Estimation of Genetic Parameters for Scrotal Circumference, Age at Puberty in Heifers, and Hip Height in Brahman Cattle[1,2]

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ABSTRACT: Genetic parameters were estimated for scrotal circumference (SC; n = 287), age at puberty in heifers (AP; n = 292), and hip height in both sexes (HH; n = 684) for Brahman cattle born from 1984 to 1994 at the Subtropical Agricultural Research Station, Brooksville, Florida. Age at puberty was defined as the age (days) at first detected ovulatory estrus. Measurements of SC and HH were taken at 18 mo of age. Fixed effects considered in the SC model were year of birth (YOB), age of dam (AOD), and age at measurement (AGE) as a linear covariate. Fixed effects fitted to the AP model were YOB and AOD. Fixed effects in the HH model were YOB, sex, AOD, and AGE as a linear covariate. Variances and covariances were estimated using REML with a derivative-free algorithm and fitting a multiple trait animal model. Estimates of heritability for SC, AP, and HH were .28, .42, and .65, respectively. Estimates of genetic correlations between SC and AP, SC and HH, and AP and HH were –.32, .19, and .25, respectively. Estimates of environmental correlations were .19 between SC and HH, and –.13 between AP and HH. Estimates of genetic parameters indicate a favorable genetic relationship between SC in Brahman bulls and AP in Brahman heifers under subtropical conditions. There was also evidence that selecting Brahman bulls for HH would not adversely affect SC but would have some detrimental effect on AP in female progeny.

Key Words: Zebu, Variance Components, Genetic Parameters, Puberty, Testes, Height

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Introduction

Age at puberty in heifers can have a major effect on the efficiency of the beef cattle enterprise when heifers are bred to calve first as 2-yr olds, especially under a restricted breeding season. Brahman heifers reach puberty at an older age than heifers of *Bos taurus* breeds (Martin et al., 1992). Martin et al. (1992) attributed average differences for age at puberty between breeds to the additive effects of genes present in diverse frequencies within breeds.

Even though considerable emphasis has been placed on scrotal circumference and its relationship to bull fertility (Lunstra et al., 1978), the relationship between scrotal circumference and reproduction in female progeny is equally important (Brinks, 1977; King et al., 1983). Because larger selection differentials are possible in males, selection response can be enhanced by including scrotal circumference as an indicator trait along with direct measures of age at puberty in females. Several studies (Brinks et al., 1978; Toelle and Robison, 1985; Martin et al., 1992) have reported favorable genetic relationships between reproductive traits in bulls (e.g., scrotal circumference) and females (e.g., age at puberty).

Favorable genetic correlations between reproductive and growth traits in beef cattle have been reported (Wolfe et al., 1990; Meyer et al., 1991). Baker et al. (1988) demonstrated a high degree of interdependence among pubertal and growth characters in cattle and concluded that height was an important source of variation for age and weight at puberty. They indicated that because height is less

[1]Names are necessary to report factually on available data; however, the USDA neither guarantees nor warrants the standard of the product, and the use of the name by USDA implies no approval of the product to the exclusion of others that may also be suitable.

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susceptible to environmental variation than weight and mature heights are reached earlier than mature weights, height should be considered in selection programs for reproductive traits.

Thus, the objective of this study was to estimate covariance components and genetic parameters among scrotal circumference (**SC**) in Brahman bulls, age at puberty (**AP**) in Brahman heifers and hip height (**HH**) in both sexes.

Materials and Methods

Data were collected from Brahman cattle between 1984 and 1994 at the Subtropical Agricultural Research Station (**STARS**) located near Brooksville, Florida. The geographical coordinates of STARS (Main Station) are 28° 37′ 00″ north latitude and 82° 21′ 30″ west longitude. Average annual rainfall is 1,372 mm, and over half falls in June, July, August, and September. Average year-round temperature is approximately 22°C, with occasional frosts from November through March.

The Brahman herd at STARS used in this study was composed of purebred and upgraded cattle. Grade cattle descended from Brahman-sired cows, with at least two-thirds Brahman breeding, upgraded two or three additional generations. Complete pedigree records relating all animals to the base herd were available. The number of sires used per year ranged from two to five. To maintain connectedness of the data across years, up to three sires were used in two consecutive years. Mating was not random. Assortative mating based on observed HH was practiced; mating groups were formed such that dams and sires were of comparable heights. The total number of sires and dams that had offspring with records were 28 and 261, respectively. The number of records per trait were 684 HH, measured on heifers and bulls at 18 mo of age (BIF, 1996), 287 SC, measured in bulls at 18 mo of age (BIF, 1996), and 292 AP, measured only in heifers.

Calves were born from late December to early April. Calves remained with their dams on bahiagrass (*Paspalum notatum*) pastures until weaning in September, when calves were grouped by sex, and fed a commercially prepared, medicated supplement (65% TDN, 14% CP, plus antibiotics) for approximately 1 mo. Heifers were fed .91 to 2.27 kg/d of concentrate (depending on the year) and 1.81 kg/d molasses (1993 to 1995), and hay (bahiagrass, perennial peanut, or Alyce clover) was provided for ad libitum intake during winter until spring of the following year when growth of bahiagrass pasture was adequate to support the heifers. Bulls were fed 4.54 kg/d of concentrate, and bahiagrass hay was offered for ad libitum intake during periods of low forage availability (bahiagrass) for about 1 yr after weaning. As heifers approached 2 yr of age, during their second winter, they were given free access to bahiagrass hay and 1.81 kg/d of molasses. All cattle had free access to minerals year round.

Age at puberty was defined to be the age (days) at first detected ovulatory estrus (Senseman, 1989). The procedure used to determine this ovulatory estrus was somewhat different in the first period (1984 to 1988) and in the second period (1989 to 1994) of this study. In both periods, estrus was detected in heifers from 10 to 24 mo of age by visual observation with the aid of bulls (sterile in Period 1, and fertile in Period 2) with chin ball marking devices. However, different procedures were used in periods 1 and 2 to ascertain the occurrence of the first *ovulatory* estrus. In Period 1, when estrus was observed, the first ovulatory estrus was considered to have occurred when 1) a corpus luteum was detected by rectal palpation (1984, 1987, and 1988) or 2) a corpus luteum was detected by rectal palpation, *and* the concentration of plasma progesterone was greater than 1 ng/mL measured by RIA (1985 and 1986). These tests (rectal palpation and progesterone concentrations) were conducted every 28 d. When estrus was not observed, but luteal tissue was present, and(or) plasma progesterone was greater than 1 ng/mL, the date of puberty was estimated to be 14 d preceding the palpation. In Period 2, the bulls used for estrus detection were fertile. Thus, these bulls were not only used for estrus detection, but also for the detection of the first ovulatory estrus by allowing them to impregnate heifers. Here, the day of the first ovulatory estrus was assumed to be the day a heifer became pregnant. Pregnancy status was checked every 28 d, and fetal age was determined from fetal size by rectal palpation. The date at first ovulatory estrus was determined based on fetal age and estrus detection data. The accuracy of detection of the first ovulatory estrus by the procedures used in Periods 1 and 2 was assumed to be similar.

Statistical Analysis

The genetic relationship was complete for the animals evaluated in this study. Thus, changes in variances and covariances that might have occurred as a result of the assortative mating would not affect the relationship matrix (Sorensen and Kennedy, 1984; Fernando and Gianola, 1990; Henderson, 1990). The data were analyzed using a multiple trait animal model (Henderson and Quaas, 1976). Hip height, SC, and AP were the traits considered. Hip height was measured in both sexes. Age at puberty was measured on females and SC on males. Fixed effects considered were different for each trait, in the SC model were year of birth (**YOB**), age of dam (**AOD**), and age at measurement (**AGE**) as a linear covariate. Fixed effects fitted to the AP model were YOB and AOD. Fixed effects in the HH model were YOB, sex, AOD, and AGE as a linear covariate. No adjustment to either trait was made before analysis. Random effects in the model were animal and residual. The AP in heifers and SC were connected through the numerator of the relationship matrix and the matrix of genetic covariances among traits. The full relationship matrix between animals was included by incorporating all pedigree information. The form of the three-trait model followed that of Henderson and Quaas (1976). The variance of the animal effects [$V(u)$] was $A \times G_o$, where A is the numerator relationship matrix among all animals and G_o is the additive genetic covariance among the three traits. The variance of the residual [$V(e)$] was $I \times R_o$, where

$$R_0 = \begin{bmatrix} r_{11} & 0 & r_{13} \\ 0 & r_{22} & r_{23} \\ r_{31} & r_{32} & r_{33} \end{bmatrix}$$

The covariance between SC and AP is zero because these are sex-limited traits (i.e., measured in different animals); thus, no environmental covariance exists between SC and AP.

Thus, the (co)variance parameters to be estimated were three additive genetic variance components (σ^2_{A1}, σ^2_{A2}, and σ^2_{A3}), three additive genetic covariance components between them (σ_{A12}, σ_{A13}, and σ_{A23}), and five residual error (co)variances (σ^2_{e1}, σ^2_{e2}, σ^2_{e3}, σ_{e13}, σ_{e23}). Genetic parameters were estimated for SC, AP, and HH. Heritability estimates for each trait and the genetic and environmental correlations between them were also computed.

Analyses were carried out using multiple trait derivative-free restricted maximum likelihood (MTDFREML, Boldman et al., 1995). The strategy for estimation of (co)variances with multiple traits was as follows: 1) starting values for the estimates of variance components for the three traits were obtained by fitting a single trait animal model for each trait; 2) multivariate estimation was initiated with a cold start holding the variance estimates from single trait analyses constant, using guessed covariances as starting values and a low level of convergence criterion of 10^{-3}; 3) a cold restart from apparently converged estimates considering all parameters in the model simultaneously was run using the same low level of convergence as in the previous step; 4) cold restarts, maintaining the convergence criterion of 10^{-3}, were repeated until −2 log likelihood did not change in the first two decimal positions; 5) a cold restart was run at a high level of convergence 10^{-9}; and 6) to check for convergence to a local rather than to a global maximum, a cold restart from previous converged estimates at a high level of convergence was repeated until the smallest −2 log likelihood was found. Changes in −2 log likelihood beyond the third decimal position were considered not important.

Table 1. Additive genetic (co)variance estimates for scrotal circumference (SC), age at puberty in heifers (AP), and hip height (HH) in Brahman cattle[a]

Traits[b]	Traits: SC	AP	HH
Scrotal circumference	2.5	−31.5	1.3
Age at puberty		3,863.6	70.1
Hip height			19.6

[a]Variances on the diagonal; covariances above.
[b]Scrotal circumference and hip height in centimeters and age at puberty in days.

Table 2. Environmental (co)variance estimates for scrotal circumference (SC), age at puberty in heifers (AP), and hip height (HH) in Brahman cattle[a]

Traits[b]	Traits: SC	AP	HH
Scrotal circumference	6.4	—	1.4
Age at puberty		5,422.2	−50.3
Hip height			10.5

[a]Variances on the diagonal; covariances above.
[b]Scrotal circumference and hip height in centimeters and age at puberty in days.

Results and Discussion

Heritabilities

Estimates of additive, environmental (co)variance components and genetic parameters are presented in Tables 1, 2, and 3, respectively. The estimate of heritability for SC was .28. Scrotal circumference has been reported as moderately to highly heritable in temperate and low to moderately heritable in tropical cattle. Estimates for *Bos taurus* breeds range from .41 to .53 for Hereford (Lunstra et al., 1988; Meyer et al., 1990; Kriese et al., 1991) and from .36 to .42 for Angus (Knights et al., 1984; Meyer et al., 1990). Reported heritability estimates for SC in Brangus (Kriese et al., 1991) and Zebu crosses (Meyer et al., 1990) were .16 and .26, respectively. The magnitude of the estimate found in the present study suggests that improvement in SC can be achieved by selection within Brahman cattle.

The estimate of heritability for AP was .42. Similar estimates were reported by Laster et al. (1979) and Splan et al. (1996) in *Bos taurus* crossbred heifers (.41 and .43, respectively) and King et al. (1983) in Hereford heifers (.48). A pooled estimate of .61 in crossbred heifers from straightbred Hereford and Angus cows mated to Hereford, Angus, Jersey, South Devon, Limousin, Charolais, or Simmental sires was reported by McNeil et al. (1984). Lower estimates

Table 3. Genetic parameter estimates for scrotal circumference (SC), age at puberty in heifers (AP), and hip height (HH) in Brahman cattle[a]

	Traits		
Traits	SC	AP	HH
Scrotal circumference	.28	–.32	.19
Age at puberty	—	.42	.25
Hip height	.19	–.13	.65

[a]Heritabilities on the diagonal; genetic correlations above; environmental correlations below.

were reported in Hereford, Angus, and Red Angus cattle (.20, Arije and Wiltbank, 1971; .10, Smith et al., 1989a). Based on this result, a selection program for early age at puberty in Brahman heifers should result in improvement for the trait.

Hip height is probably the most convenient way of describing skeletal size in beef cattle (Baker et al., 1988). Heritability for hip height was .65. Most literature reports of heritabilities for HH range from moderate to high. Neville et al. (1978) reported pooled estimates for HH in replacement heifers of .54 and .75 in herds at Tifton, GA (Angus, Polled Hereford, and upgraded Simmental) and Reidsville, GA (Angus, Polled Hereford, and Santa Gertrudis), respectively. In Hereford bulls, hip height heritabilities estimates were .55 (Bourdon and Brinks, 1986) and .66 (Kriese et al., 1991). In the Brangus breed, Kriese et al. (1991) and Choy et al. (1996) reported heritabilities estimates of .27 and .62, respectively.

Genetic Correlations

Genetic correlations between SC and AP, SC and HH, and between AP and HH are presented in Table 3. The estimate of the genetic correlation obtained between SC and AP in heifers (–.32) was favorable, which indicates that heifers that reach puberty earlier were genetically associated with bulls of large scrotal circumference at 18-mo of age. Brinks et al. (1978), reported a negative (favorable) genetic correlation of –.71 between SC in bulls with AP in their half-sib sisters. Similarly, the regression coefficient of AP on SC (–.796 d/cm) reported by Smith et al. (1989b) and the phenotypic correlations of –.98 (Lunstra, 1982) and –.91 (Gregory et al., 1991) have also indicated a favorable relationship between SC and AP in heifers. Even though no comparable values were found for the Brahman breed, Meyer et al. (1991) with Zebu crosses and MacKinnon et al. (1990) with Droughtmaster (Brahman × Shorthorn) cattle found low but favorable estimates for the genetic correlation between SC and female fertility (pregnancy rate and days to calving), and they concluded that SC could be used as an indicator trait of female reproductive performance. Toelle and Robison (1985), using data from Hereford cattle, reported a genetic correlation of age at first breeding with yearling SC of –.39, which also supports the assertion that selection on scrotal circumference would be effective in decreasing age at puberty in heifers. Even though a higher heritability value was found for AP than for SC, the favorable genetic relationship between SC and AP found here indicates that it might be possible to achieve more rapid progress in AP under indirect selection for SC than from selection for AP itself, because AP is very labor-intensive and difficult to measure directly and with precision.

The additive genetic correlation estimate between SC and HH at 18 mo of age was positive and low in magnitude (.19). This result is somewhat lower than reported estimates in the literature. In Hereford bulls, higher positive genetic correlations between SC and HH have been reported, .42 (Bourdon and Brinks, 1986) and .36 (Kriese et al., 1991). However, in Brangus, Kriese et al. (1991) found a positive genetic correlation between SC and yearling HH of a magnitude similar to the one found here (.25). Pratt et al. (1991) reported phenotypic correlations between SC and HH in Zebu-derived breed bulls, predominantly Santa Gertrudis. Their analysis was performed with two data sets that differed in test entry requirements and feeding management. Estimates of correlations between SC and HH at the end of the 140-d gain test were .09 and .61 for data sets 1 and 2, respectively. The favorable genetic correlation obtained in the present study indicates that selecting for SC may change the growth curve of bulls or vice versa (i.e., selecting for increased hip height at 18-mo of age should increase scrotal circumference).

The estimated genetic correlation between AP and HH of .25 found in this study supports the existence of an unfavorable genetic correlation between the component trait of growth and the component trait of female reproductive performance studied. Although low in magnitude, this association of hip height and age at puberty in heifers indicates that selection in Brahman cattle for increased HH of heifers at 18 mo of age should result in heifers that are taller and older at puberty. This relationship is in contrast to the positive genetic correlation found between HH and SC in bulls. Thus, because selection for large SC may result in the selection of taller bulls, culling of bulls with extreme hip heights will be an adequate selection criterion. Previous studies have shown that within a breed, growth rate had no significant effect on age at puberty in heifers (Laster et al., 1979; Nelsen et al., 1982). Wolfe et al. (1990), when evaluating three Hereford lines selected for weaning weight, final yearling weight, and final weight plus muscling score, concluded that selection for growth did not have a detrimental effect on age at puberty in heifers. Similarly, Baker et al. (1988), when analyzing puberty and growth relationships in cattle, concluded that differences in genetic potential for growth rate did not affect age at puberty to any significant extent and that the same concept would apply to the relationship between weight at puberty and growth rate for weight. However, they reported that growth rate for height affected weight and height at puberty. Thus, increased growth rate for hip height was associated with heavier, taller heifers at puberty. They found, after adjustment for breed-type and management, that taller heifers at 315 d of age were older at puberty with a regression coefficient of 2.04 d/cm and that hip height at 360 d of age was not a significant source of variation for age at puberty. Their results indicated that the majority of the variation among breed-types was due to height and made conclusions about the need to consider all pubertal characters in a simultaneous manner in order to have a full understanding of their relationships. Genetic correlations reported by Bourdon and Brinks (1982) and Smith et al. (1989a) between yearling weight, as a measure of size, and age of puberty in heifers were favorable (−.14 and −.17, respectively) but had high standard errors.

Because limited effort has been directed toward estimating genetic parameters in *Bos indicus* and *Bos indicus* derivative breeds, such as the Brahman, variances and covariances estimated in this study should be useful in future Brahman genetic evaluations. Even though the estimates of genetic parameters obtained were within the range of published values for these traits, standard errors are expected to be large because the data set was small and unbalanced. However, genetic and environmental covariances among traits were included in the three-trait model, so records for one trait had an impact on evaluations for the other traits. Furthermore, estimating covariances when traits are correlated uses information from all traits to estimate all covariances, and thus increases the accuracy of estimation of all of them. Even though caution should be exercised when interpreting the results obtained, the magnitude of the estimated additive genetic variability suggests that progress could be made through selection. Results showed evidence of a favorable genetic relationship between scrotal circumference in bulls and age at puberty in heifers under subtropical conditions. There was also evidence that selecting bulls for hip height would not adversely affect reproduction in males but would have some detrimental effect on females. Even though management practices can be used to decrease age at puberty in heifers (e.g., increasing growth rate as a function of nutrition), it is important that the animals have the genetic potential to express early puberty.

Implications

A favorable genetic association seems to exist between scrotal circumference in bulls and age at puberty in heifers. Thus, selection of Brahman sires for increased scrotal circumference at 18 mo of age should provide a useful means for making genetic progress in reducing age at puberty of heifers. Scrotal circumference thus serves as an indicator trait to indirectly select for early age at puberty in heifers. Because of an unfavorable genetic correlation between hip height at 18 mo and age at puberty in heifers was identified in this study, selection programs in Brahman cattle should be planned taking into consideration growth measurements and reproductive traits simultaneously.

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