. Rutter et al. (1983) recorded pelvic height in 476 purebred Charolais heifers and reported that it failed to account for any appreciable variation in dystocia. Yet, Laster et al. (1973) reported pelvic height to influence dystocia in Angus, Brahman, Devon, Hereford and Holstein sired calves, whereas pelvic width was shown to be significant for dystocia in Hereford and Angus cows fed three different levels of energy before calving. No reason was reported for the difference in importance of pelvic height in different breeds or the difference in importance of pelvic width on dystocia in cows fed different levels of energy. Naazie et al. (1989) reported that pelvic width provided as much information on calving difficulty as did pelvic area; thus, speculating that pelvic width is the limiting dimension. Johnson et al. (1988) reported the prebreeding residual correlation for pelvic height and pelvic width with dystocia in Hereford heifers to be -.10 and -.24, respectively.

Based on previous literature it is apparent that independent pelvic dimensions did affect calving difficulty, but the ability to use them to identify heifers that may have a predisposition for dystocia was low.

In an effort to increase total cow productivity and reduce the cost of raising replacements, it has become standard practice to calve primiparous heifers at 2 yr of age. However, in two-year-old primiparous heifers, skeletal development of the pelvis is incomplete and dystocia often occurs (Joandet et al., 1973; Burfening et al., 1978a; Philipsson, 1976d). Laster et al. (1973) analyzed calving data on Hereford and Angus cows. Variables in the analysis included age, sex, sire breed and dam breed. Dam age was the only significant main effect, when birth weight was included in the model. Price and Wiltbank (1978) reported the occurrence of dystocia to be 29.7% in 2-yr-old heifers, versus 10.5% and 7.2% in 3- and 4-yr-old cows, respectively. Rutter et al. (1983) reported a significant difference in dystocia between second and third parity females, with dystocia rates of 31.1% and 15% respectively. Kress et al., (1990a,b) analyzed 246 calf performance records from 2-yr-old straightbred and crossbred heifers and reported dystocia scores to range from 2.1 to 2.5 , whereas 706 3-,4- and 5-yr-old cows with various levels of Angus, Hereford and Simmental breeding had dystocia scores of 1.65, 1.23 and 1.26, respectively.

Nutrition

The effect of nutrition on dystocia has also been investigated for its possible role in the occurrence of dystocia. Corah et al. (1975) fed two groups of heifers a high and low ration for a 100-d prepartum period. High rations were equivalent to 100% of the NRC requirements for energy and low diets provided 65% of the NRC specifications for energy. Heifers on the high energy diet gained 36.1 kg over the feeding period whereas females fed the low energy ration lost 5.8 kg. The low heifers delivered calves with lower birth weights, but the incidence of dystocia was not different (P>.10) from the heifers fed a high level of energy. Arnett et al. (1971) found that obese heifers required more assistance at parturition. Philipsson (1976d) concluded that dystocia would befall heifers that are extremely fat or thin. Consequently, manipulation of prepartum rations by producers to reduce dystocia will not solve their dystocia problems.

Prediction of Dystocia

In order to reduce the economic loss attributed to dystocia, researchers have attempted to develop methods to aid in the prediction of dystocia. Price and Wiltbank (1978) used stepwise regression analyses to identify variables that could be used to predict dystocia. They determined calf size and dam pelvic area at breeding to be highly related to dystocia. They found the ratio of calf birth weight to calf body length and pelvic area at 35-d post breeding to account for 37% of the variability of dystocia in Angus dams. In Charolais, these variables explained 44% of the variability in dystocia.

Morrison et al. (1985) used discriminant analyses to predict dystocia in Chianina crossbred cows mated to Chianina bulls. Variables analyzed for prediction were cow age, cow weight, pelvic width, pelvic height, pelvic area and calf size. Calving difficulty was categorized as either assisted or unassisted. The model correctly classified 57.1% of the cows and the error in prediction was in cows 3-yr of age and older. This precalving prediction model correctly predicted the classification of normal parturition or dystocia in all 2 yr old first calf heifers.

Discriminant analysis was used by Rutter et al. (1983) to predict dystocia in Charolais heifers. Variables pertaining to the heifer that were used to predict dystocia were calving score of the heifers dam, age of the heifer at conception, grade of the heifer at yearling age, pelvic height of the heifer at breeding and breed of sire of calf. To evaluate all effects a second model was derived which included calf birth weight and sex of calf. Results of the discriminant analyses showed yearling weight of the heifer and calving difficulty of the cows dam to be significant. When calf effects were included in the model, birth weight was found to be the most important variable.

Laster (1973) evaluated traits in 599 2-yr-old primiparous cows. Factors analyzed in relation to dystocia were breed, precalving energy level, pelvic height, pelvic width, cow weight, calf sex, calf birth weight, calf shoulder width, hip width, chest depth, wither height and body length. Traits measured prior to calving accounted for 26% of the variation in the incidence of dystocia. He concluded that physical measurements in his study were inadequate as predictors of dystocia.

Genetic Parameters

The development and expression of traits in all species is determined by the genetic "framework" of that trait. Within each trait there is a certain amount of variation that is a function of the total genotypic and environmental effects. The additive genetic variance is a component of the total genetic variation and influences that aspect of genetic effect in regards to selection. Its proportion to the total phenotypic variance is what allows one to draw conclusions on the degree of resemblance between relatives and is referred to as heritability (h^2). It behooves one to be aware of the heritability estimates for characteristics because there are two ways producers can change genetic properties; choice of parents and management of mating system (Falconer, 1989).

Green et al. (1988) estimated the genetic parameters and breed differences associated with pelvic area on 787 females, representing Angus, Hereford, Red Angus and Simmental breeds. Heritability estimates, when age was the covariate, for pelvic height in heifers pooled over all breeds at San Juan Basin

Research Center (SJBRC) and Fort Collins (FC) were .83 and .82, respectively. When weight was the covariate h^2 estimates for pelvic height were .74 and .73 for SJBRC and FC, respectively. Contrasting h^2 estimates of .19 and 1.07, when age was in the model, were calculated for pelvic width at SJBRC and FC, respectively. A similar difference was observed when weight was the covariate, respective h^2 estimates of .09 and .49 were reported for SJBRC and FC. Heritability values for pelvic area were estimated to be .56 and .97 for SJBRC and FC, respectively, when age was the covariate. Similar values of h^2 were observed when weight was in the model with estimates of .47 and .55 for SJBRC and FC, respectively. They concluded that rapid change in pelvic measurements could be made through selection.

Benyshek and Little (1982) analyzed Simmental paternal half sibs (PHS) and reported heritability estimates which were in contrast to Green et al. (1988), with lower heritability values of .53, .43 and .58 for PA, PH and PW, respectively. Morrison et al. (1986) reported PHS h^2 values of .68, .59 and .82 for PA, PH and PW, respectively. Estimates of heritability in Hereford bulls for pelvic height were .47 and .23 at 403 and 490 d, respectively. Higher heritability estimates were calculated for pelvic width with values of .58 and .50, respectively (Nelson et al., 1986). Neville et al. (1978) estimated h^2 by using the double regression of daughter on dam method in heifers that were selected on the basis of a heavier than average weight. He reported low heritability estimates that were more aligned with Benyshek and Little (1982) with values of .24, .22 and .38 for PA, PH and PW, respectively. Therefore, since PW or PH are of moderate to high heritability, the response in the change in PH or PW as a result of selection can be achieved with some degree of confidence.

Progressive beef cattle producers are able, to some degree, to control the choice of parents. This is achieved through selection of replacement heifers and more importantly through sire selection. Today's sire services have further broadened the sire potential by expanding the overall genetic base. A common approach to reducing dystocia is through the selection of sires from breeds known for their calving ease, or by selecting sires within the breed that possess desirable actual birth weights or appropriate EPD's.

Cundiff et al. (1986) investigated the between and within breed genetic parameters of calving ease traits and calf survival to weaning. He found the correlation among breeding values of individuals of the same breed were in excess of .5 for both birth weight and dystocia. The breed of sire variance was reported to be greater than the sire within breed variance. The total heritability and within breed heritability estimates suggest that gestation length and birth weight are under a high degree of direct genetic control and that dystocia is subjected to a moderate level of direct genetic control. Overall, appraisal of heritability estimates suggest that selection to reduce birth weight or dystocia could be effective and would enhance calf survival. Bellows et al. (1982) suggested sires could be selected to sire calves that will have lower birth weight and dystocia, but have weaning weights that are equivalent to calves sired by bulls that produce high birth weight progeny that endure high rates of dystocia.

Due to the relatively high heritability of pelvic dimensions, the measurement of pelvic dimensions in bulls has become increasingly more common among seedstock producers. The notion exists that pelvic dimensions of bulls would be beneficial in a genetic selection index (Wilson, Personal communication, 1991). It has been postulated that selection of sires with large pelvic dimensions will result in female progeny with larger pelvic dimensions that are able to deliver calves with less assistance.

Siemens et al. (1989) analyzed test station bulls and found breed differences to exist for pelvic area. He reported that the exotic breeds of Chianina, Gelbvieh and Simmental to have a larger average pelvic area when compared to Hereford and Angus bulls. Cook et al. (1991) evaluated data on Angus, Hereford and Salers test station bulls and found that the exotic Salers had a significantly larger pelvic dimensions. However, not all exotics are superior for pelvic area. The Charolais breed studied by Siemens et al. (1989), which stood taller at the hip, possessed pelvic dimensions that were smaller than the British breeds. This could be a result of the heavy, doubled muscle nature of Charolais because Vissac et al. (1973) found that females of heavy, double muscled breeds had smaller pelvic area.

In order to further optimize selection, a complete understanding of the relationships between traits is critical. Failure to understand the direct and indirect relationships among traits can result in genetic trends that fail to serve any economic or utilitarian benefit. In order to improve efficiency, reduce labor and amount of stress, it is important to elucidate the degree of association between easily obtainable traits (i.e., body weight) and other traits of interest that are not as easily obtained (i.e., internal pelvic dimensions).

One of the easiest obtainable measures of body size is live weight. Live weight has been shown to account for the largest amount of variation in pelvic area (Laster, 1973). In an effort to determine the relationship of internal pelvic dimensions and external body size, Bellows et al. (1971b) analyzed the association of precalving body size with pelvic area. Heavier heifers had greater hip width, rump length, pelvic height, pelvic width and pelvic area. When weight was held constant, hip width and rump length accounted for significant amounts of variation in pelvic area. He postulated that skeletal weight is a portion of body weight, and hip width and rump length are measures of skeletal dimensions. Consequently, skeletal measures of hip width, rump length and the skeletal component of body weight would be expected to be associated with an increase in pelvic area. However, correlations by Deutscher and Zerfoss (1983) and Bolze (1985) for pelvic area with heifer weight were fairly low, with estimates between .22 to .34. They concluded that actual internal measurements should be taken because of the variation in pelvic area that exists between heifers of similar weight.

Each year producers "turn over" a portion of their bull power. This is done for a variety of reasons, one being to update the genetic input into the herd. Most bulls available for sale are fertility tested, which involves measuring the scrotum. Scrotal circumference is an easily obtained measurement that expresses moderate heritability (Knights et al., 1984; Kriese et al., 1991). As a result of the ease by which scrotal circumference is obtained, knowledge of its genetic relationships with other traits (i.e. pelvic dimensions) could prove beneficial.

Favorable relationships have been shown to exist between scrotal circumference with early growth measures and female reproductive traits (Brinks et al., 1978). Smith et al. (1989) obtained growth and reproductive data on 779 and 564 yearling heifers and bulls, respectively. He concluded that for each cm increase in scrotal circumference, birth weight decreased slightly. A favorable correlation of .14 existed with scrotal circumference and age at puberty. Similar research by King et al. (1983) found a large favorable negative correlation (-1.07) to exist between age at first estrus and scrotal circumference. Results of these two studies allow one to conclude that selection for scrotal circumference can result in a positive change in the growth curve and an improvement in the reproductive state (i.e. earlier age at puberty) in females.

In one of the first comprehensive studies with scrotal circumference and pelvic measurements in bulls, Nelson et al. (1986) studied the genetic parameters for growth and reproductive performance in 427 Hereford bulls reared in eastern Montana. Their estimated genetic correlations suggest that selection for weight at 403 or 490 d should result in a positive, correlated response for scrotal circumference, pelvic width and pelvic area. Ironically, the anticipated result for pelvic height when selection was for weight was low.

Nelson et al. (1986) also calculated genetic correlations for birth weight and performance traits. He reported negative correlations of -.29 and -.13 between birth weight and pelvic area at 403 and 490 d, respectively. These low negative genetic correlations were attributed to the maternal effect of the dam. Calculated phenotypic correlations between scrotal circumference with pelvic measurements were low. This suggests that selection for scrotal circumference, an early growth indicator, would not have a strong impact on pelvic dimensions.

MATERIALS AND METHODS

Experiment 1

Performance and anatomical data were collected on 806 bulls representing Angus, Hereford and Salers breeds. All bulls had completed the 1990 or 1991 Midland Bull Test at Columbus, Montana (Table 1). Data were gathered at the time of the breeding soundness examination (BSE) at the conclusion of the 140-d feeding trial.

An analysis of percentage Salers bulls was also performed. The .75 and .875 percentage Salers bulls were grouped together and labeled (.75). Purebred and fullblood groups were combined and labeled (FB). Fullbloods were classified as bulls that could trace their ancestry in its entirety to the French Salers Herdbook and consequently had 100% Salers breeding, whereas purebreds were bulls that had 93.75% or greater Salers breeding.

Table 1. Age and 365-day weight range for Angus, Hereford and Salers bulls for 1990 and 1991.

		Age in days		365-day weight (kg)	
Breed	No.	Mean	Range	Mean	Range
Angus	410	395	328-459	560.0	474-692
Hereford	167	400	348-455	539.3	466-650
Salers					
FB	109	381	330-423	578.1	505-667
.75	120	393	337-457	544.0	450-626

Bulls placed on test were selected by the individual consignors based on their independent selection criteria. All bulls were fed a high roughage diet and were maintained similarly while on test.

Bulls were grouped according to their biological type, but were partitioned into smaller feeding groups (n=40) based on evaluation by test station personnel.

Table 2. Age (AGE), Hip Height (HH) and 365-d weight (WT365) range for Angus, Hereford and Salers bulls for 1991.

		Age in days		365-day weight (kg)	
Breed	No.	Mean	Range	Mean	Range
Angus	235	395	331 to 449	555.0	475 to 643
Hereford	73	403	364 to 453	540.9	485 to 650
Salers					
FB	44	389	337 to 457	542.6	465 to 626
.75	32	376	330 to 417	572.6	505 to 655

		Hip Height (cm)	
Breed	No.	Mean	Range
Angus	202	132.5	113.3 to 146.0
Hereford	62	133.0	124.5 to 142.2
Salers			
FB	40	139.0	129.5 to 146.0
.75	31	138.2	130.8 to 147.3

Anatomical characteristics evaluated in 1990 were internal pelvic dimensions of pelvic height (PH), pelvic width (PW), pelvic area (PA; product of PH*PW) and scrotal circumference (SC). Additional data consisted of 365-d weight (WT365), age in days (AGE) and birth weight (BW). In 1991 hip height (HH) was measured (Table 2) at the conclusion of the feeding trial.

Internal pelvic measurements were obtained with a Rice pelvimeter[1] via rectal palpation. The pelvic measurements in 1990 were all taken by an experienced veterinarian, however 1991 measurements were obtained by two different experienced technicians utilizing the same points of reference. The PH was the linear distance (cm) between the sacral vertebrae and the pubic symphysis. The transverse measurement (PW) was the linear distance (cm) between the shafts of the ilium at the widest point. Scrotal circumference was the circumference at the widest part of the scrotum after the testis had been descended fully into the scrotum. The BW on each bull was taken by each individual consignor within a reasonable time following parturition. The AGE was calculated as age in days at the time of the BSE. Hip height was measured by descending a tape down from the top of the chute to the backbone, midway between the hooks (Doornbos et al., 1978).

Statistical Analysis.

Data on PA, PH, PW and SC were analyzed using least squares procedures (SAS, 1985). The full model included the effects of breed, linear and quadratic effects of age (or WT365) and the interactions of the linear and quadratic effects with breed. Year (YR) was included when 1990 and 1991 data were analyzed together. In 1991 technician effects along

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[1] Lane Manufacturing, Denver, Colorado

with the linear and quadratic effects of the covariate HH were also evaluated. Covariates which were not significant (P>.10) were deleted and reduced models were fitted to the data. Log transformations of PA, HH and WT365 data were also performed to estimate relative growth coefficients. Percentage Salers data was evaluated in a similar fashion with percent Salers replacing breed in the model.

Residual correlations were calculated using the SAS (1985) procedure. Correlations were calculated after the effects of breed and age were removed.

Full Model

$$Y = u + a_i + c_j + b_L(X_{ijk}) + b_Q(X^2_{ijk}) + ab_{Li}(X_{ijk}) + ab_{Qi}(X^2_{ijk}) + e_{ijk}$$

Where:

Y	=	Observation of PA, PH, PW or SC
u	=	overall mean, when $x = 0$
a_i	=	effect of the i^{th} breed (Angus, Hereford or Salers
c_j	=	effect of the j^{th} year
X	=	Age, WT365 or HH
b_L	=	linear regression of y on x
b_Q	=	quadratic regression
ab_{Li}	=	interaction of a_i and b_L
ab_{Qi}	=	interaction of a_i and b_Q
e_{ijk}	=	random residual

Experiment 2

Pelvic measurements, 365-d weight and age were obtained on 317 heifers representing Angus, Hereford and Salers breeding. Data were collected from three registered Salers ranches and the Montana State University (MSU) research ranch (Table 3). The MSU herd is comprised of crossbred cows characterized by Hereford and Angus breeds involved in a two-breed rotation.

Table 3 Distribution of heifers by breeder and proportion Salers.

Breeder	.5	.75	.875	.9	FB	Other	Total
Jacobsen	5	59	39	26	1	0	130
M.S.U.						76	76
Nichols	5	41	5	3	1	0	55
Skinner	1	10	8	13	24	0	56
	11	110	52	42	26	76	317

Prebreeding data were collected at approximately 12 mo. of age. Pelvic measurements were collected by an experienced technician using the technique previously described in experiment 1 for yearling bulls. WT365 was acquired at the time of pelvic measurement.

Calf birth weight (BW) and dystocia scores (CDS) were collected at calving. Dystocia scores were assigned in two different ways.

The first method characterized the intensity of parturition and was classified as INTENSE; dystocia was scored on a scale of 1-5:

1 = No difficulty
2 = Slight assistance
3 = Hard pull, mechanical assistance required
4 = Caesarean section
5 = Abnormal presentation

The second method measured the incidence of dystocia by grouping scores 2 through 5. Hence, difficulty was scored 1 or 2 and was labeled DIFF. Pelvic shape was also analyzed and was estimated by the PW/ PH (WHRAT) ratio.

Additional pelvic, WT365, sire and dam data were obtained on 63 bulls from Skinner Ranch Salers. These records were pooled with the heifer data from Nichols Farms, Skinner Ranch Salers and Jacobsen Salers and were used to estimate genetic parameters for PA, PH, PW, WT365 and BW.

Statistical Analysis.

Data were analyzed using the General Linear Model program of SAS (1985). The full model analyzed INTENSE and DIFF as a dependent variable. Main effects included sex of calf, herd and sire of calf nested within herd. The covariates BW, PA, WHRAT and WT365 were also included in separate models which analyzed their effect on INTENSE and DIFF dystocia.

Differences between herds in PA, PH, PW, BW and WT365 were determined by evaluating the traits as dependent variables. The main effects from the original full model were retained as independent variables.

The effect of percentage Salers on dystocia was also evaluated. This was accomplished by removing the MSU heifers and analyzing the 241 Salers and Salers cross heifers as a separate data set. Percentage groups represented were .5, .75, .875, .9 and FB heifers. The distribution of each percentage group is presented in Table 3. The statistical model was the same as the model implemented in the original analyses of dystocia, however percentage Salers of the dam (PTDAM) was added as a covariate.

Heritability estimates were calculated by using Harveys Paternal Half Sib (PHS) model (LSMLW). The PHS estimates were determined by using a model that included the independent variables of herd, sire(herd), age of dam , percentage Salers and age (or WT365) as a covariate. Since bull data were only available from one herd, the bulls were considered to be a separate herd for statistical analysis.

Experiment 3

The use of pelvic measurements in heifer selection programs to reduce dystocia has increased in recent years. The economic value of selecting for increased pelvic area has become a controversial topic among animal scientists. Many researchers have concluded that selection for pelvic area will fail to reduce dystocia, and assume that the net result from pelvic area selection will be a genetic trend toward larger cows with heavier calves. Yet, some scientists have promoted pelvic area as a valuable tool that will appreciably reduce dystocia with little or no effect on calf birth weight. However, researchers are in agreement with the fact that calf birth weight is the most important attribute responsible for dystocia.

The advent of the "expected progeny difference" (EPD) for birth weight has given producers a tool that allows them to reduce the error in selecting a bull that has a birth weight that is compatible with the maturity and development of their females. If the accuracy of the EPD is low then the predictability will vary. Just how heavy of a birth weight primiparous heifers can handle with little or no dystocia is not well defined.

The use of crossbreeding systems has allowed producers to increase calf performance and boost cow efficiency. Maternal ability, reproduction, health and cow longevity are all traits that benefit from high levels of heterosis (10-30%); while growth rate and milk production can benefit from medium levels of heterosis (5-10%). Producers that sustain a crossbreeding program also profit from the additive effects of individual and maternal heterosis (Kress and Nelson, 1988). However, the effects of different levels of calf and dam heterosis can result in an increase in dystocia; thus, possibly diminishing the returns from crossbreeding.

As a result of the complex nature of dystocia, an evaluation of the effects of selection for heifer pelvic area when mated to bulls with different EPD's for birth weight is needed. A stochastic computer simulation model was developed to: 1) evaluate various heifer and sire selection strategies and the ensuing effects on the incidence and severity of dystocia; 2) evaluate the effect of calf and dam heterosis on heifer pelvic area and dystocia.

The model was written in FORTRAN 77 and run on a microcomputer. A complete listing of the program is presented in Appendix B, Figure 11. The program simulated direct selection for pelvic area by retaining heifers based on yearling pelvic area (YRLGPA). Heifers retained for breeding were mated to bulls with different EPD's for BW representing low BW and growthy, high BW bulls. This range reflects bulls that represent the diverse types of breeds that are available for easy calving (ex: Longhorn) or growthy calves (ex: Chianina), as well as the variation of bulls within breeds.

Sire EPD's (SEPD) were assumed to be of high accuracy and representative of sires available by A.I. sire services.

The simulation procedure utilized genotypic and phenotypic parameter estimates taken from the literature. Traits included YRLGPA, calving pelvic area (CLVGPA), BW, sex (SEX), ratio of CLVGPA/BW (RATIO), the incidence of dystocia (DIFF) and calving difficulty score (CDS). SEX was based on a 50:50 ratio of bulls:heifers and was stochastically determined. DIFF was a discrete response variable that was determined stochastically by the probability of RATIO. A value of 1 indicated dystocia with 0 representing no dystocia. CDS was deterministically determined according to RATIO and was on a numerical scale from 1 to 5; CDS was categorized according to the guidelines previously described in experiment 2. Both CDS and DIFF procedures utilized RATIO, these procedures were according to Short et al. (1979).

Figure 1 illustrates the biometrical relationships for the traits simulated. Parameter estimates listed in Table 4 were derived from the literature. The foundation for the simulations were the generations of YRLGPA and BW phenotypes. When females were pregnant then phenotypes for CLVGPA and BW were simulated.

The genetic correlation between the maternal BW portion of the BW breeding value (BV) with the BV for YRLGPA and CLVGPA was assumed to be zero. Genetic and environmental correlations between YRLGPA and CLVGPA were chosen to be