ESTIMATES OF HERITABILITIES AND CORRELATIONS OF TRAITS ASSOCIATED WITH PELVIC AREA IN BEEF CATTLE

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ABSTRACT

Pelvic measurements, cow weights and cow ages were obtained on 703 Angus- and Hereford-sired cows from five Louisiana Agricultural Experiment Station herds. Cows were either purebred or crossbred, ranging in age from 1 to 14 yr, and sired by 52 Angus and 63 Hereford bulls. All pelvic measurements were obtained via the rectum by the same technician. Paternal half-sib heritability estimates and genetic (r_G) and phenotypic (r_p) correlations were computed for pelvic height (PH), pelvic width (PW), pelvic area (PA-I; the product of PH x PW), the ratio of PH to PW and cow weight (CW). Pelvic area was also calculated as an ellipse using the formula PA-II = \( \pi \times (PH/2)(PW/2) \). Mean PA-I was 298.5 cm² while PA-II averaged 234.4 cm².

The pooled heritability estimate for PA-I was 0.68 ± 0.34, indicating that pelvic area is a highly heritable trait and should respond to selection. The estimate for PA-II was similar (0.66 ± 0.34). The heritability of PW was higher than for PH or PA-I. The heritability of CW was 0.57 ± 0.34 and CW was positively correlated (r_G = 0.47 and r_p = 0.40) with PA-I. Direct selection for PA-I was estimated to yield a response of 12.2 cm² in one generation with a correlated response for CW of 12.5 kg. If change in CW was held at zero using a restricted selection index, about 90% as much increase in PA-I was estimated compared with ignoring CW in the index. Therefore, selection for increased pelvic area can be accomplished without causing large increases in cow size. This should aid in reducing calving difficulty.

(Key Words: Beef Cows, Pelvis, Body Weight, Heritability, Correlation.)

Introduction

Calf losses due to dystocia are a major factor contributing to reduction in calf crop weaned (Wiltbank et al., 1961). The major factor affecting dystocia is disproportionate calf birth weight in relation to the pelvic area (birth canal) of the dam (Wright, 1958; Lindhe, 1966; Bellows et al., 1971b; Rice and Wiltbank, 1972; Price and Wiltbank, 1978). Pelvic area is inversely related to the incidence of dystocia in cattle (Bellows et al., 1969, 1971a; Deutscher, 1978; Price and Wiltbank, 1978). Pelvic area is the highest ranking maternal variable affecting dystocia (Bellows et al., 1971b; Deutscher, 1978; Price and Wiltbank, 1978; Morrison et al., 1985). Body weight is the most important factor affecting pelvic area (Bellows et al., 1971a; Laster, 1974); larger cows have larger pelvic openings. However, larger cows also produce calves that weigh more at birth. Therefore, selection for increased cow size in an effort to reduce calving difficulty may not be effective. Selection based on pelvic area and body weight together may be more effective in reducing calving difficulty (Taylor et al., 1975).

Information concerning the heritabilities of pelvic area and its components and their genetic relationship with cow weight is limited. Neville et al. (1978) obtained pelvic area heritability estimates at two locations of 0.04 and 0.24 for Angus, Polled Hereford and Santa Gertrudis heifers, while Benyshek and Little (1982) obtained a heritability estimate of 0.53 for Simmental heifers. Green et al. (1984) and Holzer and Schlote (1984) obtained estimates of 0.61 and 0.36, respectively. The objectives of this study...
were to estimate heritabilities for pelvic area, its components and for cow weight, and to determine the genetic relationships among these traits in Angus- and Hereford-sired cows. Also of interest were estimates of direct and correlated responses to selection for pelvic area.

**Materials and Methods**

**Experimental Animals.** Pelvic measurements, body weight and age were recorded on 703 Angus- and Hereford-sired cows at five Louisiana Agricultural Experiment Station herds. Approximately 60% of the females were purebred with the remaining 40% being crossbred. Crosses included Brahman, Brangus and Charolais with 62.5 to 75% Angus or Hereford breeding. Additionally, some Angus and Hereford reciprocal crosses were included (table 1).

Sires were 52 Angus and 63 Hereford bulls. The number of daughters per sire ranged from 1 to 38 and sires were unique for each herd. Cows ranged in age from 1 to 14 yr at the time of data collection.

All pelvic measurements were obtained during the same calendar year by the same technician via the rectum using the Rice Pelvimeter. Pelvic area (PA-I) was calculated as the product of a vertical (pelvic height = PH) and a horizontal (pelvic width = PW) measurement of the internal pelvic structure of each female. The vertical measurement extended from the symphysis pubis to the ventral border of the sacral vertebrae. The horizontal measurement was the distance between the medial border of each ilius. Only one measurement per cow was recorded. For comparison, pelvic area (PA-II) was also calculated as an ellipse using the following equation:

$$\text{PA-II} = \pi(\text{PH}/2)(\text{PW}/2).$$

Pelvic measurements were obtained on all animals during mid-gestation usually at the time of the annual rectal pregnancy examination. Cow weights were recorded on either the day of pelvic measurement or within a few weeks. Cow age was recorded to the nearest month at the time of measurement.

**Data Analysis.** Data were divided into two data sets for separate analysis because of confounding that existed between sire and cow age. The first data set (Set I) consisted of sire groups whose daughters ranged in age from 1 to 14 yr. Set II included sire groups whose daughters were >5 yr of age. This division was made so that each sire would be represented in one but not both data sets.

Each data set was analyzed by least-squares procedures as described by Harvey (1978) to estimate sire components of variance and covariance. Group (purebred or crossbred), breed (Angus- or Hereford-sired females) and location were partially confounded; therefore, these three factors comprised a group-breeder-location (GBL) effect in the analysis of variance model. The model used for Set I included the effects of GBL, sires within GBL, linear and quadratic regressions on cow age and the GBL subclass regressions within the linear and quadratic cow age regressions. The model used for Set II was a reduced model in which nonsignificant sources of variation from preliminary analyses had been deleted. This model included the effects of GBL and sires within GBL.

Paternal half-sib estimates of heritability and genetic and phenotypic correlations were computed with the sire components of variance and covariance for each data set for pelvic height (PH), pelvic width (PW), pelvic area (PA-I and PA-II), pelvic shape (PH/PW, ratio of pelvic height to pelvic width) and cow weight (CW). Overall estimates of heritabilities and genetic and phenotypic correlations were obtained for each trait by pooling the estimates of the two data sets (see footnotes tables 3 and 4).

Using heritabilities and genetic correlations developed for Set I, direct and correlated responses to selection for increased PA-I were estimated. A restricted selection index (Kempthorne and Nordskog, 1959) was used to allow for selection response in PA-I but not for CW.

<table>
<thead>
<tr>
<th>Sire breed</th>
<th>Purebred</th>
<th>Crossbred</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Angus</td>
<td>264</td>
<td>96</td>
<td>360</td>
</tr>
<tr>
<td>Hereford</td>
<td>140</td>
<td>203</td>
<td>343</td>
</tr>
<tr>
<td>Total</td>
<td>404</td>
<td>299</td>
<td>703</td>
</tr>
</tbody>
</table>

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*Lane Manufacturing Co., Denver, CO 80201.*
Results and Discussion

Table 2 contains means and standard deviations of the traits studied. Pelvic measurements of animals in Set I were similar to those reported in the literature for Angus- and Hereford-sired cows of comparable age and weight. Bellows et al. (1971a) reported a mean pelvic area of 292 cm\(^2\) for 3-yr-old Hereford heifers averaging 464 kg prior to calving. Straightbred Angus and Hereford 2-yr-old heifers weighing 359 and 378 kg had pelvic areas of 247 and 251 cm\(^2\), respectively (Bellows et al., 1971b). Angus and Hereford 2-yr-olds weighing approximately 390 kg had mean pelvic areas of 236 cm\(^2\) (Laster, 1974). Pelvic areas of Angus-Hereford reciprocal crosses (Bellows et al., 1982) were 208 cm\(^2\) for 2-yr-olds weighing 358 kg and 290 cm\(^2\) for 3- and 4-yr-old cows weighing 453 kg.

Data are not available in the literature on pelvic dimensions of mature cows greater than 5 yr of age. In the present study, pelvic areas of cows in Set II that averaged approximately 7.5 yr of age were larger compared with cows in Set I which averaged about 2.5 yr of age. Pelvic shape (PH/PW) was similar for cows in both data sets.

Heritability estimates and components of variance are presented in table 3. The heritability estimate for PA-I indicates that it is a moderately to highly heritable trait and therefore should respond favorably to selection. The heritability estimate for mature cows (Set II) was higher than for the mostly young cows (Set I). Pelvic height and width measurements had moderate to high heritability estimates, with PW having the higher value in both data sets. A possible explanation for this is that pelvic width was considered to be the more easily obtained measurement and therefore may have been a more highly repeatable measurement.

These heritability estimates are considerably higher than those reported by Neville et al. (1978) for Angus, Polled Hereford and Santa Gertrudis cattle. However, in that analysis heritability was calculated by doubling the regression of daughter on dam and the number of comparisons was smaller than in the present study. Benyshek and Little (1982) reported paternal half-sib heritability estimates of .43, .58 and .53 for pelvic height, width and area, respectively, for percentage Simmental heifers at 12 to 15 mo of age. Holzer and Schlote (1984) also worked with Simmental heifers and reported a pelvic area heritability estimate of .36. Green et al. (1984) measured pelvic dimensions in Angus, Hereford and Red Angus cows and obtained estimates of .56, .36 and .61 for PH, PW and PA, respectively. Thus, in studies using paternal half-sib estimates, the heritability of pelvic area has ranged from .36 to .61. These results are in close agreement with the present study when comparing them to the mostly young cows in Set I. However, the pooled estimate is somewhat higher. In all studies except Green et al. (1984), PW heritability estimates were higher than those for PH.

The estimates of heritability of PA-II were similar to those of PA-I. This was expected because the same PH and PW measurements were used to calculate each area. The equation did not affect variance components but in effect simply multiplied PA-I by a constant equivalent

<table>
<thead>
<tr>
<th>Item</th>
<th>Set I</th>
<th>Set II</th>
<th>Pooled</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of cows</td>
<td>461</td>
<td>242</td>
<td>703</td>
</tr>
<tr>
<td>Pelvic height (PH), cm</td>
<td>16.4</td>
<td>20.1</td>
<td>17.6</td>
</tr>
<tr>
<td>Pelvic width (PW), cm</td>
<td>15.6</td>
<td>18.6</td>
<td>16.6</td>
</tr>
<tr>
<td>Pelvic area I (PA-I), cm(^2)</td>
<td>259.3</td>
<td>373.4</td>
<td>298.5</td>
</tr>
<tr>
<td>Pelvic area II (PA-II)*, cm(^2)</td>
<td>203.6</td>
<td>293.1</td>
<td>234.4</td>
</tr>
<tr>
<td>PH/PW</td>
<td>1.06</td>
<td>1.08</td>
<td>1.07</td>
</tr>
<tr>
<td>Cow weight (CW), kg</td>
<td>374.2</td>
<td>494.6</td>
<td>415.6</td>
</tr>
<tr>
<td>Cow age, mo</td>
<td>32.1</td>
<td>89.5</td>
<td>51.8</td>
</tr>
</tbody>
</table>

*Calculated using the equation PA-II = π(PH/2)(PW/2).
The heritability estimate for CW was much higher in Set I than in Set II. The older cows of Set II had considerably more within-sire variation as compared with cows in Set I. A portion of this within-sire variation could be the result of scaling effects because the Set II cows were 120 kg heavier than Set I cows. Pooled estimates of heritability from the present study were similar to those reported in the literature. Brinks et al. (1962) determined heritability estimates of mature weight in spring or fall to be .57 and .62, respectively. Fitzhugh and Taylor (1971) reported heritability of weight at maturity was .57.

Genetic and phenotypic correlations among the traits studied are shown in table 4. Because large standard errors exist, data interpretation for genetic correlations is difficult. The genetic correlation between PH and PW was very low for cows in Set I. This may indicate that in young cows growth in PH and PW occurs independently; or growth in PH can occur without a large corresponding increase in PW. However, in mature cows (Set II) where maximum pelvic size had been attained, PH and PW were more highly correlated. Green et al. (1984) also obtained low genetic and phenotypic correlations for PH and PW of .14 and .10, respectively. However, Benyshek and Little (1982) and Holzer and Schlote (1984) reported genetic correlations for PH and PW of .35 and .36, respectively, in Simmental cattle, which is in closer agreement with the pooled estimate (.40) of the present study.

There were large, positive genetic and phenotypic associations between the actual pelvic measurements and PA-I. This would be expected because PA-I is the product of PH and PW. The ratio of PH to PW was positively associated with PH but negatively associated with PW and PA-I. Similar relationships were reported by Benyshek and Little (1982) and Holzer and Schlote (1984).

The genetic correlations between PH, PW, PA-I and cow weight were positive but had large standard errors. This indicates that direct selection for increased pelvic size may result in positive changes in cow weight and presumably cow size. Conversely, selection for increased
TABLE 4. ESTIMATES OF GENETIC AND PHENOTYPIC CORRELATIONS OF TRAITS BY DATA SET<sup>a</sup>

<table>
<thead>
<tr>
<th>Trait&lt;sup&gt;b&lt;/sup&gt;</th>
<th>Pelvic width</th>
<th>Pelvic area</th>
<th>Pelvic height/pelvic width</th>
<th>Cow weight</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Set I</td>
<td>Set II</td>
<td>Pooled&lt;sup&gt;cd&lt;/sup&gt;</td>
<td>Set I</td>
</tr>
<tr>
<td>PH</td>
<td>.05 ± .26</td>
<td>.78 ± .27</td>
<td>.40 ± .37</td>
<td>.65 ± .16</td>
</tr>
<tr>
<td>PW</td>
<td>.26</td>
<td>.34</td>
<td>.29</td>
<td>.78</td>
</tr>
<tr>
<td>PA-I</td>
<td>.75 ± .11</td>
<td>.94 ± .07</td>
<td>.88 ± .13</td>
<td>.58</td>
</tr>
<tr>
<td>PH/PW</td>
<td>.16 ± .26</td>
<td>.25 ± .49</td>
<td>.18 ± .55</td>
<td>.02</td>
</tr>
</tbody>
</table>

<sup>a</sup>First line — genetic correlations ± SE; second line — phenotypic correlations.

<sup>b</sup>Definitions of abbreviations can be found in Table 2.

<sup>c</sup>Equation for pooled genetic correlations ($r_{G_{pit}}$) = $\frac{1/(SE)\hat{r}_{G_{E_{pit}}} (r_{G_{pit}}) + 1/(SE)\hat{r}_{G_{H_{pit}}} (r_{G_{pit}})}{1/(SE)\hat{r}_{G_{E_{pit}}} + 1/(SE)\hat{r}_{G_{H_{pit}}}}$.

<sup>d</sup>Equation for pooled phenotypic correlations ($r_{P_{pit}}$) = $\frac{1/\sqrt{1/n_t-3} (r_{P_E}) + 1/\sqrt{1/n_H-3} (r_{P_H})}{1/\sqrt{1/n_t-3} + 1/\sqrt{1/n_H-3}}$. 

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cow size may result in larger pelvic areas. This is in agreement with Benyshek and Little (1982), who showed a genetic correlation between pelvic area and 365-d adjusted weight of .65.

Laster (1974) stated that a large percentage of the differences in pelvic size among breeds were due to differences in body weight. Larger cows tend to have larger pelvic openings and the tendency is similar in different breeds. However, pelvic size (PH or PW), independent of cow weight, had a significant influence on dystocia.

The phenotypic correlations between the various pelvic measures and cow weight in the present study were generally low. Therefore, it would appear that selecting females with large pelvic areas as replacements would not necessarily involve selecting those females with the potential for large mature weights. Benyshek and Little (1982) reported low environmental correlations between pelvic area and growth characteristics and concluded that environmental effects on growth and pelvic area were not similar. They stated that composition of gain may have to be considered in order to develop the proper relationship between growth and pelvic area. In the present study, the environmental correlation between pelvic area and cow weight for the mature cows of Set II was also very low (r_E = .07).

Direct selection for increased PA-I was calculated using the parameters developed from Set-I. An increase of 12.2 cm² was estimated per generation of selection. A correlated response of 12.5 kg in CW would also be expected because of the positive genetic correlation. A restricted selection index was used to allow response to selection for PA-I but not for CW. The index took the form I = PA - .091 CW. Selection of females using this index should result in an increase of 11.0 cm² in PA-I, with no change in CW. Thus, use of this index would give 90% as much change in PA-I as when selecting directly for PA-I without consideration of cow size. As suggested by Taylor et al. (1975), selection based on pelvic area and body weight together may be effective in reducing calving difficulty. Realistically, a breeder might not apply direct selection to pelvic area as a primary trait. However, by setting minimum standards, such as through independent culling levels, some progress toward increasing pelvic area would still occur in subsequent generations.

**Literature Cited**


Harvey, W. R. 1978. Users guide for LSML76. Ohio State Univ., Columbus (Mimeo.).


