GROWTH RATES AND RELATIONSHIPS AMONG FRAME SIZE, PERFORMANCE TRAITS AND SCROTAL CIRCUMFERENCE IN YOUNG BEEF BULLS

By

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Bachelor of Science

North Dakota State University

Fargo, North Dakota

1979

Submitted to the Faculty of the Graduate College
of the Oklahoma State University
in partial fulfillment of the requirements
for the Degree of
MASTER OF SCIENCE
December, 1981

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ACKNOWLEDGMENTS

I wish to express my sincere appreciation to Drs. E. J. Turman and Bob Kropp for their guidance and advisement during the course of this study and the preparation of this manuscript. I would also like to thank Drs. J. V. Whiteman, Dave Buchanan, and Richard Hintz for their counsel and assistance in the analysis of this study.

I wish to thank my fellow colleagues Ernie Minton, Harold Gaugler, Carla Chenette, Randy Walker, and Don Marshall for their friendship and help with the collection of data. Additional thanks are extended to all the other graduate students for their friendship and fellowship in making graduate school almost fun.

I am sincerely grateful to Dr. Charles McPeake, Gaylin Bryson, Jerry Allen, Bob Cowan, Jim Thompson, and the rest of the OBI and beef barn crews for their time and assistance with collection of data.

Finally, I would like to thank my parents, Kenneth and Arlene, and brothers and sisters, John, Jim, Julie, Joan, Jay, and Joel, for their love and support throughout my life and allowing me to continue my education.

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CHAPTER I

INTRODUCTION

In beef cattle herds, the level of reproductive performance of both cows and bulls is probably the single most important factor contributing to gross returns. Since a bull is used on so many females during a breeding season, especially if artificial insemination is practiced, his genetic contribution to the herd is relatively greater. Therefore, it is especially important to understand all the factors influencing the reproductive performance of the bull. One such factor is testicular size, with scrotal circumference being the most common measurement of size.

With the trend in beef selection in the 1980's toward larger-framed, later-maturing bulls, many concerns have been expressed by cattlemen relative to the effect of increased size and body growth on the reproductive development and performance of both the bull and the cow. Although extensive data exists on the relationship between body size and testicular growth, especially in dairy bulls, few results have been published concerning the relationship between reproductive development and skeletal growth or body size.

The purpose of this study was to evaluate the relationship between scrotal circumference in young beef bulls and their respective growth traits as measured by linear hip height, body weight, and average daily gain on a performance test program. In addition, a major objective was to evaluate the effect of breed, age, season, environment and ambient temperature on scrotal circumference measurements in young beef bulls.

CHAPTER II

REVIEW OF LITERATURE

The Relationship of Testicular Size to Spermatozoa Production and Output

Testicular weight is an important indicator of the amount of sperm-producing parenchyma of the testis (Almquist and Amann, 1961; Amann and Almquist, 1962; McMillan and Hafs, 1968). Many studies have shown the correlation between testicular weight and sperm output to be high, averaging .75 (Hahn et al., 1969a, 1969b; Foote et al., 1976; Weisgold and Almquist, 1979). Since castration must be used to accurately estimate testicular weight, indirect measurements, such as scrotal circumference, testes length and diameter, and paired testes width, have been proposed for use in intact bulls (Boyd and VanDemark, 1957; Willet and Ohms, 1957; Foote et al., 1972; Almquist et al., 1976; Coulter and Foote, 1976; Elmore et al., 1976; Lunstra et al., 1978).

Of the various measurements that have been studied, scrotal circumference is, by far, the most widely used. It has been shown to be highly repeatable. Hahn et al. (1969b) reported a repeatability of .98 even when measurements were made by different technicians or at different times. Scrotal circumference also appears to be an accurate estimate of testicular weight. Boyd and VanDemark (1957), VanDemark and Mauger (1964) Coulter and Foote (1969b), and Hahn et al. (1969b) reported correlations between scrotal circumference and testicular weight at or near slaughter in dairy bulls ranging from .89 to .95. Coulter (1978) reported a correlation of .95 in young beef bulls.

To obtain an accurate measurement of scrotal circumference, the bull should be adequately restrained in a squeeze chute. The testicles are drawn as far as possible into the scrotum to remove excess wrinkles of the skin and a cloth or steel self-releasing tape is fitted, without compression, over the largest diameter of the scrotum (Willet and Ohms, 1957).

The relationship between scrotal circumference and sperm output varies with age and frequency of ejaculation. Most researchers have reported a marked effect of age, with a high relationship between scrotal circumference and sperm output in young bulls, declining as the bull ages to become negative in aged bulls. Hahn et al. (1969b) reported the correlation between scrotal circumference and sperm output in growing dairy bulls was .81, .72, .64, .40, and -.22 at 17 to 22, 34 to 42, 42 to 53, 59 to 69, and 72 to 150 months of age, respectively. Willet and Ohms (1957) reported correlations of .43 for dairy bulls 12 to 18 months of age in routine service, .92 for young bulls with four exhaustions at weekly intervals and -.53 for aged bulls. Hahn et al. (1969a) suggested that the negative relationship observed in aged bulls may be a degeneration of the semeniferous tubule or an increase fibrotic and tumorous tissue. Almquist et al. (1976) reported a correlation of .78 in young beef bulls, with frequent ejaculation having no significant effect on scrotal circumference size. Thus, these studies suggest that scrotal circumference is a good indicator of sperm output only in young bulls.

The Relationship of Testicular Consistency to Seminal Quality and Fertility

Soft testicular consistency is often associated with poor semen quality and low fertility (Haq, 1949 and Roberts, 1971). Testicular consistency is usually determined by manual palpation to estimate the firmness of the testicles. However, manual palpations are too subjective to accurately classify the firmness of the testicle. Some researchers have proposed the use of a tonometer to obtain a more precise estimate. Hahn et al. (1969a) describes the tonometer as an instrument which measures the pressure required to depress a spring-loaded plunger against the testicles. This pressure is directly proportional to the firmness of the material against which the plunger is pressed. This device yields highly repeatable readings if the technician is trained in its use and the bull is properly restrained. Hahn et al. (1969a) reported when bulls were first measured 14, 30, and 56% of the testes were classified as having a soft, medium, or firm consistency, respectively. One year later, 85, 69, and 63% of the testes originally classified as soft, medium, or firm, respectively, remained the same.

Hahn et al. (1969a) ejaculated 64 bulls of various ages twice a day, two days a week for four or five weeks. He reported that correlations between tonometer reading and semen volume, concentration and total sperm were low and nonsignificant. However, correlations between tonometer readings and semen quality, as measured by percent unstained sperm, percent normal sperm, and percent motile sperm after one day at $5^{o}C$ were high ($r = .60$ to $.80$). Furthermore, the correlation between tonometer reading and fertility, as measured by percent 60 to 90 day non return to service, was .67 (Hahn et al. 1969a and Foote et al., 1970). Thus, because of the difficulties involved in semen collection and accurately determining semen quality, the tonometer may be a very useful tool.

Factors Influencing Testicular Size

Testicular size is one of the important parameters of reproductive performance in young bulls, because of its high relationship to sperm output. Therefore, it is important to understand the many factors that influence testicular size as measured by scrotal circumference. These factors include age, breed, season, year, body weight, nutrition, and testosterone output.

Age

The most important single factor influencing testicular size is age of bull. Many reports have provided information on changes in scrotal circumference that are associated with growth and aging in dairy bulls (Boyd and VanDemark, 1957; Willet and Ohms, 1957; Almquist and Amann, 1961; Amann and Almquist, 1961 and 1962; Hahn et al., 1961b; VanDemark and Mauger, 1964; Foote et al., 1970; Coulter et al., 1975) and in beef bulls (Almquist et al., 1971; Cates, 1975; Coulter et al., 1975; Elmore et al., 1975; Underwood et al., 1977; Coulter, 1978; Lunstra et al., 1978). In general, there is a linear increase in scrotal circumference up to approximately two years of age, followed by a gradual slowing until it ceases at about four years of age, and may even decline in aged bulls (Coulter et al., 1975 and Coulter, 1978). Correlations between scrotal circumference and age of .87, .67, and .88 were reported by Hahn et al. (1969b), Underwood et al. (1977), and Lunstra et al. (1978), respectively. Coulter and Foote (1975) reported the correlation between scrotal circumference and age in Holstein bulls 60 months of age or less was .59. However, a correlation of .13 was reported for bulls over 60 months of age.

Almquist et al. (1976) reported an increase in scrotal circumference and scrotal width from puberty until two years of age, but scrotal circumference at puberty was not closely related to scrotal circumference at two years of age (r = .37). However, he observed scrotal circumference at 52 and 65 weeks of age were good indicators of scrotal circumference at two years of age (r = .80 and .90, respectively).

Coulter and Foote (1977) studied 160 Holstein bulls and reported correlations of .48 and .56, respectively, between scrotal circumference at 12 to 23 months and 24 to 36 months of age and scrotal circumference at maturity (60 to 71 months of age). These workers also reported a correlation of .58 between the combination of the two earlier measurements and those at maturity.

Most papers report a wide variation in testicular weight and scrotal circumference among bulls of the same age within a particular breed. For example, Coulter and Foote (1976b) reported a range of 600 grams in paired testes weight and Coulter et al. (1975) reported a range of 15 centimeters in scrotal circumference. This large difference in testicular size within an age group provides an excellent opportunity to improve reproductive traits by selecting individual bulls on the basis of these testicular measurements.

Breed

Relatively little is known on the relationship of breed and scrotal circumference. In the literature, there is some disagreement among the different breeds quoted. These differences may be due to small numbers of bulls used, genetic variation within a breed or genetic differences between lines within a breed.

Coulter et al. (1975) reported that Angus bulls had larger scrotal circumference measurements than did Holstein bulls up to three years of age, but were surpassed after that age. Fields et al. (1979) stated there was a large breed difference between Santa Gertrudis, Brahman, Hereford, and Angus yearling bulls. Santa Gertrudis bulls had the largest scrotal circumference while Brahman bulls had the smallest measurements. Weisgold and Almquist (1979) reported differences in testicular weight between Angus, Hereford, and Charolais bulls. Angus bulls had the heaviest testicles followed by Charolais and Hereford bulls, respectively. Cates (1975) showed that Hereford, Polled Hereford, Shorthorn, Charolais, and Galloway bulls were similar in scrotal circumference at one year of age but data collected over many years showed the mean scrotal circumference of Angus bulls was constantly larger at one year of age. Underwood et al. (1977) reported scrotal circumference measurements for bulls of several breeds were different when they were put on a performance test program. Although the number of bulls for some breeds were small, there were definite breed differences noticed. Brangus, Simmental and Hereford had the largest; Angus, Red Angus, and Polled Hereford had intermediate; and Santa Gertrudis, Charolais, and Devon had the smallest scrotal circumference.

Bierschwal (1976) has devised a scrotal circumference classification chart for bulls of different ages in which different scrotal circumference measurements are given a score of very good, good, and poor for certain age groups. This chart was designed for bulls of all breeds, thus, with the breed differences mentioned previously, these standards may be too high or low for certain breed groups.

In contrast, Lunstra et al. (1979) reported that although young bulls of Brown Swiss, Hereford, Angus, and Red Poll breeds and Hereford X Angus crossbreds varied considerably in body weight and calendar age at puberty (as defined as the age when the ejaculate first has 50 X 10^6 sperm/ml with at least 10% progressive motility), all were at, or near, a constant scrotal circumference of 27.9 ± .2 centimeters. He suggested that scrotal circumference should be useful to select early-maturing bulls. These results suggest that, although significant breed differences exist in testicular size at a given age, it may not be necessary to consider breed of bull when doing breeding soundness evaluations, as long as minimum standards are met for a given age.

Season and Year

A definite effect of season has been reported for growing Holstein bulls measured in early spring vs late summer (Coulter and Foote, 1976a). Scrotal circumference decreased ($P<.01$) and testicular consistency increased ($P<.01$) which is just the reverse of the changes normally associated with increasing age. It was also noted that bulls of different ages interact differently with different seasons. The decrease in scrotal circumference between early spring and late summer could be due to high temperatures causing a more pendulous arrangement of the scrotum with reduced scrotal wrinkling.

Fields et al. (1979) reported the seasonal effects on testicular volume in Angus, Florida Herefords, Montana Herefords, Brahman, and Santa Gertrudis bulls. In their study, testicular width and length was measured and testicular volume was estimated by the formula $V = \pi r^2 h$. Both breed and year effects on testicular volume were highly significant. Santa Gertrudis bulls had the longest testes, followed by the Florida Herefords, Montana Herefords, Angus and Brahman. When expressed as testicular volume per unit of body weight Hereford and Angus bulls ranked above Santa Gertrudis. All breeds except Herefords showed an increase in testicular size from April to August with Brahman bulls exhibiting the greatest increase followed by Santa Gertrudis. Fields et al. (1979) stated that there was a reduction in testicular volume and semen quality only in both lines of Hereford bulls from April to August. He suggests that this reduction may have happened because the hypothalamic-pituitary axis was adversely affected by the high humidity and temperature resulting in decreased gonadotropin secretion and reduced seminiferous tubule volume. In addition, both lines of Herefords were from highly inbred lines thus their reproductive characteristics could have been lower than the other breeds studied.

There have been only a limited number of papers reporting studies on the effect of season and year on scrotal circumference, therefore, these influences are relatively unknown. Because of the drastic climate changes beef bulls undergo from season to season and from year to year, more information is needed on the temperature ranges and seasonal interactions that affect testicular size.

Body Weight

The relationship between body weight and testicular size is not clear; however, testicular size could influence body weight through increased androgen production. As testicular size is quite dependent on age, one might expect a high correlation between the two measurements in young, growing bulls. Coulter and Foote (1977a) made 1203 measurements of scrotal circumference and testicular consistency on 411 Holstein bulls. They found that body weight was highly correlated with scrotal circumference (r = .81). In growing bulls, both testes measurements were positively correlated with age, furthermore when age was held constant, the partial correlation coefficient between body weight and scrotal circumference was .58, thus, age accounted for only part of the correlation. The simple and partial correlation coefficient between body weight and testicular consistency was -.45 and -.16, respectively, indicating that heavier bulls having a greater degree of fat cover may have softer testes. Lunstra et al. (1978) reported a correlation between body weight and scrotal circumference of .80 in young beef bulls. In addition, Willet and Ohms (1957), reported when bulls were placed on a 140-day performance test there was a correlation between body weight and scrotal circumference of .60 and a correlation between these same traits at the end of the test was .56. These results are very similar to those obtained by Coulter (1978) who reported correlations between on-test body weight and scrotal circumference of .66, .56, and .60 for bulls during a three-year period. These three groups of bulls, plus another group, showed off-test correlations between body weight and scrotal circumference of .47, .56, .45, and .47 for the test run over a four-year period. Partial correlations, holding age constant, between body weight and scrotal circumference were from .32 to .52. In addition, Willet and Ohms (1957) obtained a negative correlation of -.03 between body weight and scrotal circumference on aged Holstein bulls.

These results suggest there is a strong relationship between body weight and scrotal circumference on young, growing bulls. However, this relationship does not seem to exist in mature bulls.

Nutrition

Level of nutrition obviously affects body weight and average daily gain, thus, one might expect nutrition to contribute to some of the differences found in scrotal circumference. Both testicular weight and scrotal circumference have been reported to be influenced by plane of nutrition in dairy bulls (Bratton et al., 1959; VanDemark et al., 1964; VanDemark and Mauger, 1964). VanDemark and Mauger (1964) reported when the TDN content of rations fed to Holstein bulls was reduced to 60% of recommended levels, testicular growth slowed and this reduction in growth never recovered to that of bulls fed 100% of the recommended TDN levels. Coulter (1978) reported when Hereford and Angus bulls were fed ration containing two different energy levels (low - 120 Kcal digestible energy and high - 150 Kcal digestible energy). The scrotal circumference of bulls (30.5 ± .3) on the high energy level was different ($P<.05$) than that of those on the low energy level (28.9 ± .4). However, since paired testes weight did not differ significantly, the increase in scrotal circumference in the bulls fed the high energy ration may have resulted from the deposition of scrotal lipids. In contrast, Sitarz et al. (1977) reported that feeding diets with 9, 10, or 14% protein had no significant effect on scrotal circumference of young beef bulls.

The amount of finish that a bull is carrying can influence the predictive accuracy of the scrotal circumference measurement. Cates (1975) reported the average scrotal circumference of yearling beef bulls varied with ration fed. Furthermore, he stated that heavily-fitted two-year-old bulls (scrotal circumference = 37.8 cm) may have an average scrotal circumference that is 2 to 3 cm larger than those in non-fitted condition (scrotal circumference = 34.6 cm). The heavily-fitted bulls had a decrease of 1.5 to 5 cm after a "let-down" period. Therefore, it is important to know the nutritional level and degree of condition when evaluating scrotal circumference for certain ages of bulls.

Relationship Between Scrotal Circumference and Other Traits Testicular Size and Testosterone Levels

If testes size does affect body growth, one mechanism might be through differences in concentration of circulating testosterone. However, data on this subject is limited and inconsistent. Coulter and Foote (1977) suggested there may be a relationship between testis size, androgen production, and body weight or growth rate. Lunstra et al. (1978) showed a positive correlation of .51 between scrotal circumference and testosterone concentration on bulls between 7 and 13 months of age. He also reported Red Poll and Brown Swiss bulls had higher testosterone levels and, thus, reached puberty earlier than Hereford and Hereford X Angus crossbred bulls with low testosterone levels.

In contrast to the above studies, Chenoweth et al. (1977) and Sitarz et al. (1977) failed to find a relationship between scrotal circumference and peripheral blood testosterone concentrations. Sitarz et al. (1977) found bulls weaned at 120 days averaged higher ($P<.01$) in testosterone at 375 days of age than those bulls weaned at 207 days ($7.8 \pm .5$ vs $6.1 \pm .4$ nanograms/milliliter plasma). Likewise, scrotal circumference at 375 days of age was greater ($P<.01$) in bulls weaned at 120 days than those weaned at 207 days of age. Although, concentrations of testosterone in plasma was not significant to scrotal circumference, weaning weight, and body frame. One weakness of this study was bulls were bled one time per period which may not be frequent enough to pick up the true testosterone peaks.

Libido

Libido, or sexual behavior, is a very important trait especially in young bulls. Therefore, a logical question is if a young bull is adequate in his testicular size does this mean he will also have adequate libido. Chenoweth et al. (1977) reported that there was a low and non-significant correlation between scrotal circumference and libido in yearling Hereford, Angus, and Red Angus bulls. The highest correlation was between scrotal circumference and the number of services performed in a service capacity test ($r = .16$). Farin et al. (1978) also found no correlation between scrotal circumference and libido in young beef bulls.

Genetic Implications of Testicular Measurements

The heritability of reproductive traits are very low ranging from .0 to .2 (Falcnor, 1960). Bull management and seminal collection practices have improved semen collection (Hafs et al., 1959 and 1962; Almquist and Cunningham, 1967; Hafs, 1972) but it is doubtful that sperm producing capabilities have improved. Little attention has been given to testicular selection as a method of improving quality and quantity of spermatozoa produced. The known relationship between scrotal circumference on semen output and testicular consistency on seminal quality makes improving semen traits very promising if these traits are heritable.

Coulter et al. (1976) reported on 4,275 measurements of scrotal circumference and 3,859 measurements of testicular consistency made on 1,521 Holstein bulls. He reported heritabilities of scrotal circumference and testicular consistency, using a parental half-sibs analysis, of .67 ± .10 and .34 ± .14, respectively. This indicates that sires with larger, firmer testicles will sire progeny that tend to have larger, firmer testicles. A heritability for scrotal circumference of similar magnitude (.68 ± .15) has been reported in beef bulls (Coulter, 1978). Thus, the high heritability of these traits provides a means to improve sperm production and seminal quality through an evaluation, selection and culling program based partially on testicular measurements.

Brinks et al. (1978) reported the genetic correlation between scrotal circumference in Hereford, Red Angus, and Angus bulls and age at puberty of parental half-sib sisters to be -.71. This means that female progeny from sires with large scrotal circumference measurements reach puberty at an earlier age. This is very important when one is breeding yearling heifers, although, in most cases, nutrition has the greatest effect on age of puberty. In contrast, Hickman (1976) states that the genetic correlation coefficient between age of first estrus and scrotal circumference of parental half-sib brothers are .44 for Holstein, .41 for Ayrshires, and .21 for both breeds. The reason for these contrasting results between dairy and beef breeds is unknown indicating more research is needed in this area.

Linear Measurements

For more than fifty years the beef cattle industry has been very interested in using linear measurements as an indication of skeletal size. Unfortunately, in many cases, the industry has misused these measurements. This section of the literature review is primarily concerned with the reports in the literature dealing with height measurements and their implications.

Linear measurements are very objective. They serve as another means of describing animals, and are useful supplemental information for performance testing, since they can be used with growth information to predict the accuracy of selection. The use a breeder makes of linear measurements depends on his goals relative to shape and growth patterns of his cattle.

Relationships Between Linear Measurements at the Withers and Hips

Differences have been observed between wither and hip height measurements for many years. Lush (1928) reported that hip height was practically a duplication of wither height, with hip height being larger by a fairly constant amount. Kidwell (1955) reported a correlation between hip height and wither height of .927 this is in agreement with a correlation of .90 reported by Lush (1928).

During normal growth wither height increases faster than hip height but these two measurements tend to reach equality as maturity is approached. Kidwell (1955) reported a difference of 1.5 in (3.807 cm) between wither and hip height in 10 to 16 month old Hereford steers with hip height being larger. Massey (1979) reported a difference of 1.65 to 1.75 in between wither and hip height in many breeds of beef cattle at 205 days of age with hip height being the largest with a standard deviation of 1.73 inches. Calculations from data reported by Guilbert and Gregory (1952) showed a mean difference of 1.83 in (4.67 cm) in wither and hip height of Hereford bulls from 124 to 725 days of age. Likewise, calculations from data collected by Brown (1958) showed the difference between wither and hip height measurements to be approximately 2.0 in (5.07 cm) for Angus and Hereford heifers, steers and bulls at 240 days of age.

If a linear measurement is to have any significant meaning, it is essential that it be accurate and repeatable. Most repeatability estimates in the literature suggest that if the technician is willing to take the time necessary to insure that the animal is standing in a natural position, linear measurements can be very accurate. Orne et al. (1959) reported a repeatability of .96 for Hereford and Angus long yearlings. A repeatability of .85 was also reported for Hereford and Angus calves and yearlings (Green and Carmon, 1976). In contrast, deBaca and McInerney (1979) cited the repeatability of .30 between two persons, one of whom had a .61 correlation between his first and second measures.

Linear Measurements and Body Growth

Relationships Between Birth Weight and Height

The trend today is to breed larger-framed cattle, therefore, cattlemen would like to increase body size at a given age. However, they do not wish to increase birth weight unfortunately the literature tends to show this is not possible. Kohli et al. (1951) reported that Milking Shorthorn steers that were heavier at birth exhibited larger wither height and body length when measurements were taken at a 900 pound slaughter weight. These steers were also heavier at weaning and had a longer leg measurement than lighter birth weight calves. Wyatt et al. (1977) also reported that crossbred calves that were taller and heavier at birth were also taller and heavier at weaning. Flock et al. (1962) reported a phenotypic correlation of .60 between wither height and birth weight on Angus, Hereford, and Shorthorn calves at weaning.

Relationship Between Body Weight and Height

There has been few studies on the relationship between body weight and height but in all cases, there was a positive relationship between these traits. Lush (1932) reported correlations of .72 and .73 between initial on-test weight and wither or hip height measurements, respectively. He also reported similar correlations of .71 and .69 between final weight and wither or hip height, respectively. Correlations of .38 and .62 between wither height and body weight were also reported on Hereford steers (Gregory, 1933 and Kidwell, 1955, respectively). Brungardt (1979) stated that wither height of Angus, Charolais and Hereford steers increased as on-test and off-test weights increased. He also reported correlations of .70 and .83 between wither height and on-test or off-test weights, respectively. Brungardt concluded that although cattle with more height at the withers gained faster and achieved heavier market weights, the association was not great enough to merit selection for height instead of weight adjusted for age. In addition, within cattle of similar heights a rather wide range in weight and finish did exist. Jeffery and Berg (1972) reported correlations between height and post calving weight or body weight of .54 and .62, respectively, on a group of Hereford X Angus X Galloway cross cows. In contrast, Kholi et al. (1951) reported a correlation of .26 between wither height and final weight at 900 pounds on Milking Shorthorn steers. This low correlation may be due to the fact that these steers were a dairy breed and their body type is much different than the beef breeds. The correlations reported in these studies indicate that as animals increase in height, they also increase in body weight. Weight alone tells little or nothing about body shape or condition, thus, a weight and height measurement would be a much better method of describing a particular animal than weight alone. For example, if two bulls weighed 1000 pounds and one was 47 in tall while the other was 50 in tall, you might expect the 50 in bull was either much trimmer or shallower-bodied.

Relationship Between Height and Body Growth Rate

Growth in cattle has been the subject of many studies, but mainly in terms of weight and with only limited information on height. In addition, the value of the latter studies are reduced because measuring techniques vary considerably between experiments and most of the studies utilized small-framed animals of various ages.

The concensus of several studies is that at birth, length and width of cannon bone is approximately 85 and 55%, respectively, of the mature measurement and wither height is about 50% of the mature height. An additional observation is that skeletal growth has practically ceased at

30 to 40 months of age (Eckles, 1915; Brody et al., 1937; Davis et al., 1937; Guilbert and Gregory, 1952; and Brown et al., 1956a, 1956b). Since all of these studies were done with small-framed cattle, these percentages may vary with today's larger-framed, later-maturing cattle. These high percentages for skeletal size at birth suggest that the majority of later size comes from the increase of muscular and fat tissue.

Lush (1928) stated that steers of the same age that were fattened and measured under similar conditions grew at nearly the same rate per day. Calculations derived from the data published by Guilbert and Gregory (1952) showed hip height growth to be very linear up to 12 months of age then slowed at a constant rate until maturity. This data showed a growth rate of .0338 in/day (.0857 cm/day) from 124 to 369 days of age in Hereford bulls, and .0167 in/day (.0424 cm/day) from 369 to 487 days of age. Calculations from data reported by Brown et al. (1973) showed a growth rate of .04367 in/day (.1108 cm/day) for 267 Hereford bulls and a growth rate of .0397 in/day (.1008 cm/day) for 283 Angus bulls. In addition, calculations from the data of Doir et al. (1974) revealed that Israeli-Friesian bulls on a growing ration grew at a rate of .0438 in/day (.111 cm/day) from 180 to 270 days of age and .0267 in/day (.070 cm/day) from 270 to 505 days of age. Massey (1979) reported growth rates on male calves of many breeds up to 365 days of age to be .03 in/day (.076 cm/day). This is very similar to results reported by Maino et al. (1981) of growth rates of .031 in/day (.078 cm/day). Healey (1979) reported growth rates on a single herd of Herefords to be .033 in/day (.0838 cm/day) from weaning to one year of age.

Healey (1979) reported a correlation of .84 between hip height at weaning and hip height at one year of age. Maino et al. (1981) reported correlations of .37 and .39 between November weaning hip height and February or September hip heights, respectively. However, a higher correlation of .80 was reported between February and September hip height measurements. He stated that correlations of .37 and .39 would have been higher except measurement errors might have been made at weaning in assignment of frame score categories.

Brown et al. (1956) reported that in Hereford and Angus bulls, 46 and 56%, respectively, of the mature weight and 71-86% and 80-89%, respectively, of mature skeletal size was achieved by 12 months of age. He concluded from his data that maturity for dimensions of height, depth, width, length, and heart girth was reached at an earlier age than was maturity for weight.

A statistical technique called principle component analysis has been reported (Brown et al., 1973; Brown et al., 1973a) to quantify size and shape of Hereford and Angus bulls on which several measurements including weight and skeletal size were taken at 4, 8, and 12 months of age. The first principle component, which represents size as large-framed and heavy, accounted for 56 to 68% of the variation in the ten linear measurements taken and provided a linear function of size with nearly all emphasis on all ten standardized traits. The second principle component for each of the age groups contrasted tall, narrow bulls with short, wide bulls. This contrast in shape accounted for more than 10% of the variation. Principle component analysis shows that size is more than weight alone, although weight is the largest contributor. This study suggests that two fundamental contrasts exist in young, growing bulls of similar ages; large- vs small-framed and short-statured, wide vs tall, narrow individuals with 70 to 80% of the variation attributed to these two principle components.

Relationship of Height on Performance and Carcass Traits

Average Daily Gain

Many studies have looked at the relationship of height to average daily gain with varying results depending on type and breed of cattle. Most research has shown a positive relationship between height measurements and weight, thus it would be logical that larger-type steers should gain more in the feedlot than smaller-type steers with the difference in gain most likely due to size rather than to type (Woodward et al., 1942 and Knox and Koger, 1946). In an extensive study looking at the relationship between linear measurements and gain, Flock et al. (1962) reported phenotypic correlations of .25, .33, and .04 between wither height and average daily gain in Hereford, Angus, and Shorthorn, respectively. They also stated that, although these correlations are low, other than weight, wither height is the best predictor for gain in Hereford and Angus.

In contrast, Hultz and Wheeler (1927) reported that small-framed steers made slightly more rapid and economical gains during a 156-day feeding period than did intermediate- or large-framed steers. A negative correlation of -.19 between wither height and average daily gain for dual purpose and dairy breeds has also been reported (Black et al., 1938).

Jeffery and Berg (1972) reported that age of dam, birth weight, and average daily gain of calf were positively correlated with body weight and skeletal measurements of dam when considered across breed for

Hereford X Angus X Galloway crosses and a synthetic strain of hybrid crosses. They reported a correlation of .50 between height of dam and average daily gain of their calves until weaning. Jeffery and Berg (1972) also looked at the influence of increasing or decreasing values of cow height on preweaning performance of progeny. They reported a centimeter increase in height of dam was associated with an increase in weaning weight of .97 kg for all cows across breed group; 1.82 kg for Hereford X Angus X Galloway cross cows; and .63 kg for hybrid and other cross cows. A centimeter decrease in height of Hereford X Angus X Galloway cross dams resulted in a decline of 3.73 kg in final weight of calf. When post calving weight was included as a constant variable, a centimeter increase in height of dam resulted in a 6.61 kg increase in final weight of calf. From these results, they concluded that the relationship of weight and height of dam with calf performance was low and fluctuating, but combining height and weight would be more consistent than either variable alone.

Brown et al. (1973b) reported genetic correlations between height and preweaning gain or final test weight, respectively, to be .77 and .76 for Herefords and −.72 ± .46 for Angus. Thus, among bulls of the same weight, genes influencing weight did not influence preweaning gain similarly for the two breeds. Genetic correlations at 8 and 12 months showed similar results with the correlations between height and preweaning gain or final weight, respectively, being 1.15 and .78 at 8 months and .71 and .99 at 12 months for Herefords and .83 and .86 at 8 months and .76 and .79 at 12 months for Angus. Their conclusions were that tall, narrow bulls at 4 and 8 months of age ate more feed, gained more weight, weighed more at 12 months and were less efficient than were short, wide bulls.

Efficiency of Gain

There is no consensus of opinion as to the relationship between body size and efficiency of feed utilization. Most studies report there is none (Brody and Proctor, 1932; Kleiber, 1936; Brody and Nesbit, 1938; Kleiber and Mead, 1941; and Guilbert and Gregory, 1944). However, a few studies have found some relationship. Black et al. (1938) reported that larger-framed cattle from dual purpose and dairy breeds were not as efficient as shorter, blockier cattle. He reported a correlation of -.367 between wither height and efficiency of gain. Despite the relatively low correlation, he felt that height with weight held nearly constant, is one of the best measures of performance. Kohli et al. (1951) also reported a correlation between wither height and efficiency of gain to be a nonsignificant -.13 for Milking Shorthorns. In beef cattle, Brungardt (1972) reported that when weights are constant, larger, faster-gaining cattle are more efficient than smaller, slower-gaining cattle and faster-gaining cattle are approximately as efficient at their heavier weights as smaller cattle at their lighter weights.

Relationship of Height to Carcass Traits

Black et al. (1938) reported that correlations between wither height and carcass traits in dual purpose and dairy breeds were all negative. They reported correlations of -.501, -.799, -.830, and -.829 between wither height and dressing percent, percent fat in carcass, percent total edible meat and slaughter grade, respectively. Thus, larger-framed steers had a lower dressing percent, less total fat, less total fat, less total meat and a lower quality grade. Yao et al. (1953) reported similar results with correlations of -.28 and -.31 between wither height and slaughter or carcass grades, respectively, for Milking Shorthorn. Kidwell (1955) reported non-significant correlations between hip height and carcass or slaughter grades of .131 and .099, respectively, and a significant positive correlation of .332 between hip height and dressing percent. Orne et al. (1959) reported non-significant correlations of .11 and -.04 between wither height and rib eye area or percent primal cuts, respectively. They also reported a significant multiple correlation of .48 between wither height and rib eye area with live weight. Busch et al. (1969) reported intra subclass correlations between wither height and closely-trimmed, edible portions of retail cuts of .60, .57, and .54 for three different groups of Hereford steers. deBaca and McInerney (1979) reported correlations of .23, .30, and -.38 between wither height and hot carcass weight, percent retail yield and marbling score, respectively. Most recently Maino et al. (1981) reported that, although not statistically significant, larger-framed steers tend to have heavier carcass weights, larger rib eye areas, less fat thickness, less kidney, heart, and pelvic fat, percent total fat, a greater percent of carcass lean, lower yield grades, and lower quality grades.

Klosterman et al. (1968) reported that with mature 3/4 Charolais and straight Hereford cows, a weight-height ratio was a reliable measure of body condition. They found a significant correlation of .89 and .51 between height-weight ratio and condition score or ultrasonic measurements of fat, respectively. In addition, deBaca and McInerney (1979) reported a correlation of .30 between hip height and actual backfat.

Finally, Lush (1938) concluded that fat thickness had no influence on either wither or hip height measurements of Hereford and Brahman cross calves.

Other Influences on Skeletal Growth

Environment

Animal breeders have known for many years that environment affects performance, but these effects are sometimes hard to measure and understand. Black and Knapp (1927) reported that growth of a beef animal takes place in two ways, through the increase of skeletal structure and development of muscular and fat tissue. Skeletal growth is the last of these growth parameters to be adversely affected by any negative influences. Therefore, there may be some question as to whether environment has an effect on skeletal growth?

Lush et al. (1930) stated that hip height, wither height, elbow length, and head length measurements increased at about a normal rate regardless of season or pasture conditions. Schmidt and VonPatow (1938) reported that unfavorable environmental conditions had little effect on various body measurements of Black Pied cattle. Furthermore, Davis et al. (1937) stated that, unlike body weight, skeletal development of dairy breeds is relatively independent of environmental influences and at maturity is essentially a constant reflecting the genotype for size of skeleton.

Brown (1958) reported that Hereford calves born in February, March, and April were heavier and taller than were calves born in other months, although this was not true for the Angus. These results suggest there may have been a difference between the two breeds used in this seasonal study in effect of seasonal factors such as climate and nutritional value of the forage on the milking ability of the cows.

Neville et al. (1978) reported that genetically similar Angus heifers showed a large difference in hip height between different locations. In a Montana-Florida genotype interaction study, reported by Butts et al. (1971), yearling Hereford heifers from Montana line were .827 in (2.1 cm) taller when they were raised in Montana than when raised in Florida. Furthermore, Hereford calves raised in Montana tended to be larger than calves raised in Florida, although these values were not significant.

Environmental influences are hard to separate from other factors such as dam effects, nutrition, climate, season, temperature, and location. This is a likely explanation for the variation between studies in the reported influences between environment and height measurements.

Nutrition

Kohli et al. (1951) found that different rations did not significantly influence wither height of Milking Shorthorn steers provided the rations met the requirements for growth. Similar results were reported when different restricted rations were fed to Israeli-Friesian cattle. There was a decrease in body weight past 500 days, with the restricted rations having a much more adverse effect on soft tissue than on skeletal growth (Levy et al., 1971).

Stuedeman et al. (1968) reported that when Hereford calves were slaughtered at 8 months of age there was a significant difference between carcass growth depending on the plane of nutrition imposed. There was a decrease in carcass length, length of leg and depth of body as the level of nutrition decreased. Bone development was reduced by the least amount followed by muscle and fat. Furthermore, in calves slaughtered at a constant body weight of 430 kg, the nutritional level imposed from birth to 8 months of age had no significant effect on final skeletal development. However, calves on the lower nutritional levels required a longer time to reach carcass weight and were less efficient than were calves fed higher nutritional levels. In addition, bone development increased after eight months with the increase in the plane of nutrition. VanDemark and Mauger (1964) reported two groups of Holstein bulls were fed from 8 weeks to 46 months of age. The restricted and control groups received 60 and 100% of the recommended digestible nutrient levels, respectively. Underfeeding greatly impaired the growth of the body, endocrine glands, and reproductive tracts, especially in the early period of growth. Wither height in the underfed group was 15% less than in the control at a year of age, 12% less at two years of age, 7% less at three years of age and 4% less at 4.8 years of age. Dori et al. (1974) also reported that Israeli-Fresian bull calves put on a restricted diet from 180 to 270 days of age did not grow at the same rate as the control group. When restricted calves were given a growing ration they grew at a constant rate from 270 days until slaughter, were approximately the same height at slaughter but reached slaughter weight at a later date than the control group. Maino et al. (1981) reported that steers wintered on forage sorghum grass vs native grass were taller, heavier, larger in the heart girth, and in the best condition.

Age of Dam and Milk Production

Brown (1958) reported that calves from two and three year old dams were consistently lighter and smaller-framed at weaning than were calves from mature cows. Maino et al. (1981) reported that at weaning, steer calves out of two year old dams were .867 in (2.2 cm) smaller in height and 26.2 kg lighter in body weight than were calves out of dams three years of age and older. Both groups of calves grew at a constant rate but calves out of two year old dams never caught up in height to the calves from older dams. Steers from older dams were 36.4 kg heavier and 1.14 in (2.9 cm) taller than steers out of two year old dams when final measurements were taken. Massey (1979) reported a significant difference for age of dam and breed group effects for calf height at weaning and he has devised adjustments factors for each at weaning. A calf height correction factor at weaning were 102 for male calves of British breeds out of dams 2 or 13 plus years of age; 101.5 for dams 3 or 12 years old; 101 for dams 4 or 11 years old; 101 for female calves out of dams 2, 3, 4, 11, 12, and 13 plus years of age. No correction factor is given for exotic breeds for height and age of dam.

Wyatt et al. (1972) reported that Angus X Hereford calves grafted on Holstein cows to receive a high level of milk tended ($P<.20$) to be taller and longer at weaning than Angus X Hereford calves receiving high levels of milk showed a greater increase in height ($P<.05$) from birth to weaning and were 2.36 in (6 cm) taller at weaning than calves on low milk levels or both native range or drylot conditions. Charolais X Holstein calves on Holstein dams showed a significantly larger increase in height from birth to weaning (35.1 cm) than Charolais X Holstein calves on Hereford dams (29 cm) or native range. In addition, there was also a similar, but non-significant, trend for Charolais X Holstein calves in a drylot.

Heritability of Linear Measurements

Heritability estimates for skeletal size measurements are presented in Table I. In general, wither height and hip height measurements are moderately to highly heritable (.56 and .44 for average reported wither and hip heights, respectively). Thus with the high heritabilities reported, breeders should be able to make improvement through selection for height measurements.

TABLE I

HERITABILITY ESTIMATES OF LINEAR HEIGHT MEASUREMENTS

Author	Breed	Kind	h^2 Wither	h^2 Hip	h^2 Other Heights
Gowen (1933)	Jersey	Cows	.52		
Schutte (1935)	X-bred	Calves	.76		
Schott (1950)	------	Steers	1.00		
Touchberry (1951)	Holstein	Cows	.73		
Buiatti (1954)	Chiana	Heifers	.69		
Dawson (1955)	Milking Shorthorn	Steers	.66		
Blackmore (1958)	Holstein	Yr Heifers	.44		
Blackmore (1958)	Holstein	2-yr heifers	.86		
Brown (1958)	Hereford	Calves	.29	.21	
Brown (1958)	Angus	Calves	.38	.22	
Udris (1961)	Red Danish	Yr Heifers	.45		
Brum (1969)	Holstein	Yr Heifers	.52		
Arapovic (1973)	------	Yr Bulls	.52		
Newman (1973)	Black Pied Cattle	Yr Bulls	.14 & .40		
Green (1977)	Angus	Bull Calves			1.03
Green (1977)	Angus	Yr Bulls			1.21
Green (1977)	Angus	Heifer Calves			.51
Green (1977)	Angus	Yr Heifers			.47
Massey (1978)	-----	Yearlings	.60	.48	
Neville (1978)	-----	Yr Heifers		.54	
Neville (1978)	-----	Yr Heifers		.75	

CHAPTER III

MATERIALS AND METHODS: STUDY I

This study utilized performance data and testicular measurements from Hereford, Polled Hereford, Angus, Brangus, and Charolais bulls on test at Oklahoma Beef, Incorporated during the period from December 19, 1979 to April 2, 1981. A total of 497 bulls in 20 different groups were placed on test and 485 bulls completed the 140-day test period. Twelve bulls were taken off test for reasons of health or unsoundness reasons. Appendix Table XXXIV presents the on and off-test dates for the 20 groups of bulls.

These bulls were approximately seven months of age when placed on test. Prior to beginning the official 140-day test, the bulls were placed on a 14-day warm up period to acclimate them to new feed and surroundings. Table II shows the ration fed to Angus, Brangus, and Charolais bulls and Table III shows the ration fed to Hereford and Polled Hereford bulls. Because two different rations were used, breed was confounded with ration in the entire study.

When bulls were placed on-test, measurements of hip height, weight, and scrotal circumference were obtained. Scrotal circumference is obtained by drawing the testicles down into the scrotum and placing a self-releasing metal tape around the widest diameter. The hip height measurement was used as the basis for classifying each bull into a frame size group. The frame size classification used was based on adjusted

TABLE II

OBI RATION FED TO ANGUS, BRANGUS, AND CHAROLAIS BULLS

Ingredient	Percent of Ration
Crimped Corn	36
Crimped Oats	30
Molasses	7
Dehydrated Alfalfa	5
Cotton Seed Hulls	10
Soybean Oil Meal	10
Mineral Mixture	2

TABLE III

OBI RATION FED TO HEREFORD AND POLLED HEREFORD BULLS

Ingredient	Percent of Ration
Crimped Corn	33.5
Crimped Oats	30.0
Cotton Sead Meal	5.0
Soybene Oil Meal	5.0
Cotton Seed Hulls	17.0
Molasses	5.0
Mineral Mixture	1.5
Alfalfa Pellets	3.0

hip height calculated as the number of days to the closest month of age multiplied by .03 in/day plus or minus the actual hip height depending on whether the actual hip height is nearer to the younger or older month of age (Hubbard, 1981). The actual classification used in this study are presented in Table IV developed from data collected on bulls at the University of Missouri (Prosser, 1978).

Bulls were weighed every 28 days throughout the 140-day test for Oklahoma Beef, Incorporated performance information. These bulls were approximately 12 to 13 months of age when they completed the test, and at that time body measurements of hip height, scrotal circumference, weight, backfat thickness, and rib eye area were obtained. Fat thickness and rib eye area were estimated with a scanogran manufactured by Ithaco Company, Ithaca, New York. Growth data, such as hip height growth rate measured in in/day, scrotal circumference growth rate measured in cm/day, and weight per day of age and average daily gain measured in lb/day were all calculated. Table V describes how each of these calculations were made.

Two measurements of hip height and scrotal circumference were taken by different people. When a large difference between the measurements were recorded, both people repeated the measurements. Repeating the measurements was done to acquire the most accurate measurement for each trait. The correlations between the measurers on a bull were .96 and .98 for hip height and scrotal circumference, respectively.

Statistical Analysis

The data in this study was analyzed by least squares procedures and several models were used. The performance and testicular traits used in

TABLE IV

HIP HEIGHT MEASUREMENT IN INCHES TO DETERMINE VARIOUS FRAME SIZES AT DIFFERENT AGES

Age in Months	Frame Size 1	Frame Size 2	Frame Size 3	Frame Size 4	Frame Size 5	Frame Size 6
6	35	37	39	41	43	45
7	36	38	40	42	44	46
8	37	39	41	43	45	47
9	38	40	42	44	46	48
10	39	41	43	45	47	49
11	40	42	44	46	48	50
12	41	43	45	47	49	51
13	41.5	43.5	45.5	47.5	49.5	51.5
14	42	44	46	48	50	52
15	42.5	44.5	46.5	48.5	50.5	52.5
16	43	45	47	49	51	53
17	43.5	45.5	47.5	49.5	51.5	53.5

TABLE V

CALCULATION OF ON-TEST AND OFF-TEST TRAITS

Traits	Calculation
ON TEST TRAITS	
Hip Height (HI)	Actual HI
Scrotal Circumference (SCI)	Actual SCI
Weight (WI)	Actual WTI
Weight/Day of Age (WTAGEI)	$\frac{\text{WTI}}{\text{Days of Age}}$
Adjusted HI	HI ± (Number of days to the closest Month X .03)
OFF TEST TRAITS	
Hip Height (HO)	Actual HO
Scrotal Circumference (SCO)	Actual SCO
Hip Height Growth/day (HG) day (HG)	$\frac{\text{HI} - \text{HO}}{\text{Days Between HI and HO}}$
Scrotal Circumference Growth/day (SCG)	$\frac{\text{SCI} - \text{SCO}}{\text{Days between SCI and SCO}}$
Weight (WTO)	Actual WTO
Weight/Day of Age (WTAGEO)	$\frac{\text{WTO}}{\text{Days of Age}}$
Average Daily Gain	$\frac{\text{WTI} - \text{WTO}}{\text{Days Between WTI and WTO}}$
Fat (FAT)	Estimated Fat
Rib Eye Area (REA)	Estimated REA

this study were analyzed by the following models.

Model I consisted of a common constant, breed of bull, test group within breed, linear effect of age in days, and residual error. This model was used for both on and off test traits and least squares means were obtained to compare differences between breed. Model II was used for each of the five breeds. This model consisted of a common constant, test group within breed, linear effect of age in days, and residual error for both on and off test traits. Pooled within class correlations from the residual mean squares and mean products were calculated to examine the relationships between traits when age is held constant. Model III was used for each of the five breeds and this model consisted of a common constant, test group within breed, body weight, and residual error for both on and off test traits. Pooled within class correlations from the residual mean squares and cross products were calculated to compare the weight constant correlations with age constant correlations from Model II. Model IV was used for each of the five breeds. This model consisted of a common constant, frame size, test group within breed, linear effect of age in days and residual error for both on and off test traits. Least squares means were obtained for performance traits and scrotal measurements for each of the respective frame scores.

CHAPTER IV

RESULTS AND DISCUSSION

This chapter is divided into two main sections comparing performance traits and testicular measurements: 1) between breeds and 2) between frame size within breed and pooled within class correlation coefficients holding age or weight constant for each breed.

Breed Comparisons

Tables VI and VII present mean squares from the analysis of variance for the various on-test and off-test traits. Breed of bull, on-test group within breed and linear effect of age were significant sources of variation for all on-test traits. Breed of bull was not a significant source of variation for hip height growth and linear effect of age was not a significant source of variation for average daily gain and fat thickness. Table VIII presents least squares means for all on-test and off-test performance and testicular traits.

Hip Height

On-test hip height was different (P<.05) between the different breeds tested (Table VIII). Charolais bulls were taller (P<.05) than Brangus bulls. On-test hip height were similar between Hereford, Polled Hereford, and Angus bulls, but less (P<.05) than Charolais and Brangus bulls. Breed ranking for off-test hip height were very similar to those

TABLE VI

MEAN SQUARES FOR PERFORMANCE TRAITS (ON TEST)

Source	df	Initial Hip Height (in)	Initial Scrotal Circumference (cm)	Initial Weight (lb)	Initial Weight/day of Age (lb)
Breed	4	54.12**	68.62**	128406.54**	3.239**
Group within Breed	14	4.98**	159.41**	26576.85**	.626**
Age linear	1	36.10**	492.98**	245680.58**	6.626**
Error	477	1.72	6.80	5492.05	.0858

*P<.05
**P<.01

TABLE VII

MEAN SQUARES FOR PERFORMANCE TRAITS AND SCROTAL MEASUREMENTS (OFF TEST)

Source	df	Final Hip Height (in)	Hip Height Growth Rate (in)	Final Scrotal Circ. (cm)	Scrotal Circ. Growth Rate (cm)	Average Daily Gain (lb)	Final Weight (lb)	Final Weight/day of age (lb)	Fat (in)	Rib eye Area (in)
Breed	4	61.78**	.000062	80.22**	.0012**	1.480**	219469.91**	1.6516**	.3111**	36.293**
Group within Breed	14	7.64**	.0005114**	8.92*	.0052**	2.732**	14657.67*	.1003*	.0296*	3.933**
Age linear	1	9.48*	.000404**	43.33**	.0118**	.0213	252917.17**	5.1533**	.0205	19.830**
Error	465	1.66	.000038	4.63	.0003	.1960	8514.10	.0564	.01437	.783

*P<.05
**P<.01

TABLE VIII

BREED LEAST SQUARES MEANS FOR PERFORMANCE TRAITS OF TESTED BULLS

	BREED				
	Hereford	Polled Hereford	Angus	Brangus	Charolais
			ON TEST PERFORMANCE DATA		
Number	119	120	141	90	27
Hip Height (in)	43.5 ± .13	43.2 ± .15^{cd}	43.1 ± .13^{d}	44.5 ± .1^{b}	45.8 ± .25^{a}
Scrotal Circumference (cm)	25.7 ± .25^{c}	25.6 ± .30^{c}	27.7 ± .25^{a}	26.6 ± .38^{b}	26.0 ± .51^{bc}
Weight (lb)	605 ± 7^{b}	562 ± 9^{c}	620 ± 7^{b}	602 ± 11^{b}	722 ± 14^{a}
Weight/day of Age (lb)	2.51 ± .03^{bc}	2.31 ± .03^{d}	2.58 ± .03^{b}	2.45 ± .04^{c}	3.11 ± .06^{a}
			OFF TEST PERFORMANCE DATA		
Number	116	118	135	90	26
Hip Height (in)	48.2 ± .13^{c}	47.6 ± .15^{d}	48.0 ± .13^{c}	49.2 ± .19^{b}	50.8 ± .26^{a}
Hip Height Growth Rate (in)	.0322 ± .0006^{a}	.0318 ± .0007^{a}	.0339 ± .0006^{a}	.0332 ± .0009^{a}	.0335 ± .0012^{a}
Scrotal Circumference (cm)	33.6 ± .21^{b}	33.1 ± .26^{b}	35.2 ± .21^{a}	35.6 ± .31^{a}	34.9 ± .43^{a}
Scrotal Circumference Growth Rate (cm)	.054 ± .002^{bc}	.054 ± .002^{bc}	.052 ± .002^{c}	.062 ± .003^{a}	.059 ± .003^{ab}
Weight (lb)	1073 ± 9^{cd}	1047 ± 11^{d}	1118 ± 9^{b}	1082 ± 13^{c}	1251 ± 18^{a}
Average Daily Gain (lb)	3.18 ± .04^{c}	3.47 ± .05^{ab}	3.45 ± .04^{ab}	3.37 ± .06^{b}	3.58 ± .09^{a}
Weight/day of Age (lb)	2.77 ± .02^{c}	2.72 + .03^{c}	2.89 ± .02^{b}	2.79 ± .03^{c}	3.27 ± .05^{a}
Fat (in)	.38 ± .01^{b}	.44 .01^{a}	.45 ± .01^{a}	.42 ± .02^{ab}	.21 ± .02^{c}
Rib Eye Area (in)	13.0 ± 09^{c}	12.5 .01^{d}	13.5 ± .09^{b}	12.6 ± .13^{d}	15.1 ± .18^{a}

^{a,b,c,d}Means in the same row that do not share at least one superscript are significantly different by LSD test ($P<.05$).

for on-test hip height with Charolais being the tallest (P<.05). Brangus bulls in turn, were taller (P<.05) than Hereford, Angus, and Polled Hereford bulls. Hip height growth rate from on-test to off-test were not different (P>.10) among breeds ranging from .0318 to .0339 in/day.

Body Weight

When placed on test, Charolais bulls were heavier (P<.05) than the other breeds, Brangus, Hereford, and Angus were all similar and Polled Hereford bulls were lighter (P<.05) than the other breeds (Table VIII). Interpretation of off-test weight and average daily gain is difficult, because Angus, Brangus, and Charolais were fed a different ration than Hereford and Polled Hereford, thus, ration is confounded with breed throughout the analyses. Charolais bulls were the heaviest (P<.05) when taken off-test followed by Angus, Brangus, Hereford, and Polled Hereford. Average daily gain were similar for Charolais, Polled Hereford, Angus, and Brangus bulls ranging from 3.58 lb/day for Charolais to 3.37 lb/day for Brangus. Hereford bulls had an average daily gain of 3.18 lb/day, which was lower (P<.05) than the other breeds.

Scrotal Circumference

On-test scrotal circumference was larger (P<.05) for Angus bulls than the other breeds (Table VIII). On-test scrotal circumference of bulls were, in descending order: 27.7, 26.6, 26.0, 25.7, and 25.6 cm for Angus, Brangus, Charolais, Hereford, and Polled Hereford, respectively. Off-test scrotal circumference of 35.6, 35.2, and 34.9 cm were similar (P<.05) for Brangus, Angus, and Charolais bulls, respectively, while Hereford and Polled Hereford bulls were smaller (P<.05) being 33.6

and 33.1, cm, respectively. These results are in agreement with Cates (1975) and Weisgold and Almquist (1979) who reported differences between various breeds with Angus bulls having larger scrotal circumference than the other breeds studied.

The scrotal circumference growth rate of Brangus bulls (.062 cm/day) was faster (P<.05) than Hereford (.054 cm/day), Polled Herefords (.054 cm/day), and Angus (.052 cm/day), but not statistically different (P>.10) than Charolais (.059 cm/day). Hereford, Polled Hereford, and Angus bulls scrotal growth rates were not different (P>.10). This may be because these breeds are earlier maturing than Brangus and Charolais bulls. This difference in scrotal growth rate between breeds may be due to: first, Brangus growth rate was the largest possibly due to the residual heterosis from crossing Brahman and Angus; secondly, Charolais are a large, later-maturing breed that mature sexually later in their growth curve; finally Hereford, Polled Hereford, and Angus bulls are smaller, earlier-maturing breeds that possibly reach sexual maturity sooner.

Fat Thickness

Off-test fat thickness estimated between the 12th and 13th rib with a scanogran were different (P<.05) between breeds (Table VIII). The fat thickness of Charolais bulls (.21 in) was less (P<.05) than that of bulls of all other breeds. Hereford bulls (.38 in) were leaner (P<.05) than Polled Hereford (.44) and Angus (.45), but not different (P>.05) than Brangus bulls (.42 in).

Rib Eye Area

Rib eye area, as estimated between the 12th and 13th rib by the scanogran, was used in this study as an indicator of muscle. Rib eye area was different ($P<.05$) between breeds (Table VIII). The rib eye area of Charolais (15.1 sq in) was greater ($P<.05$) than bulls of the other breeds. Rib eye area of Angus (13.5 sq in) was larger ($P<.05$) than Herefords (13.0 sq in) with both Angus and Hereford bulls being greater ($P<.05$) than Brangus (12.6 sq in) and Polled Herefords (12.5 sq in).

Performance Traits and Scrotal Measurements Classified by Frame Size

Frame Size Comparisons

Skeletal frame size is a classification system based on hip height at a certain age in months. The frame size chart (Table IV) ranges from one to six, with six being the tallest and each frame size is exactly two inches different from the one above and below it. In this study, hip height measurements were obtained and bulls were classified into a frame size. Data was separately analyzed for on-test and off-test frame size because some bulls changed frame size during the test period. Bulls were classified in a frame size group when they were on-test, and remained in this frame size group even though their frame size changed during the test. In addition, these same bulls were classified for frame sizes on the basis of their off-test hip height measurements and, for purposes of analysis, were considered to be in the same on-test frame size regardless of what their actual on-test frame size was.

Analysis of variance for on-test and off-test performance traits and scrotal measurements are presented in Tables IX and X. Tables XI through XV present the least squares means for each breed with bulls classified on the basis of their on-test frame size. Tables XVI through XX present the least squares means by breed with bulls classified on the basis of their off-test frame size. Pooled within class correlation coefficients for each breed holding age and weight constant when frame size was not included in Models II and III are reported in Tables XXI through XXV.

Scrotal Circumference and Scrotal Growth Rates

When bulls were classified into groups on the basis of on-test frame size, there was an increase ($P<.05$) in on-test scrotal circumference in Hereford, Angus and Brangus bulls as frame size increased. On-test frame size of Hereford bulls with frame size of 2, 3, 4, and 5 were 22.9, 25.0, 26.0, and 27.8 cm, respectively (Table XI). Angus bulls had on-test scrotal circumference of 27.0, 26.7, 28.3, and 29.4 cm for frame size 2, 3, 4, and 5, respectively (Table XIII). Brangus bulls had on-test scrotal circumference of 26.2, 28.0, 28.7, and 29.5 cm for frame size 3, 4, 5, and 6, respectively (Table XIV). Similar trends were observed in Polled Hereford and Charolais bulls, but the relationships were not statistically different ($P>.10$). The on-test scrotal circumference of Polled Hereford bulls increased from 24.4 to 25.7 cm from frame size 2 through 5 while Charolais bulls on-test scrotal circumference increased from 24.2 to 26.3 cm from frame size 4 through 6.

Similar trends were observed in off-test scrotal circumference of

TABLE IX

MEAN SQUARES FOR PERFORMANCE TRAITS AND SCROTAL MEASUREMENTS (ON TEST)

Source	df	Initial Hip Height (in)	Initial Scrotal Circumference (cm)	Initial Weight (lb)	Initial Weight/day of Age (lb)
BRANGUS					
Frame	3	43.325**	24.346*	42289.34	.5728**
Group	2	.0549	171.359**	3276.41	.0487
Age linear	1	43.635**	153.606**	191265.64**	.7263**
Error	84	.394	9.249	3660.72	.0569
HEREFORD					
Frame	3	53.457**	38.720**	122297.93**	2.029**
Group	4	.444	52.158**	34713.28**	.575**
Age linear	1	34.398	233.155	170964.95**	.007
Error	115	.242	4.456	2929.02	.0500
POLLED HEREFORDS					
Frame	4	41.222**	6.866	37674.34**	.9189**
Group	2	.188	31.760**	91455.04**	1.4069**
Age linear	1	15.217**	79.609**	29345.54**	1.9904**
Error	112	.545	6.273	3891.18	.0484
ANGUS					
Frame	4	42.293**	24.094**	61062.9**	1.1370**
Group	6	.247	101.169**	7912.20*	.1364*
Age linear	1	63.132**	373.153**	287473.46**	.0403
Error	138	.307	4.973	3026.84	.0511
CHAROLAIS					
Frame	3	8.977**	8.235	19794.13*	.370*
Group	0				
Age linear	1	6.487**	22.15*	2310.64	1.312**
Error	22	.365	4.25	5110.93	.091

*P<.05
**P<.01

TABLE X

MEAN SQUARES FOR PERFORMANCE TRAITS AND SCROTAL MEASUREMENTS (OFF TEST)

Source	df	Final Hip Height (in)	Hip Height Growth Rate (in)	Final Scrotal Circ (cm)	Scrotal Circ. Growth Rate (cm)	ADG (lb)	Final Weight (lb)	Final Weight/day of age (lb)	Fat (in)	Rib eye Area (in)
BRANGUS										
Frame	3	48.76**	.00016*	7.589	.00056	1.375**	84543.01**	.5186**	.0138	4.679**
Group	2	5.572**	.00047**	27.932**	.00364**	.528	10426.38	.0620	.0629	3.147**
Age linear	1	10.555**	.00024*	1.997	.00484**	.001	164453.96**	.7664**	.0151	9.892**
Error	83	.477	.000042	5.233	.00035	.211	6591.04	.0413	.0186	.489
HEREFORD										
Frame	3	43.765**	.00010**	7.863	.00004	.301	80545.59**	.5305**	.0082	6.047**
Group	4	.489	.00047**	1.293	.00288**	.477*	6392.96	.0416	.0109	1.204
Age linear	1	4.581**	.00049*	9.242	.00500**	.531	61882.90**	.3072**	.0291	4.981**
Error	104	.311	.000024	3.256	.00024	.171	4625.59	.0307	.0185	.577
POLLED HEREFORD										
Frame	4	34.32**	.000082	7.515	.00075*	.899**	56203.12**	.4933**	.0181	8.719**
Group	2	1.876*	.0005**	2.790	.00167**	5.530**	49851.04**	.2529**	.0060	12.634**
Age linear	1	8.204**	.000002	14.629	.0016*	1.071**	79405.97**	1.5400**	.0087	7.369**
Error	109	.562	.000042	4.498	.00027	.119	5589.93	.0330	.0138	.668
ANGUS										
Frame	3	43.980**	.0002**	13.90*	.00198	.950**	115243.25**	.807**	.0031	10.723**
Group	6	.498	.00013**	7.396	.00735**	3.832**	20006.30**	.136**	.0469*	3.045**
Age linear	1	11.672**	.00011	95.843**	.00184*	.176	235973.99**	.122	.0584	15.208**
Error	124	.360	.000031	4.841	.00030	.155	6305.03	.042	.0165	.484
CHAROLAIS										
Frame	2	5.267**	.00003	4.924	.00022	.525	17249.00	.11907	.0035	.332
Group	0									
Age linear	1	2.874*	.000006	1.359	.00066	.383	12539.27	1.208**	.00029	.1171
Error	19	.374	.00003	2.917	.00031	.311	8835.23	.064	.0061	.707

*P<.05

**P<.01

TABLE XI

HEREFORD BULLS LEAST SQUARES MEANS OF PERFORMANCE TRAITS AND SCROTAL MEASUREMENTS CLASSIFIED BY ON TEST FRAME SCORES

	2	3	4	5
		ON TEST PERFORMANCE DATA		
Number	5	43	60	16
Hip Height (in)	$40.5 \pm .23^{d}$	$42.3 \pm .08^{c}$	$44.0 \pm .07^{b}$	$45.4 \pm .13^{a}$
Scrotal Circumference (cm)	$22.9 \pm .97^{d}$	$25.0 \pm .34^{c}$	$26.0 - .29^{b}$	$27.8 \pm .55^{a}$
Weight (1h)	474 ± 25^{d}	546 ± 9^{c}	633 ± 7^{b}	696 ± 14^{a}
Weight/day of Age (lb)	$1.96 \pm .10^{d}$	$2.25 \pm .04^{c}$	$2.60 \pm .03^{b}$	$2.87 \pm .06^{a}$
		OFF TEST PERFORMANCE DATA		
Number	5	43	60	16
Hip Height (in)	$45.7 \pm .37^{d}$	$47.2 \pm .13^{c}$	$48.7 \pm .12^{b}$	$49.6 \pm .21^{a}$
Hip Height Growth Rate (in)	$.0359 \pm .002^{a}$	$.0337 \pm .001^{ab}$	$.0322 \pm .001^{ab}$	$.0288 \pm .001^{c}$
Scrotal Circumference (cm)	$31.7 \pm .78^{c}$	$33.3 \pm .28^{b}$	$33.4 \pm .25^{b}$	$35.5 \pm .46^{a}$
Scrotal Circumference Growth Rate (cm)	$.0605 \pm .007^{a}$	$.0569 \pm .003^{a}$	$.0514 \pm .003^{a}$	$.0528 \pm .004^{a}$
Average Daily Gain (lb)	$3.25 \pm .19^{a}$	$3.19 \pm .07^{a}$	$3.19 \pm .06^{a}$	$3.20 \pm .11^{a}$
Weight (lb)	950 ± 29^{d}	1012 ± 10^{c}	1094 ± 9^{b}	1160 ± 17^{a}
Weight/day of Age (lb)	$2.45 \pm .07^{d}$	$2.60 \pm .03^{c}$	$2.81 \pm .02^{b}$	$3.00 \pm .04^{a}$
Fat (in)	$.41 \pm .05^{a}$	$.37 \pm .05^{a}$	$.40 \pm .02^{a}$	$.37 \pm .03^{a}$
Rib Eye Area (in)	$12.1 \pm .37^{c}$	$12.5 \pm .12^{c}$	$13.1 \pm .10^{b}$	$13.9 \pm .19^{a}$

[a,b,c,d]Means in the same row that do not share at least one superscript are significantly different by LSD test ($P<.05$).

TABLE XII

POLLED HEREFORD BULLS LEAST SQUARES MEANS OF PERFORMANCE TRAITS AND SCROTAL MEASUREMENTS CLASSIFIED BY ON TEST FRAME SCORES

	2	3	4	5
ON TEST PERFORMANCE DATA				
Number	8	48	50	13
Hip Height (in)	41.0 ± .28[d]	42.1 ± .12[c]	43.9 ± .12[b]	45.2 ± .21[a]
Scrotal Circumference (cm)	24.4 ± .94[a]	25.3 ± .40[a]	26.1 ± .41[a]	25.7 ± .72[a]
Weight (lb)	491 ± 23[c]	535 ± 10[c]	578 ± 10[b]	630 ± 18[a]
Weight/day of Age (lb)	1.96 ± .08[d]	2.20 ± .04[c]	2.36 ± .04[b]	2.65 ± .06[a]
OFF TEST PERFORMANCE DATA				
Number	8	48	50	13
Hip Height (in)	46.0 ± .34[c]	46.6 ± .15[c]	48.0 ± .15[b]	49.5 ± .25[a]
Hip Height Growth Rate (in)	.0365 ± .002[a]	.0331 ± .001[ab]	.0299 ± .001[abc]	.0309 ± .002[c]
Scrotal Circumference (cm)	32.2 ± .81[a]	32.7 ± .36[a]	33.3 ± .36[a]	33.3 ± .61[a]
Scrotal Circumference Growth Rate (cm)	.0571 ± .007[a]	.0544 ± .003[a]	.0572 ± .003[a]	.0561 ± .005[a]
Average Daily Gain (lb)	3.19 ± .14[c]	3.30 ± .06[c]	3.58 ± .06[ab]	3.62 ± .11[a]
Weight (lb)	934 ± 25[d]	993 ± 11[c]	1074 ± 11[b]	1133 ± 19[a]
Weight/day of Age (lb)	2.43 ± .06[d]	2.61 ± .03[c]	3.01 ± .05[b]	3.29 ± .16[a]
Fat (in)	.45 ± .05[a]	.44 ± .02[a]	.45 ± .02[a]	.39 ± .04[a]
Rib Eye Area (in)	10.9 ± .31[d]	12.0 ± .14[c]	12.7 ± .14[b]	13.4 ± .24[a]

[a,b,c,d]Means in the same row that do not share at least one superscript are significantly different by LSD test (P<.05).

TABLE XIII

ANGUS BULLS LEAST SQUARES MEANS OF PERFORMANCE TRAITS AND SCROTAL MEASUREMENTS CLASSIFIED BY ON TEST FRAME SCORE

	2	3	4	5
		ON TEST PERFORMANCE DATA		
Number	7	63	69	10
Hip Height (in)	40.6 ± .22[d]	42.2 ± .08[c]	43.8 ± .07[b]	45.0 ± .19[a]
Scrotal Circumference (cm)	27.0 ± .87[bc]	26.7 ± .33[c]	28.3 ± .28[ab]	29.4 ± .76[a]
Weight (lb)	550 ± 21[c]	586 ± 8[c]	652 ± 7[b]	717 ± 19[a]
Weight/day of Age (lb)	2.28 ± .09[c]	2.45 ± .03[c]	2.72 ± .03[b]	3.02 ± .08[a]
		OFF TEST PERFORMANCE DATA		
Number	7	63	69	10
Hip Height (in)	46.1 ± .38[d]	47.5 ± .14[c]	48.4 ± .12[b]	49.5 ± .36[a]
Hip Height Growth Rate (in)	.0389 ± .002[a]	.0368 ± .001[ab]	.0322 ± .001[c]	.0305 ± .002[c]
Scrotal Circumference (cm)	33.6 ± .93[a]	34.7 ± .34[a]	35.5 ± .29[a]	36.4 ± .87[a]
Scrotal Circumference Growth Rate (cm)	.0480 ± .007[a]	.0574 ± .002[a]	.0506 ± .002[a]	.0488 ± .007[a]
Average Daily Gain (lb)	3.13 ± .17[a]	3.47 ± .06[a]	3.47 ± .05[a]	3.60 ± .16[a]
Weight (lb)	995 ± 35[d]	1080 ± 12[c]	1145 ± 11[b]	1205 ± 33[a]
Weight/day of Age (lb)	2.60 ± .09[d]	2.82 ± .03[c]	3.00 ± .03[b]	3.16 ± .08[a]
Fat (in)	.42 ± .05[ab]	.42 ± .02[b]	.48 ± .02[a]	.39 ± .05[ab]
Rib Eye Area (in)	12.5 ± .31[d]	13.2 ± .11[c]	13.7 ± .09[b]	14.4 ± .29[a]

[a,b,c,d] Means in the same row that do not share at least one superscript are significantly different by LSD Test ($P<.05$).

TABLE XIV

BRANGUS BULLS LEAST SQUARES MEANS OF PERFORMANCE TRAITS AND SCROTAL MEASUREMENTS CLASSIFIED BY ON TEST FRAME SCORES

	3	4	5	6
		ON TEST PERFORMANCE DATA		
Number	20	47	22	2
Hip Height (in)	$43.2 \pm .15^{d}$	$44.9 \pm .12^{c}$	$46.6 \pm .15^{b}$	$47.8 \pm .45^{a}$
Scrotal Circumference (cm)	$26.2 \pm .72^{c}$	$28.0 \pm .56^{b}$	$28.7 \pm .74^{ab}$	29.5 ± 2.2^{a}
Weight (lb)	587 ± 14^{d}	637 ± 6^{c}	676 ± 14^{b}	795 ± 43^{a}
Weight/day of Age (lb)	$2.17 \pm .06^{d}$	$2.36 \pm .04^{c}$	$2.49 \pm .06^{b}$	$2.95 \pm .17^{a}$
		OFF TEST PERFORMANCE DATA		
Number	20	47	22	2
Hip Height (in)	$48.0 \pm .26^{d}$	$49.4 \pm .19^{c}$	$50.8 \pm .26^{ab}$	$51.9 \pm .78^{a}$
Hip Height Growth Rate (in)	$.0344 \pm .002^{a}$	$.0319 \pm .001^{a}$	$.0303 \pm .002^{a}$	$.0295 \pm .005^{a}$
Scrotal Circumference (cm)	$34.6 \pm .59^{ac}$	$36.2 \pm .40^{ab}$	$36.3 \pm .55^{ab}$	37.8 ± 1.6^{a}
Scrotal Circumference Growth Rate (cm)	$.0602 \pm .005^{a}$	$.0580 \pm .003^{a}$	$.0543 \pm .005^{a}$	$.0595 \pm .014^{a}$
Average Daily Gain (lb)	$3.30 \pm .12^{a}$	$3.32 \pm .09^{a}$	$3.52 \pm .12^{a}$	$3.56 \pm .36^{a}$
Weight (lb)	1046 ± 20^{d}	1101 ± 15^{c}	1162 ± 21^{b}	1293 ± 62^{a}
Weight/day of Age (lb)	$2.56 \pm .05^{d}$	$2.69 \pm .04^{c}$	$2.84 \pm .05^{b}$	$3.17 \pm .15^{a}$
Fat (in)	$.44 \pm .03^{a}$	$.40 \pm .02^{a}$	$.41 \pm .03^{a}$	$.63 \pm .10^{a}$
Rib Eye Area	$12.5 \pm .18^{c}$	$12.6 \pm .14^{c}$	$13.2 \pm .18^{ab}$	$13.5 \pm .54^{a}$

[a,b,c,d]Means in the same row that do not share at least one superscript are significantly different by LSD Test ($P<.05$).

TABLE XV

CHAROLAIS BULLS LEAST SQUARES MEANS OF PERFORMANCE TRAITS AND SCROTAL MEASUREMENTS CLASSIFIED BY ON TEST FRAME SCORE

	4	5	6
ON TEST PERFORMANCE DATA			
Number	4	15	8
Hip Height (in)	$44.0 \pm .31^{c}$	$45.4 \pm .16^{b}$	$46.6 \pm .23^{a}$
Scrotal Circumference (cm)	24.2 ± 1.07^{a}	$25.1 \pm .55^{a}$	$26.3 \pm .77^{a}$
Weight (lb)	634 ± 37^{b}	692 ± 19^{b}	761 ± 27^{a}
Weight/day of Age (lb)	$2.84 \pm .16^{b}$	$3.10 \pm .08^{b}$	$3.41 \pm .11^{a}$
OFF TEST PERFORMANCE DATA			
Number	4	15	8
Hip Height (in)	$49.6 \pm .46^{b}$	$50.5 \pm .25^{ab}$	$51.2 \pm .34^{a}$
Hip Height Growth Rate (in)	$.0383 \pm .003^{a}$	$.0342 \pm .002^{a}$	$.0310 \pm .002^{a}$
Scrotal Circumference (cm)	$33.4 \pm .97^{a}$	$34.7 \pm .53^{a}$	$35.0 \pm .71^{a}$
Scrotal Circumference Growth Rate (cm)	$.0617 \pm .010^{a}$	$.0639 \pm .005^{a}$	$.0589 \pm .007^{a}$
Average daily Gain (lb)	$3.70 \pm .31^{a}$	$3.45 \pm .17^{a}$	$3.76 \pm .23^{a}$
Weight (lb)	1182 ± 47^{b}	1199 ± 26^{b}	1319 ± 35^{a}
Weight/day of Age (lb)	$3.17 \pm .12^{b}$	$3.22 \pm .07^{b}$	$3.55 \pm .09^{a}$
Fat (in)	$.21 \pm .04^{a}$	$.18 \pm .02^{a}$	$.25 \pm .03^{a}$
Rib Eye Area (in)	$14.8 \pm .42^{a}$	$14.8 \pm .25^{a}$	$15.4 \pm .30^{a}$

^{a,b,c}Means in the same row that do not share at least one superscript are significantly different by LSD test (P<.05).

TABLE XVI

HEREFORD BULLS LEAST SQUARES MEANS OF PERFORMANCE TRAITS AND SCROTAL MEASUREMENTS CLASSIFIED BY OFF TEST FRAME SCORE

	2	3	4	5
		ON TEST PERFORMANCE DATA		
Number	4	30	51	26
Hip Height (in)	$40.8 \pm .42^{d}$	$42.3 \pm .17^{c}$	$43.8 \pm .13^{b}$	$44.8 \pm .19^{a}$
Scrotal Circumference (cm)	25.6 ± 1.11^{a}	$25.1 \pm .46^{a}$	$25.8 \pm .34^{a}$	$26.5 \pm .49^{a}$
Weight (lb)	499 ± 31^{c}	556 ± 13^{c}	613 ± 9^{b}	657 ± 13^{a}
Weight/day of Age (lb)	$2.08 \pm .13^{c}$	$2.29 \pm .13^{c}$	$2.51 \pm .04^{b}$	$2.71 \pm .06^{a}$
		OFF TEST PERFORMANCE DATA		
Number	4	30	51	26
Hip Height (in)	$45.0 \pm .26^{d}$	$46.8 \pm .11^{c}$	$48.4 \pm .08^{b}$	$49.9 \pm .12^{a}$
Hip Height Growth Rate (in)	$.0292 \pm .002^{b}$	$.0310 \pm .001^{b}$	$.0315 \pm .001^{b}$	$.0351 \pm .001^{a}$
Scrotal Circumference (cm)	$32.8 \pm .86^{a}$	$32.9 \pm .35^{a}$	$33.8 \pm .26^{a}$	$34.3 \pm .38^{a}$
Scrotal Circumference Growth Rate (cm)	$.0483 \pm .007^{a}$	$.0536 \pm .003^{a}$	$.0540 \pm .002^{a}$	$.0536 \pm .003^{a}$
Average Daily Gain (lb)	$2.90 \pm .20^{a}$	$3.12 \pm .08^{a}$	$3.18 \pm .06^{a}$	$3.33 \pm .09^{a}$
Weight (lb)	927 ± 32^{d}	1013 ± 13^{c}	1079 ± 10^{b}	1145 ± 14^{a}
Weight/day of Age (lb)	$2.39 \pm .08^{d}$	$2.61 \pm .03^{c}$	$2.77 \pm .03^{b}$	$2.95 \pm .04^{a}$
Fat (in)	$.31 \pm .05^{a}$	$.39 \pm .02^{a}$	$.39 \pm .02^{a}$	$.39 \pm .02^{a}$
Rib Eye Area (in)	$12.1 \pm .40^{c}$	$12.5 \pm .15^{c}$	$13.0 \pm .11^{b}$	$13.70 \pm .16^{a}$

^{a,b,c,d}Means in the same row that do not share at least one superscript are significantly different by LSD Test (P<.05).

TABLE XVII

POLLED HEREFORD BULLS LEAST SQUARES MEANS OF PERFORMANCE TRAITS AND SCROTAL MEASUREMENTS CLASSIFIED BY OFF TEST FRAME SCORE

	3	4	5
ON TEST PERFORMANCE DATA			
Number	44	58	13
Hip Height	42.3 ± .17^{c}	43.9 ± .17^{b}	44.9 ± .32^{a}
Scrotal Circumference (cm)	25.1 ± .40^{a}	26.3 ± .40^{a}	25.0 ± .76^{a}
Weight (lb)	540 ± 10^{c}	578 ± 11^{ab}	598 ± 20^{a}
Weight/day of Age (lb)	2.21 ± .04^{c}	2.38 ± .04^{ab}	2.47 ± .07^{a}
OFF TEST PERFORMANCE DATA			
Number	44	58	13
Hip Height (in)	46.5 ± 12^{c}	48.3 ± .12^{b}	49.8 ± .23^{a}
Hip Height Growth Rate (in)	.0310 ± 001^{a}	.0318 ± .001^{a}	.0358 ± .002^{a}
Scrotal Circumference (cm)	32.5 ± 34^{a}	33.4 ± .35^{a}	33.5 ± .65^{a}
Scrotal Circumference Growth Rate (cm)	.0545 ± 003^{a}	.0521 ± .003^{a}	.0630 ± .005^{a}
Average Daily Gain (lb)	3.28 ± 06^{b}	3.58 ± .06^{a}	3.75 ± .11^{a}
Weight (lb)	999 ± 2^{b}	1077 ± 12^{a}	1117 ± 23^{a}
Weight/days of Age (lb)	2.63 ± .03^{b}	2.84 ± .03^{a}	2.95 ± .06^{a}
Fat (in)	.45 ± .02^{a}	.44 ± .02^{a}	.37 ± .04^{a}
Rib Eye Area (in)	11.9 ± .13^{c}	12.8 ± .13^{c}	13.5 ± .26^{a}

^{a,b,c}Means in the same row that do not share at least one superscript are significantly different by LSD test ($P<.05$).

TABLE XVIII

ANGUS BULLS LEAST SQUARES MEANS OF PERFORMANCE TRAITS AND SCROTAL MEASUREMENTS CLASSIFIED BY OFF TEST FRAME SCORES

	3	4	5
ON TEST PERFORMANCE DATA			
Number	32	83	19
Hip Height (in)	42.2 ± .17[c]	43.3 ± .12[b]	44.4 ± .40[a]
Scrotal Circumference (cm)	27.0 ± .42[b]	27.4 ± .29[b]	29.6 ± .56[a]
Weight (lb)	593 ± 11[c]	621 ± 8[b]	697 ± 14[a]
Weight/day of Age (lb)	2.46 ± .05[c]	2.59 ± .03[b]	2.91 ± .06[a]
OFF TEST PERFORMANCE DATA			
Number	32	83	19
Hip Height (in)	46.5 ± .11[c]	48.3 ± .07[b]	49.7 ± .14[a]
Hip Height Growth Rate (in)	.0303 ± .001[b]	.0351 ± .001[a]	.0368 ± .001[a]
Scrotal Circumferenc Circumference (cm)	34.5 ± .41[a]	35.1 ± .28[a]	36.4 ± .52[a]
Scrotal Circumference Growth Rate (cm)	.0528 ± .003[a]	.0540 ± .002[a]	.0488 ± .004[a]
Average Daily Gain (lb)	3.24 ± .07[c]	3.51 ± .05[ab]	3.64 ± .09[a]
Weight (lb)	1054 ± 15[c]	1118 ± 10[b]	1218 ± 19[a]
Weight/day of Age (lb)	2.76 ± .04[c]	2.93 ± .03[b]	3.19 ± .05[a]
Fat (in)	.45 ± .02[a]	.45 ± .02[a]	.45 ± .03[a]
Rib Eye Area (in)	12.9 ± .13[c]	13.5 ± .09[b]	14.4 ± .17[a]

[a,b,c]Means in the same row that do not share at least one superscript are significantly different by LSD test (P<.05).

TABLE XIX

BRANGUS BULLS LEAST SQUARES MEANS OF PERFORMANCE TRAITS AND SCROTAL MEASUREMENTS CLASSIFIED BY OFF TEST FRAME SCORE

	3	4	5	6
ON TEST PERFORMANCE DATA				
Number	17	50	21	2
Hip Height (in)	$43.5 \pm .25^{d}$	$44.8 \pm .16^{c}$	$46.3 \pm .24^{ab}$	$47.0 \pm .70^{a}$
Scrotal Circumference (cm)	$27.5 \pm .80^{a}$	$27.2 \pm .54^{a}$	$29.2 \pm .54^{a}$	26.3 ± 2.29^{a}
Weight (lb)	626 ± 17^{ac}	618 ± 11^{ac}	678 ± 16^{ab}	686 ± 49^{a}
Weight/day of Age (lb)	$2.30 \pm .07^{ac}$	$2.28 \pm .04^{ac}$	$2.51 \pm .06^{ab}$	$2.55 \pm .19^{a}$
OFF TEST PERFORMANCE DATA				
Number	17	50	21	2
Hip Height (in)	$47.4 \pm .18^{d}$	$49.3 \pm .11^{c}$	$51.2 \pm .17^{b}$	$52.2 \pm .51^{a}$
Hip Height Growth Rate (in)	$.0282 \pm .002^{ac}$	$.0324 \pm .001^{ab}$	$.0350 \pm .002^{ab}$	$.0380 \pm .005^{a}$
Scrotal Circumference (cm)	$35.0 \pm .60^{a}$	$35.8 \pm .39^{a}$	$36.6 \pm .56^{a}$	35.5 ± 1.70^{a}
Scrotal Circumference Growth Rate (cm)	$.0537 \pm .005^{a}$	$.0613 \pm .003^{a}$	$.0522 \pm .005^{a}$	$.0660 \pm .014^{a}$
Average Daily Gain (lb)	$3.14 \pm .08^{ac}$	$3.31 \pm .08^{ac}$	$3.72 \pm .11^{ab}$	$3.93 \pm .34^{a}$
Weight (lb)	1066 ± 21^{c}	1080 ± 14^{c}	1197 ± 20^{ab}	1231 ± 60^{a}
Weight/day of Age (lb)	$2.61 \pm .05^{c}$	$2.64 \pm .03^{c}$	$2.93 \pm .05^{ab}$	$3.05 \pm .15^{a}$
Fat (in)	$.44 \pm .04^{a}$	$.40 \pm .02^{a}$	$.45 \pm .03^{a}$	$.45 \pm .10^{a}$
Rib Eye Area	$12.6 \pm .18^{c}$	$12.6 \pm .12^{c}$	$13.4 \pm .17^{ab}$	$14.3 \pm .52^{a}$

[a,b,c,d] Means in the same row that do not share at least one superscript are significantly different by LSD test ($P<.05$).

TABLE XX

CHAROLAIS BULLS LEAST SQUARES MEANS OF PERFORMANCE TRAITS AND SCROTAL MEASUREMENTS CLASSIFIED BY OFF TEST FRAME SCORE

	4	5	6
	ON TEST PERFORMANCE DATA		
Number	3	14	7
Hip Height (in)	44.2 ± .68[b]	45.5 ± .25[ab]	46.0 ± .35[a]
Scrotal Circumference (cm)	24.8 ± 1.55[a]	25.6 ± .58[a]	25.2 ± .82[a]
Weight (lb)	705 ± 60[a]	705 ± 22[a]	701 ± 22[a]
Weight/day of Age (lb)	3.11 ± .26[a]	3.15 ± .10[a]	3.12 ± .14[a]
	OFF TEST PERFORMANCE DATA		
Number	3	14	7
Hip Height (in)	48.8 ± .45[c]	50.3 ± .17[b]	51.6 ± .24[a]
Hip Height Growth Rate (in)	.0309 ± .004[a]	.0324 ± .002[a]	.0374 ± .002[a]
Scrotal Circumference (cm)	34.4 ± 1.23[a]	33.9 ± .46[b]	35.9 ± .64[a]
Scrotal Circumference growth rate (cm)	.0647 ± .013[a]	.0561 ± .005[a]	.0721 ± .007[a]
Average Daily Gain (lb)	3.71 ± .39[a]	3.37 ± .15[a]	3.96 ± .21[a]
Weight (lb)	1253 ± 71[a]	1204 ± 26[a]	1287 ± 37[a]
Weight/day of Age (lb)	3.35 ± .19[a]	3.24 ± .07[a]	3.45 ± .10[a]
Fat (in)	.20 ± .05[a]	.20 ± .02[a]	.23 ± .03[a]
Rib Eye Area (in)	15.1 ± .60[a]	14.9 ± .23[a]	15.3 ± .35[a]

[a,b,c]Means in the same row that do not share at least one superscript are significantly different by LSD test ($P<.05$).

TABLE XXI

POOLED WITHIN CLASS CORRELATION COEFFICIENTS[a] IN HEREFORD BULLS

Traits	1	2	3	4	5	6	7	8	9	10	11	12	13
Initial Hip Height (1)	1.00	.43	.76	.75	.82	-.31	.24	-.26	0	.68	.68	.07	.59
Initial Scrotal Circumference (2)	-.04	1.00	.60	.60	.24	-.34	.47	-.68	-.24	.37	.37	.05	.28
Initial Weight (3)			1.00	1.00	.57	-.33	.24	-.45	.27	.69	.69	.03	.62
Initial Weight/ day of Age (4)	-.05	-.33		1.00	.57	-.32	.23	-.45	-.26	.70	.70	.04	.62
Final Hip Height (5)	.61	-.06	.12	.16	1.00	.29	.25	-.04	.26	.71	.71	.10	.57
Hip Height Growth (6)	-.50	-.48	-.55	-.27	.38	1.00	0	.36	.43	.02	.03	.05	-.04
Final Scrotal Circumference (7)	.04	.39	.04	-.01	.02	-.04	1.00	.33	.14	.32	.34	.07	.08
Scrotal Circumference Growth (8)	-.32	-.74	-.57	-.31	.09	.47	.34	1.00	.34	-.13	-.14	0	-.25
Average Daily Gain (9)	-.59	-.59	-1.0	-.75	-.12	.55	-.05	.56	1.00	.50	.50	.36	.23
Final Weight (10)										1.00	1.00	.30	.73
Final Weight/day of Age (11)	-.28	-.42	-.33	.36	.08	.41	-.08	.37	.34		1.00	.30	.73
Final Fat (12)	-.17	-.05	-.22	-.25	-.17	.01	-.02	.01	.22		-.06	1.00	-.09
Final Rib Eye Area (13)	.19	.05	.23	.20	.11	-.10	-.24	-.23	-.23		-.05	-.46	1.00
Age (14)	.27	.43	.33	-.35	-.08	-.39	.07	-.38	-.34		-1.00	.07	.06

[a]Correlations on the right of the diagonal are age constant and correlations on the left of the diagonal are weight constant.

$|r| > .19$, $P < .05$; $|r| > .23$, $P < .01$

TABLE XXII

POOLED WITHIN CLASS CORRELATION COEFFICIENTS[a] IN POLLED HEREFORD BULLS

Traits	1	2	3	4	5	6	7	8	9	10	11	12	13
Initial Hip Height (1)	1.00	.39	.67	.63	.80	-.38	.38	-.07	.36	.75	.71	.03	.60
Initial Scrotal Circumference (2)	-.10	1.00	.66	.54	.25	-.22	.54	-.59	.02	.52	.42	.24	.37
Initial Weight (3)			1.00	.93	.47	-.37	.37	-.36	.01	.81	.74	.24	.57
Initial Weight/day of Age (4)	.02	-.38		1.00	.47	-.28	.33	-.26	.02	.76	.79	.18	.56
Final Hip Height (5)	.64	-.12	-.06	.07	1.00	.25	.33	.04	.42	.62	.62	-.14	.63
Hip Height Growth (6)	-.31	-.09	-.27	-.14	.53	1.00	-.07	.18	.06	-.24	-.19	-.26	.01
Final Scrotal Circumference (7)	.11	.43	.11	0	.12	.03	1.00	.35	.15	.38	.35	.15	.37
Scrotal Circumference Growth (8)	.16	-.60	-.30	.05	.23	.12	.46	1.00	.12	-.21	-.13	-.12	-.05
Average Daily Gain (9)	-.17	-.40	-1.0	-.58	.07	.27	-.10	.29	1.00	.60	.62	.06	.55
Final Weight (10)										1.00	.96	.23	.77
Final Weight/day of Age (11)	.14	-.33	.04	.82	.11	0	-.07	.26	-.0		1.00	.18	.77
Final Fat (12)	-.23	.15	.09	-.03	-.37	-.21	.07	-.08	-.09		-.08	1.00	-.03
Final Rib Eye Area (13)	.04	-.07	-.17	-.04	.30	.33	.13	.19	.18		.05	-.33	1.00
Age (14)	-.16	.23	-.11	-.78	-.08	.07	.05	-.18	.10		-.95	.04	0

[a]Correlations on the right of the diagonal are age constant and correlations on the left of the diagonal are weight constant.
$|r|>.17$, $P<.05$; $|r|>.23$, $P<.01$

TABLE XXIII

POOLED WITHIN CLASS CORRELATION COEFFICIENTS[a] IN ANGUS BULLS

Trait	1	2	3	4	5	6	7	8	9	10	11	12	13
Initial Hip Height (1)	1.00	.32	.67	.69	.75	-.35	.29	-.08	.25	.60	.60	.15	.57
Initial Scrotal Circumference (2)	0	1.00	.47	.46	.27	-.12	.46	-.57	.07	.38	.39	.24	.36
Initial Weight (3)			1.00	.99	.48	-.26	.30	-.21	.13	.77	.77	.39	.62
Initial Weight/day of Age (4)	.06	-.35		1.00	.49	-.26	.34	.16	.11	.78	.78	.37	.64
Final Hip Height (5)	.60	0	0	.08	1.00	.34	.28	-.01	.40	.59	.59	.07	.57
Hip Height Growth (6)	-.41	-.15	-.38	-.18	.46	1.00	-.05	.08	.21	-.05	-.05	-.12	-.03
Final Scrotal Circumference (7)	0	.37	-.05	-.15	0	-.05	1.00	.47	.36	.47	.47	.13	.38
Scrotal Circumference Growth (8)	-.16	-.66	-.43	-.12	0	.11	.44	1.00	.28	.05	.06	-.11	0
Average Daily Gain (9)	-.28	-.37	-.90	-.56	0	.37	0	.38	1.00	.70	.69	.16	.50
Final Weight (10)										1.00	1.00	.37	.77
Final Weight/day of Age (11)	-.07	-.37	-.29	.62	.06	.14	-.16	.22	.27		1.00	.37	.77
Final Fat (12)	-.10	.10	.18	.10	-.20	-.11	-.05	-.14	-.15		0	1.00	0
Final Rib Eye Area (13)	.23	.13	.10	0	.23	0	.06	-.08	-.09		-.05	-.47	1.00
Age (14	.08	.38	.28	-.62	-.05	-.15	.18	-.21	-.27		-.99	0	.07

[a]Correlations on the right of the diagonal are age constant and correlations on the left of the diagonal are weight constant.
$|r|>.18$, $P<.05$; $|r|>.21$, $P<.01$

TABLE XXIV

POOLED WITHIN CLASS CORRELATION COEFFICIENTS[a] IN BRANGUS BULLS

Traits	1	2	3	4	5	6	7	8	9	10	11	12	13
Initial Hip Height (1)	1.00	.35	.53	.52	.79	-.21	.31	-.15	21	.52	.51	0	.35
Initial Scrotal Circumference (2)	0	1.00	.65	.63	.14	-.29	.60	-.69	0	.49	.49	.10	.26
Initial Weight (3)			1.00	.98	.27	-.33	.38	-.48	0	.71	.71	0	.53
Initial Weight/day of Age (4)	0	0		1.00	.30	-.26	.35	-.48	0	.72	.74	0	.55
Final Hip Height (5)	.70	-.13	-.13	0	1.00	.43	.23	0	.40	.48	.49	0	.37
Hip Height Growth (6)	-.27	-.36	-.52	0	.49	1.00	-.10	.27	.33	0	0	0	.08
Final Scrotal Circumference (7)	.11	.47	.08	.13	.05	-.07	1.00	.16	.20	.41	.40	.06	.23
Scrotal Circumference Growth (8)	-.08	-.70	-.51	-.11	.18	.33	.30	1.00	.15	-.24	24	-.07	-.11
Average Daily Gain (9)	-.27	-.53	-1.00	-.37	.13	.51	-.08	.51	1.00	.69	.67	.22	.46
Final Weight (10)										1.00	.99	.17	.70
Final Weight/day of Age (11)	-.16	-.20	-.37	.73	.07	.30	.08	.28	.36		1.00	.16	.72
Final Fat (12)	-.13	0	-.20	0	-.10	0	0	0	.20	.16	.16	1.00	-.21
Final Rib Eye Area (13)	-.15	-.12	.09	0	0	.08	-.10	0	-.08		-.07	-.47	1.00
Age (14)	-.16	.19	.39	-.70	-.06	-.27	-.10	-.29	-.38		-.99	-.17	.10

[a]Correlations on the right of the diagonal are age constant and correlations on the left of the diagonal are weight constant.
$|r|>.20$, $P<.05$; $|r|>.26$, $P<.01$

TABLE XXV

POOLED WITHIN CLASS CORRELATION COEFFICIENTS[a] IN CHAROLAIS BULLS

Traits	1	2	3	4	5	6	7	8	9	10	11	12	13
Initial Hip Height (1)	1.00	.56	.73	.73	.67	-.55	.13	-.30	-.10	.50	.51	.20	.22
Initial Scrotal Circumference (2)	.25	1.00	.71	.72	.39	-.22	0	-.73	-.26	.28	.26	-.11	0
Initial Weight (3)			1.00	1.00	.31	-.60	.13	-.39	-.29	.56	.53	0	.41
Initial Weight/day of Age (4)	-.32	-.47		1.00	.33	-.60	.11	-.42	-.29	.55	.53	0	.41
Final Hip Height (5)	.63	.40	.16	-.10	1.00	.25	.12	-.22	.17	.40	.41	.21	.20
Hip Height Growth (6)	-.53	-.21	-.61	-.38	.31	1.00	-.03	.15	.32	.21	-.21	0	0
Final Scrotal Circumference (7)	-.11	-.10	-.10	0	-.08	0	1.00	.64	.27	.34	.33	.24	.10
Scrotal Circumference Growth (8)	-.46	-.80	-.51	-.12	-.34	.19	.68	1.00	.39	.12	0	.25	0
Average Daily Gain (9)	-.63	-.60	-1.00	-.66	-.16	.60	.10	.50	1.00	.63	.66	.52	.42
Final Weight (10)										1.00	1.00	.53	.70
Final Weight/day of Age (11)	-.36	-.40	-.21	.60	-.30	.12	.18	.40	.21		1.00	.54	.69
Final Fat (12)	0	-.22	-.25	-.36	0	.09	0	.18	.25		-.17	1.00	.24
Final Rib Eye Area (13)	0	0	.10	-.21	0	0	-.26	-.12	-.10		-.40	-.13	1.00
Age (14)	.37	.38	.17	-.63	.32	-.11	-.19	-.39	-.17		.19	.38	-.99

[a]Correlations on the right of the diagonal areaage constant and correlations on the left of the diagonal are weight constant.
$|r|>.39$, $P<.05$; $|r|>.53$, $P<.01$

bulls based on their on-test frame size classification. Again, Hereford and Brangus bulls showed an increase ($P<.05$) in off-test scrotal circumference as frame size increased. The scrotal circumference of Hereford bulls was 31.7, 33.3, 33.4, and 35.5 cm for frame size 2, 3, 4, and 5, respectively (Table XVI). Brangus bulls had off-test scrotal circumferences of 34.6, 36.2, 36.3, and 37.8 for frame size 3, 4, 5, and 6, respectively (Table XIX). Angus, Polled Hereford, and Charolais bulls showed a similar trend in scrotal circumference as frame size increased, although, these relationships were not different ($P>.10$).

Scrotal circumference growth rates were very similar ($P>.10$) for bulls classified into groups on the basis of their on-test frame size for all breeds. No basic trends were observed between the different frame sizes (Tables XI through XV). In addition, no differences ($P>.10$) were observed between scrotal circumference growth for bulls of different off-test frame size classifications (Tables XVI through XX). Pooled within class correlation coefficients between on-test or off-test height and scrotal circumference growth rate were not significant ($P>.05$) and these relationships tended to be zero or slightly negative (Tables XXI through XXV). Thus, 7 and 12 month hip height measurements have little relationship to scrotal circumference growth rate for this period of growth in young beef bulls.

When bulls were classified into frame size groups on the basis of their off-test frame size differences between scrotal circumference and frame size were generally not observed. Angus bulls did show a difference ($P<.05$) for on-test scrotal circumference between frame size 4 and 5 with an increase of 27.0 to 29.6 cm (Table XVIII). No significant differences ($P>.05$) were observed between off-test scrotal circumference and frame size on Angus bulls, but a similar trend was noticed. Hereford bulls off-test scrotal circumference showed an increasing trend (P<.07) of 32.8 to 34.3 cm as frame size increased from 2 to 5 (Table XVI). Polled Hereford, Brangus, and Charolais bulls showed little difference (P>.10) between on-test and off-test scrotal circumference as frame size increased (Tables XVII, XIX, and XX). Thus, when bulls finished the 140-day test at approximately 12 months of age, there was little basic relationship between frame size and either on-test or off-test scrotal circumference. However, when classified into groups on the basis of on-test frame size there was a tendency for larger-framed bulls to have larger on-test and off-test scrotal circumferences. Pooled within class correlation coefficients of .43, .49, .32, .35, and .56 between on-test hip height and on-test scrotal circumference and correlations of .25, .33, .28, .23, and .12 between off-test hip height and off-test scrotal circumference were observed for Hereford, Polled Hereford, Angus, Brangus, and Charolais bulls, respectively (Tables XXI through XXV).

A seven-months hip height measurement was more closely related to scrotal circumference than a 12-months hip height. When pooled within class correlations were calculated with weight in the model, the correlations between on-test or off-test hip height and on-test or off-test scrotal circumference were zero for all breeds. This indicates that weight, and not height, is responsible for the relationship between hip height and scrotal circumference.

Pooled within class correlation coefficients between on-test scrotal circumference and on-test weight were .60, .66, .47, .65, and .71 for Hereford, Polled Hereford, Angus, Brangus, and Charolais bulls, respectively. In addition, correlations between off-test scrotal circumference and off-test weight were .32, .38, .47, .41, and .34 for Hereford, Polled Hereford, Angus, Brangus, and Charolais, respectively. These correlations are in agreement with age held constant correlations reported by Willet and Ohms (1957), Coulter and Foote (1977a) and Coulter (1978). These results show there is a higher relationship between scrotal circumference and weight at seven months of age than at twelve months of age.

Pooled within class correlations between on-test scrotal circumference and scrotal circumference growth rate were highly negative (Table XXI through XXV), suggesting that bulls with larger scrotal circumference at seven months of age had slower scrotal growth until 12 months of age. Hereford, Polled Hereford, Angus, Brangus and Charolais bulls had pooled within class correlations between off-test scrotal circumference and scrotal circumference growth rate of .33, .38, .47, .41, and .34, respectively. This would suggest that a 12-month of age measurement of scrotal circumference is a better indicator of scrotal growth than a seven-month measurement.

Body Weight and Performance Traits

The initial on-test weight of the bulls of all breeds involved in this study, showed a significant increase ($P<.05$) as frame size increased when the on-test frame size was in the model (Table XI through XV). Hereford, Polled Hereford, and Angus bulls showed an increase in on-test weight of 222, 139, and 167 lb, respectively, as frame size increased from 2 to 5. Brangus bulls showed a similar increase of 208 lb as frame size increased from 3 to 6 and Charolais bulls increased 127 lb as frame size increased from 4 to 6. Pooled within class correlation coefficients between on-test hip height and on-test weight were .76, .67, .67, .53, and .73 for Hereford, Polled Hereford, Angus, Brangus, and Charolais bulls, respectively. These results are in agreement with correlations between hip height and initial weight of .78 and .70 reported by Lush (1932) and Brungart (1979), respectively.

Hereford, Polled Hereford, Angus, and Brangus bulls showed an increase ($P<.05$) in off-test weight as frame size increased when bulls were classified by their off-test frame size, but there was no significant difference ($P>.10$) in Charolais bulls (Tables XVI through XX). There were increases of 118 and 164 lb in Polled Hereford and Angus bulls, respectively, as frame size increased from 3 to 5. Hereford bulls showed an increase of 218 lb as frame size increased from 2 to 5 and Brangus bulls increased 165 lb from frame sizes 3 to 6. Charolais bulls showed only a small increase in weight as frame size increased. This breed difference may be due to small numbers within each frame size and the large variation in weight noticed between the Charolais bulls. Pooled within class correlation coefficients between off-test hip height and off-test weight were .71, .63, .59, .48, and .40 for Hereford, Polled Hereford, Angus, Brangus, and Charolais bulls, respectively. This shows there is still a strong relationship between height and weight at 12 months of age. These results are slightly lower than off-test correlations reported by Lush (1932), Kidwell (1955) and Brungart (1979).

Pooled within class correlation coefficients between on-test hip height and average daily gain for Hereford, Polled Hereford, Angus, Brangus, and Charolais bulls were .00, .36, .25, .21, and -.10, respectively, and between off-test hip height and average daily gain were .26, .42, .40, .40, and .17, respectively. These results suggest that correlations between hip height and average daily gain were low to moderate at seven and 12 months of age, with a 12-month hip height showing the strongest relationship to average daily gain. These results are in agreement with Flock et al. (1967) who reported correlations between wither height and average daily gain of .25, .33, and .04 for Hereford, Angus, and Shorthorn, respectively.

When Hereford, Angus, Brangus, and Charolais bulls were classified into groups on the basis of on-test frame size there was no difference ($P>.05$) in average daily gain as on-test frame size increased. Although not significant, Angus and Brangus bulls did show an increasing trend in average daily gain as frame size increased. Polled Herefords showed an increase ($P<.05$) in average daily gain from 3.28 to 3.75 lb/day from frame size 3 to 5. However, when bulls were classified into groups by their off-test frame size, average daily gain increased ($P<.05$) as frame size increased for Polled Hereford, Angus, and Brangus bulls, but not for Hereford and Charolais bulls. Thus, a 12- to 13-month measurement of frame size appears to be a better indicator of true average daily gain than measurements made at 7 to 8 months of age. Hereford and Charolais bulls possibly would have shown a difference in average daily gain to frame size if these bulls had been taken to a later end point, because the smaller-framed bulls would be physiologically older and they would slow down in their growth curve earlier, thus gaining less weight. Finally, pooled within class correlation coefficients between hip height growth and average daily gain with weight held constant in the model were .55, .27, .37, .51, and .60 for Hereford, Polled Hereford, Angus, Brangus and Charolais bulls, respectively. Thus, bulls that exhibited rapid skeletal growth gained more weight during the 140-day test period.

Hip Height Growth Rate

Hip height growth rate was similar (P>.10) in all breeds from approximately 7 to 12 months of age (.0328 in/day). This value is very similar to growth rates reported by Guilbert and Gregory (1955), Brown et al. (1973), Healey (1979), Massey (1979), and Maino (1981).

When bulls were classified into groups on the basis of off-test frame size, all breeds showed an increase in hip height growth rate as frame size increased, but the differences were not significant (P>.05) in Polled Hereford and Charolais bulls (Tables XVI through XX). Hereford bulls showed a difference (P<.05) in hip height growth of .0315 and .0351 in/day between frame size 4 and 5. Angus and Brangus bulls hip height growth rate of .0303 to .0351 and .0282 to .0340 in/day, respectively, between frame size 3 and 4 were different (P<.05). These results show when bulls are classified by a 12-month frame size, larger-framed bulls tended to grow faster from 7 to 12 months of age. This may indicate that bulls that are taller at 12 months of age may be slightly later-maturing than smaller-framed bulls within a breed.

When bulls were classified into groups on the basis of on-test frame size, there was a constant decline in hip height growth as frame size increased. There was a decrease (P<.05) in hip height growth as frame size increased in Hereford, Polled Hereford, and Angus bulls, but the differences were not significant (P>.05) in Brangus and Charolais bulls (Tables XI through XV). Thus, larger-framed bulls that went on-test grew slower than did smaller bulls until approximately 12 months of age.

Pooled within class correlation coefficients of Hereford, Polled Hereford, Angus, Brangus, and Charolais bulls between on-test hip height, and hip height growth rate were -.31, -.38, -.35, -.21, and -.55, respectively, and between off-test hip height and hip height growth rate were .29, .25, .34, .43, and .25, respectively (Tables XXI through XXV). This conflict on hip height growth rate between bulls classified by on-test and off-test frame size may possibly be explained by three points. First, and probably the most important reason, is these bulls went on test in varying degrees of condition and there was no way to measure preweaning effect of the dam, environmental conditions, and management of each bull. Thus, bull calves that were on a higher plane of nutrition possibly were larger in their skeletal frame due to the additive preweaning influences when they started the test period, but they did not grow as rapidly as smaller-framed calves in lesser body condition. This is in agreement with Wyatt et al. (1972) who reported that Hereford X Angus calves grafted on Holstein cows were taller and longer than similar calves grafted on Hereford cows. Secondly, these calves' physiological ages were different, thus, some bulls were earlier-maturing than others. Finally, there is no means of confirming the true chronological age of these bulls. These results show that a 12- to 13-month measurement of frame size is a better indicator of hip height growth since it is more closely related to the bulls' true growth because maternal preweaning influences should not have as drastic effect on frame size. Although, differences ($P<.05$) were noticed between hip height growth rate and frame size, practical differences were not large enough to change the adjustment factor of .03 in/day for hip height under 12 months of age reported by Hubbard (1981) in Beef Improvement Federation Guidelines.

Fat Thickness

There were no significant differences (P>.05) in fat thickness as frame size increased in any breed. Pooled within class correlations between fat thickness and all traits measured were generally low and not significant. The only correlation that was significant (P<.05) was between fat thickness and off-test weight with values of .30, .20, .37, .17, and .53 for Hereford, Polled Hereford, Angus, Brangus, and Charolais bulls, respectively (Tables XXI through XXV). These results do not agree with Black et al., (1938), Klosterman et al. (1967), deBaca and McInerney (1979), and Maino et al. (1981) where they reported positive correlations between height and fat on steers of different ages. All bulls in this study were fed a high energy ration and they were of a fairly constant age, therefore, no difference in fat would be anticipated for frame size. If all bulls were fed to a constant end point (weight), then differences in fat as related to hip height (physiological maturity) would be more likely to be expressed.

Rib Eye Area

When bulls were classified by on-test and off-test frame size, rib eye area increased (P<.05) as frame size increased in Hereford, Polled Hereford, Angus, and Brangus bulls, but not in Charolais bulls (Tables XI through XX). Hereford, Polled Hereford, Angus, Brangus and Charolais bulls had pooled within class correlation coefficients between off-test weight and rib eye size of .73, .77, .77, .70, and .70, respectively, and between off-test hip height and rib eye area they were .57, .63, .57, .37, and .20, respectively (Tables XXI through XXV). When weight was held constant in the model the correlations between off-test hip height and rib eye area were generally very low and nonsignificant. Thus, the majority of the relationship between hip height and rib eye area is probably due to weight. These results are in agreement with Orme et al. (1959) who showed no relationship between wither height and rib eye area, but a significant ($P<.05$) multiple correlation of .48.

CHAPTER V

MATERIALS AND METHODS: STUDY II

The data used in this study were the performance traits and scrotal measurements obtained on Hereford and Angus bulls in the Oklahoma State University purebred herd. Data was collected from 20 Hereford and 12 Angus bulls born between January 1 and May 30, 1979, and classified as spring-born, and 12 Hereford and 16 Angus bulls born between September 1 and December 10, 1979, and classified as fall-born. The Hereford bulls were mainly out of D4 Mischief dams and sired by seven different L1 Domino sires. The Angus bulls were by Emulous sires and dams with four different sires represented.

Bulls used in this study were weaned at an average age of six months and placed on a warm up period for 14 days prior to the start of this study. All bulls were fed the same ration (Table XXVI) and all bulls grouped by season were penned together on a Bermuda grass pasture during the entire study.

Spring-born bulls were placed on test and hip height, scrotal circumference, weight, and ambient temperature readings were obtained every 30 days until the bulls reached approximately 17 months of age. Both hip height and scrotal circumference were measured by two different technicians and repeatabilities of .99 and .97 were recorded, respectively. These highly-significant values are mainly due to the fact that great care was taken in each measurement and the bulls became very

TABLE XXVI

O.S.U. PUREBRED BULL RATION

Ingredients	Percent of Ration
Alfalfa Hay (ground or pellet)	30.0
Rolled Corn	32.0
Soybean Meal	12.5
Cotton Seed Hulls	10.0
Rolled Oats	10.0
Molasses	5.0
Trace Mineral Salt	.5

gentle and accustomed to the handling procedure during the two, 10-month studies.

The fall-born group was handled exactly the same as the spring-born bulls. However, due to inconsistent scrotal circumference measurements noticed when ambient temperature readings changed drastically more frequent measurements were taken when temperature changes were anticipated. Table XXVII shows the least squares means for each scrotal circumference measurement at the various temperature levels. The least squares means for scrotal circumference at temperatures less than 30^{o}F were different ($P < .05$) than the remaining scrotal circumference measurements at the respective higher temperatures. There is no physiological explanation for why scrotal circumferences increased at temperatures 71 to 80^{o}F, thus, because numbers were small in this group, and the bulls were older, this discrepancy was considered to be a chance occurrence. This difference in scrotal circumference to cold temperature could possibly be due to the tunica dartos and cremaster muscle drawing the testicles closer to the body cavity. Since, the difference ($P < .05$) in scrotal circumference associated with temperature below freezing showed a statistical difference and actual data collection differences for both breeds were noticed, adjustment factors were calculated. These adjustment factors were derived by taking a weighted average of the remaining scrotal circumference and subtracting this average from the 21 to 30^{o}F scrotal circumference mean. The adjustment factors calculated for Hereford and Angus bulls were -1.92 and -1.05 cm, respectively, and these adjustments were used throughout the analyses.

TABLE XXVII

HEREFORD AND ANGUS LEAST SQUARES MEANS FOR TEMPERATURE ADJUSTMENT ON SCROTAL CIRCUMFERENCE

Temperature °F	Number	Scrotal Circumference
Hereford		
21-30	38	34.09 ± .20
31-40	75	32.70 ± .15
41-50	22	31.76 ± .28
51-60	59	32.37 ± .16
61-70	105	31.68 ± .13
71-80	9	33.96 ± .44
81-90	85	32.05 ± .14
Angus		
21-30	36	34.96 ± .16
31-40	95	33.93 ± .11
41-50	22	33.86 ± .21
51-60	60	33.99 ± .12
61-70	109	33.51 ± .10
71-80	13	34.60 ± .30
81-90	68	34.00 ± .13

Statistical Analysis

Most of the data in this study were analyzed by least squares procedure utilizing the following models. Model I was used for each of the two breeds. This model consisted of a common constant, season of birth, bull within season of birth, linear and quadratic effects of age in days, and residual error. Model II was used for both breeds combined. This model consisted on a common constant, breed of bull, season of birth, breed of bull by season of birth, bull within season and breed, linear and quadratic effects of age and residual error. Solutions to the equations were used to derive predicted values from the actual data for each age by day. In this way, growth curves could be drawn to indicate expected performance of bulls in the absence of differences of breed, season of birth, bulls within season and breed, breed of bulls by season and linear and quadratic effects of age.

CHAPTER VI

RESULTS AND DISCUSSION

Season of Birth on Performance Traits and Scrotal Size

Season of birth has been reported to influence hip height, scrotal circumference, and body weight (Brown, 1958; Butts et al., 1971; Coulter and Foote, 1976a; Neville et al., 1978; and Fields et al., 1979). In this study, Hereford and Angus bulls were of similar breeding between the two calving seasons. Furthermore, both groups of bulls were fed and handled exactly the same, thus, seasonal comparisons should be meaningful.

Analyses of variance for growth rates and scrotal size for Hereford and Angus bulls are presented in Tables XXVIII and XXIX, respectively. Bull within season of birth and linear and quadratic effects of age were a significant source of variation for all bull traits. Season of birth was the only significant source of variation for Angus bulls for hip height and weight. The analyses of variance for each trait with breeds combined are reported in Appendix Table XXXV. Table XXX shows the least squares for hip height, weight and scrotal circumference separated by season for Hereford and Angus bulls.

There was a difference ($P<.05$) between spring- and fall-born Angus calves for hip height and weight from 6 to 17 months of age. Hip height

TABLE XXVIII

ANALYSIS OF VARIANCE FOR HIP HEIGHT, SCROTAL CIRCUMFERENCE, AND WEIGHT IN HEREFORD BULLS

Source	df	Hip Height (in)	df	Scrotal Circumference (cm)	df	Weight (lb)
Season	1	.999	1	1.734	1	8056.4
Bull within Season	30	8.288**	30	39.168**	30	65152.2**
Age linear	1	93.881**	1	731.141**	1	573162.3**
Age quadratic	1	20.611**	1	449.641**	1	82090.5**
Error	327	.142	363	1.621	363	1359.9

*P<.05
**P<.01

TABLE XXIX

ANALYSIS OF VARIANCE FOR HIP HEIGHT, SCROTAL CIRCUMFERENCE, AND WEIGHT IN ANGUS BULLS

Source	df	Hip Height (in)	df	Scrotal Circumference (cm)	df	Weight (lb)
Season	1	103.39**	1	60.36	1	306023.7**
Bull within season	26	12.88**	26	37.36**	26	44377.7**
Age linear	1	50.09**	1	401.39**	1	383010.4**
Age quadratic	1	14.36**	1	242.84**	1	83373.3**
Error	325	.15	373	.949	373	961.2

**P<.01

TABLE XXX

SEASON[1] OF YEAR LEAST SQUARES MEANS FOR HIP HEIGHT, SCROTAL CIRCUMFERENCE, AND WEIGHT IN HEREFORD AND ANGUS BULLS

	Month of Age								
	6-17			6-12			12-17		
Season	Hip Height	Scrotal Circumference	Weight	Hip Height	Scrotal Circumference	Weight	Hip Height	Scrotal Circumference	Weight
Hereford									
Spring	47.79 ± .03[a]	32.12 ± .10[a]	955.8 ± 3.0[a]	45.47 ± .04[a]	29.73 ± .11[a]	755.0 ± 2.3[a]	49.48 ± .04[a]	33.76 ± .10[a]	1088.0 ± 4.3[a]
Fall	47.69 ± .03[a]	32.27 ± .09[a]	967.9 ± 2.6[a]	45.25 ± .06[a]	29.58 ± .17[a]	741.2 ± 3.4[a]	49.36 ± .03[a]	33.86 ± .07[a]	1105.3 ± 3.2[a]
Angus									
Spring	49.20 ± .04[a]	34.44 ± .10[a]	1081.5 ± 3.2[a]	46.73 ± .06[a]	30.92 ± .17[a]	860.4 ± 3.7[a]	50.20 ± .06[a]	35.88 ± .10[a]	1163.0 ± 4.2[a]
Fall	47.94 ± .03[b]	33.51 ± .06[a]	1015.1 ± 1.8[b]	45.48 ± .06[b]	30.57 ± .16[a]	776.7 ± 3.4[b]	48.93 ± .02[b]	34.65 ± .05[a]	1102.0 ± 2.0[b]

[1]Season of year bulls were born in

[a,b]Means in the same column that do not share the same superscript are significantly different by LSD Test ($P<.05$).

least squares means for spring- and fall-born Angus bulls were 49.20 and 47.94 in, respectively, with a difference of 1.26 inches. Angus bulls also showed a difference in weight of 1081.5 and 1015.1 lb for spring- and fall-born bulls, respectively. As explained in materials and methods, there was a difference (P>.05) in scrotal circumference due to ambient temperature. However, when adjustment factors for temperature were included in the analysis there was no significant difference (P<.05) in scrotal circumference for the different seasons. Scrotal circumference for spring- and fall-born Angus bulls were 34.44 and 33.51 cm, respectively. Thus, Angus bulls born in the spring were 1.26 in taller, 66.4 lb heavier, and .93 cm larger in scrotal circumference.

There was no significant difference (P>.05) in hip height, weight, and scrotal circumference in Hereford bulls between the two seasons. Hip height, weight, and scrotal circumference least squares means for spring and fall seasons were 47.79 and 47.67 in, 32.12 and 32.27 cm and 955.8 and 967.9 lb, respectively. Therefore, the season in which Hereford bulls were born had little influence on hip height, weight and scrotal circumference from 6 to 17 months of age.

These results are in disagreement with most research, especially with Brown (1958) who reported a difference (P<.05) in height and weight in Hereford calves born in February, March, and April, but no difference in Angus bulls. Because these different groups of bulls in our study were fed the same, grown out on the same pastures, and handled exactly the same, the differences detected must be due to preweaning influence. Spring-born Angus bulls were taller (P<.05) than the spring-born Hereford bulls, but there were no significant differences between bulls of the two breeds born in the fall. Thus, in the spring when grass is green, Angus cows milked better making available extra nutrients for calf growth. In the fall, Angus cows did not milk as well and thus calf size was similar for both breeds. This is in agreement with Wyatt et al. (1972) who reported skeletal differences dur to milking ability.

Changes in scrotal circumference were not significantly different (P>.10) between season in both breeds, although, Angus bulls born in the spring tended to have larger scrotal circumference measurements. This should be expected, since, there is a high relationship between scrotal circumference and weight and spring-born Angus calves were taller and heavier. The similarities noted between seasons for hip height, scrotal circumference and weight may be due to Oklahoma's weather patterns. Severe weather extremes were not noted during the period of data collection, therefore, seasonal influences on hip height, scrotal circumference, and weight were of little magnitude.

Performance and Scrotal Growth Rates

In this study, hip height growth, scrotal circumference growth, and average daily gain were calculated from predicted values obtained from regression equations found in Table XXXI for Hereford and Angus bulls. Regression equations on age for growth traits and scrotal circumference, linear measurements and predicted daily growth rates for both breeds combined are reported in Appendix Tables XXXVI, XXXVII, and XXXIX, respectively.

The desire to increase frame size and growth rate in cattle has generated considerable interest on hip height growth rates. Hip height growth rates have been reported up to 12 months of age by Guilbert and Gregory (1952), Brown et al. (1973), Dori et al. (1974), Healey (1979),

TABLE XXXI

REGRESSION ON AGE[a] FOR HIP HEIGHT, SCROTAL CIRCUMFERENCE, AND WEIGHT

	Hip Height (in)	6-17 Scrotal Circumference (cm)	Weight (lb)	6-12 Hip Height (in)	12-17[b] Hip Height (in)
Angus Bulls					
Intercept	33.79748*	1.2434	-246.716*	31.60638*	35.481916*
Age linear	.05055*	.136622*	4.22032*	.063813*	.04246*
Age quadratic	-3.4308^{-05}*	-.000134*	-.002482*	-5.3892^{-05}*	-2.5029^{-05}*
Hereford Bulls					
Intercept	33.77294*	2.301*	-166.72*	33.74597*	38.12378*
Age linear	.04959*	.13493*	3.7294*	.04961*	.03063*
Age quadratic	-3.1666^{-05}*	-.00014*	-.00189*	-3.1433^{-05}*	-1.1272^{-05}

*P<.05
[a]Age in days
[b]Month of age

Massey et al. (1979), Hubbard (1981), and Maino et al. (1981), but little has been reported on bulls after 12 months of age. In addition, some concern exists in the beef industry relative to the effect of increasing frame size and growth rates on scrotal circumference and sexual development. Relatively little is known about scrotal circumference growth rates in young beef bulls of different breeds. Although many studies have looked at the effect of age on scrotal circumference, few have reported actual growth rates that may be important for scrotal circumference adjustment factors at different ages. Coulter et al. (1975) and Coulter (1978) reported there is a linear increase in scrotal circumference up to approximately two years of age, followed by a gradual slowing until it plateaus at four years of age. Lunstra et al. (1979) reported that although beef bulls of many breeds varied considerably in body weight and age at puberty, all were at or near a constant scrotal circumference of 27.9 $\pm$ .2 centimeters. If this is true, scrotal circumference growth rate would be very important in evaluating sexual maturity in young beef bulls.

Tables XXXII and XXXIII show the predicted daily growth rates for Hereford and Angus bulls. Figures 1, 2, and 3 show the effect of age on hip height growth, scrotal circumference growth, and average daily gain, respectively. These traits show a definite linear decline in growth rate as age in days increases. Hip height growth from 180 to 365 days of age ranged from .0373 to .0277 in/day (Table XXXII) with an average growth rate of .0325 in/day in Hereford bulls and from .0373 to .0270 in/day (Table XXXIII) with an average growth rate of .0321 in/day in Angus bulls. These results are in complete agreement with data obtained in Study I as well as with growth rates reported by Healey (1979),

TABLE XXXII

PREDICTED DAILY GROWTH RATES ON HEREFORD BULLS

	Age Linear			Age Quadratic	
Months[a]	Hip Height Growth Rate in/day	Scrotal Circumference Growth Rate cm/day	ADG lb/day	Hip Height Growth Rate in/day	Hip Height Growth Rate in/day
6-7	.0373	.0790	2.97	.0377	
7-8	.0353	.0707	2.90	.0353	
8-9	.0333	.0620	2.77	.0337	
9-10	.0316	.0533	2.67	.0317	
10-11	.0296	.0450	2.53	.0297	
11-12	.0277	.0363	2.43	.0280	
12-13	.0267	.0277	2.30	.0260	.0221
13-14	.0240	.0190	2.20		.0217
14-15	.0220	.0167	2.07		.0207
15-16	.0200	.0017	2.00		.0203
16-17	.0183	-.0067	1.83		.0193

[a]Month of age.

TABLE XXXIII

PREDICTED DAILY GROWTH RATES ON ANGUS BULLS

	Age Linear			Age Quadratic	
Months[a]	Hip Height Growth Rate in/day	Scrotal Circumference Growth Rate cm/day	ADG lb/day	Hip Height Growth Rate in/day	Hip Height Growth Rate in/day
6–7	.0373	.0843	3.23	.0427	
7–8	.0350	.0763	3.13	.0397	
8–9	.0333	.0680	2.93	.0363	
9–10	.0307	.0603	2.80	.0330	
10–11	.0290	.0523	2.67	.0300	
11–12	.0270	.0440	2.50	.0263	
12–13	.0247	.0363	2.37	.0235	.0236
13–14	.0230	.0280	2.23		.0223
14–15	.0206	.0200	2.03		.0207
15–16	.0187	.0120	1.93		.0193
16–17	.0163	.0040	1.80		.0177

[a]Month of age.

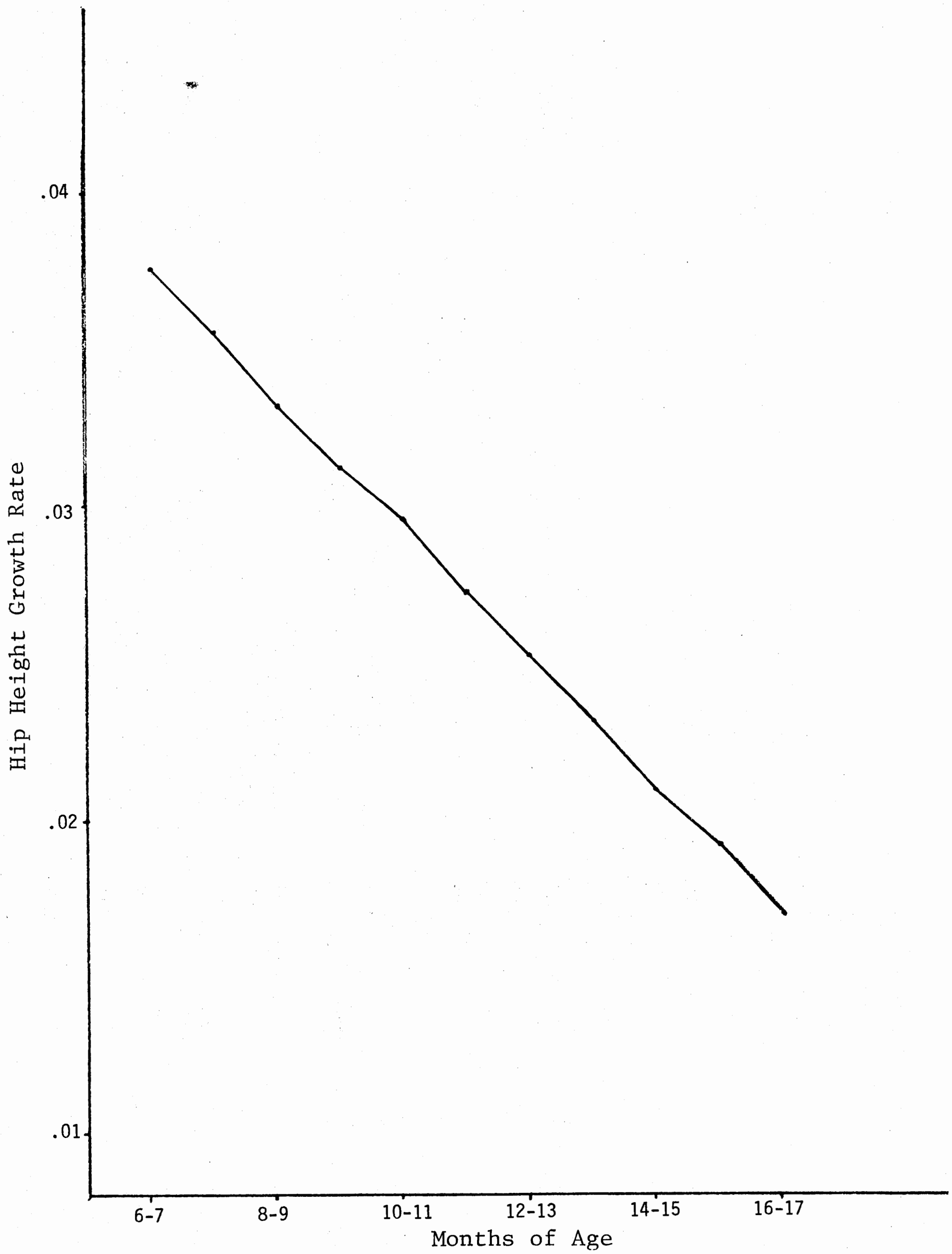

Figure 1. Predicted Effect of Age on Hip Height Growth Rates (in/day) in Hereford and Angus Bulls.

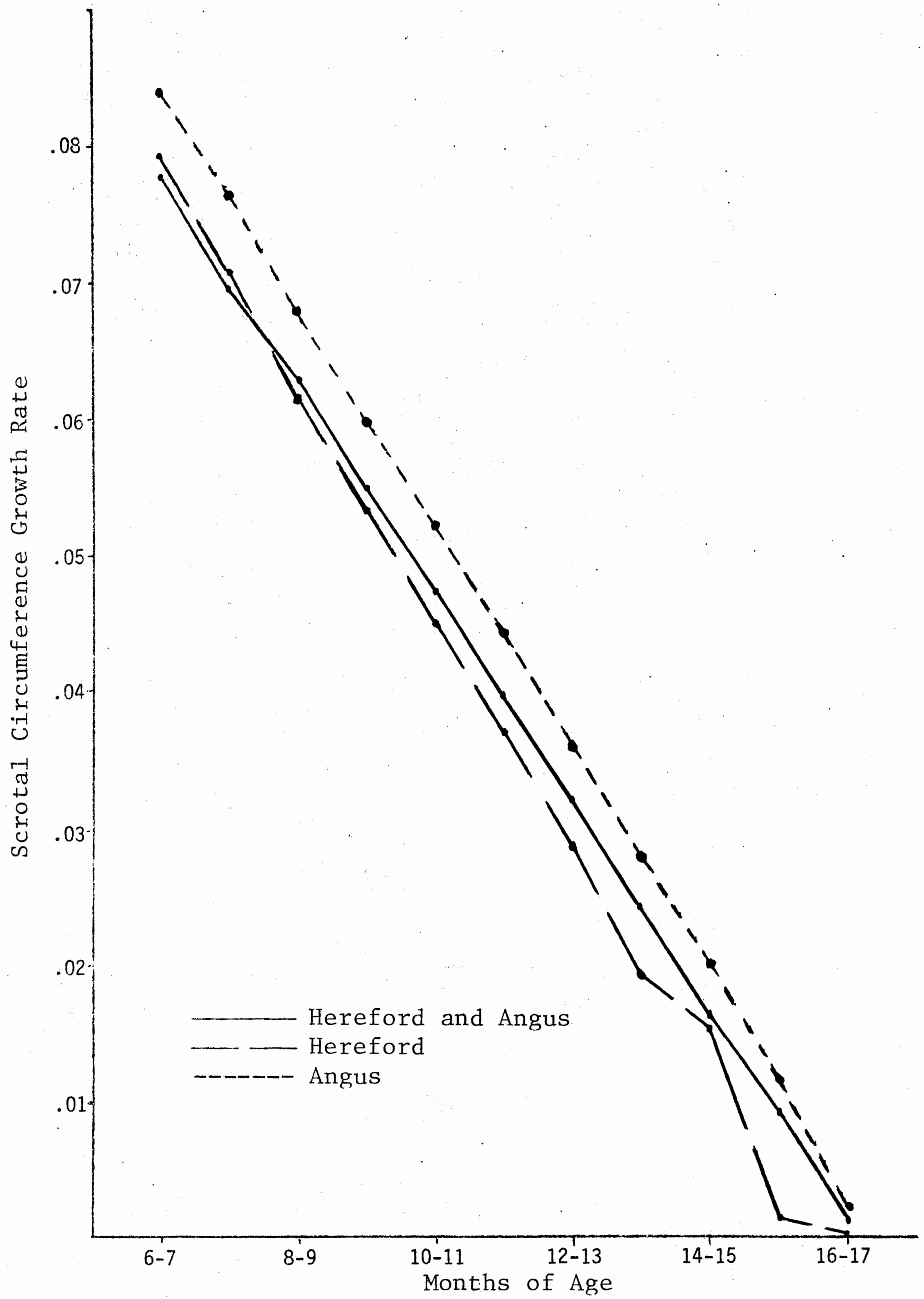

Figure 2. Predicted Effect of Age on Scrotal Circumference Growth Rate (cm/day) in Hereford and Angus Bulls.

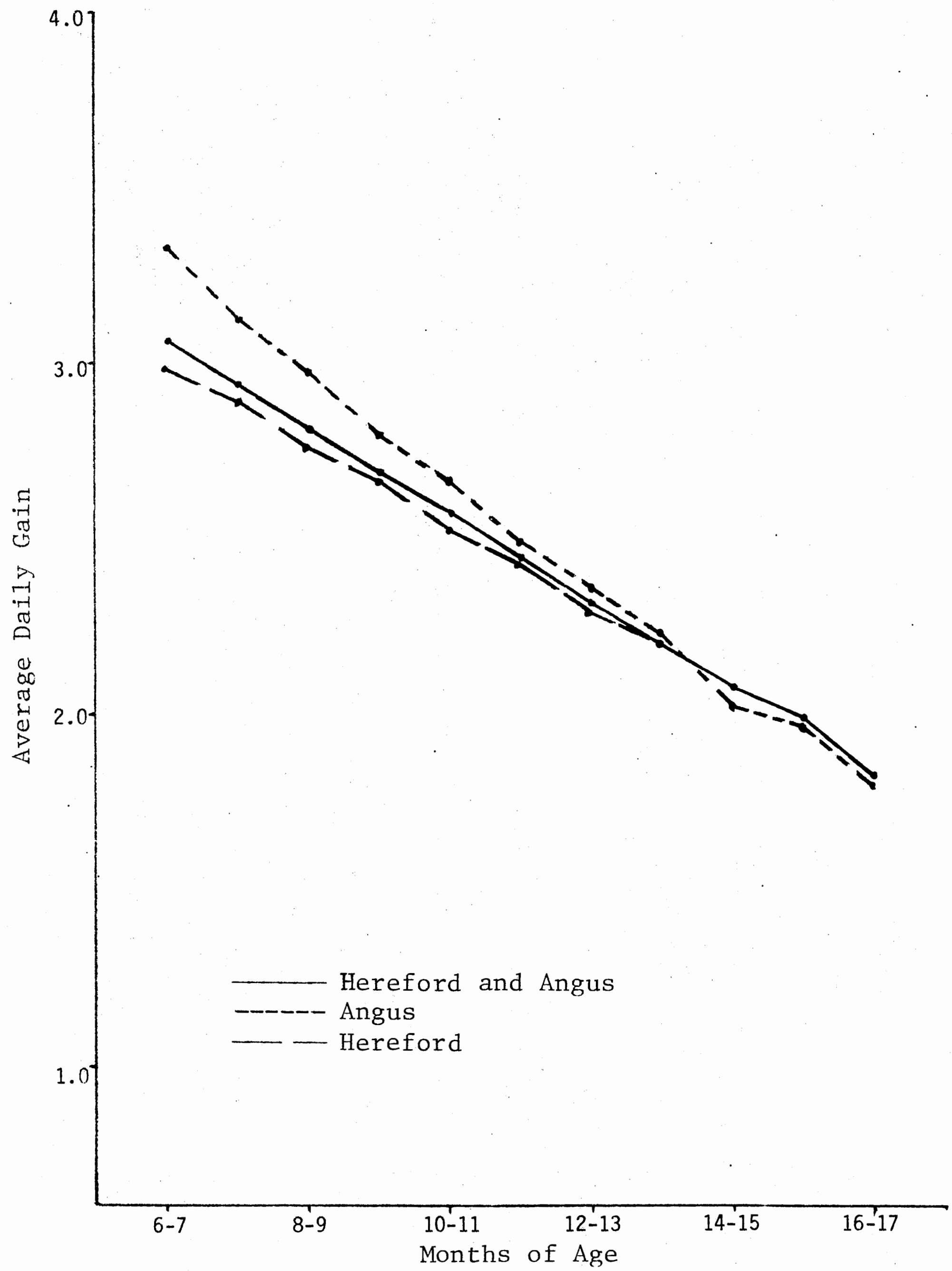

Figure 3. Predicted Effect of Age on Average Daily Gain (lb/ day) in Hereford and Angus Bulls.

Massey (1979), Hubbard (1981), and Maino et al. (1981). Although there was a linear decline in hip height growth rate as age increased, the difference was not great enough to recommend changing the adjustment factor of .03 in/day reported by Hubbard (1981). Hip height growth rate from 365 to 510 days of age ranged from .0267 to .0183 in/day (Table XXXII) with an average growth rate of .0222 in/day in Hereford bulls, and from .0247 to .0163 in/day (Table XXXIII) with an average growth rate of .0207 in/day in Angus bulls. These results are higher than the calculated data reported by Guilbert and Gregory (1952), similar to calculations from data reported by Dori et al. (1974) on Holstein bulls 270 to 505 days of age, and lower than the adjustment factor of .025 in/day for bulls between 365 and 540 days of age reported by Hubbard (1981). Differences between these studies after 365 days of age may indicate that bulls grow about the same until 12 months of age, but the bulls used in different studies may possibly reach different points in their growth curve where some begin to slow down in hip height growth more rapidly than others. Figure 4 shows the hip height growth curve for Hereford and Angus bulls from 180 to 540 days of age.

Figure 2 shows the scrotal circumference growth rate from 180 to 520 days of age for Hereford and Angus bulls. Scrotal circumference growth rate of Hereford bulls ranged from .0790 to -.0067 cm/day (Table XXXII) from 180 to 510 days of age. Very rapid growth in scrotal circumference was observed up to 13 months of age with a gradual decline in growth rate until the end of the test. The negative growth rate observed on the final calculation is probably due to the fact that five bulls were taken off test at approximately 15 months of age to be used in the breeding herds. These bulls were the largest-framed, heaviest

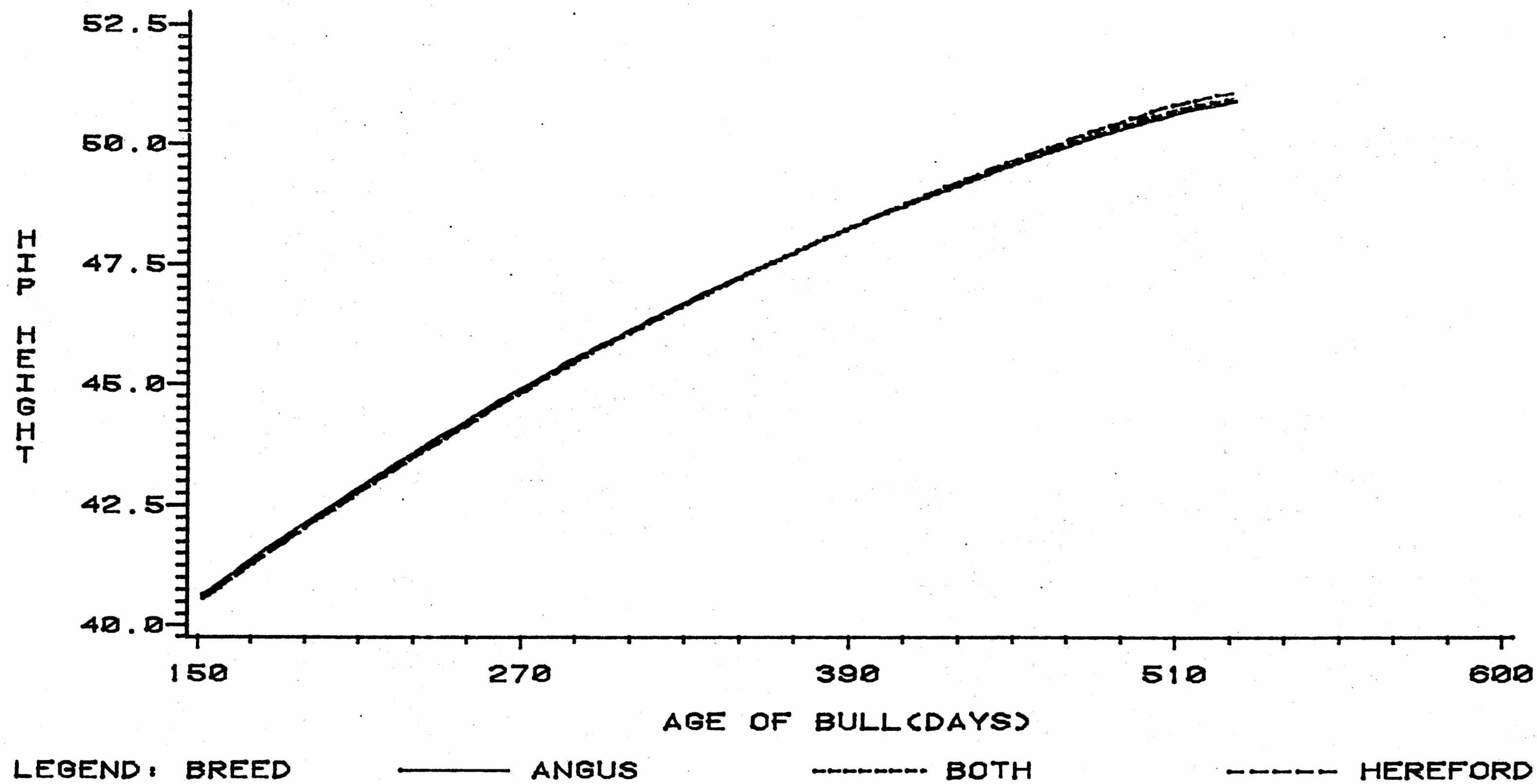

Figure 4. Predicted Hip Height Growth Curves (in) in Hereford and Angus Bulls

bulls that tended to have the largest scrotal circumference. Because the growth rate starts to level off at 390 days of age, the average scrotal circumference growth rate from 180 to 390 days of age in Hereford bulls was .0543 cm/day. This growth rate was exactly the same as the scrotal circumference growth rate found in Study I on Hereford bulls from 7 to 13 months of age. Scrotal circumference growth rate of Angus bulls ranged from .0843 to .0040 cm/day (Table XXXIII) from 180 to 510 days of age with the average of .0602 cm/day between 180 and 390 days of age. This growth rate was slightly larger than the .052 cm/day found in Study I on Angus bulls from 7 to 13 months of age. Although these values are slightly different, there is not a big enough practical difference for these values not to be useful for scrotal circumference adjustment factors at a certain age. Figure 5 shows the scrotal circumference growth curve for Hereford and Angus bulls from 180 to 540 days of age.

Average daily gain in Angus bulls was faster than Herefords initially, but slowed down at a faster pace as age increased. Average daily gain in Angus bulls ranged from 3.23 to 1.80 lb/day (Table XXXIII) from 180 to 510 days of age with an average gain of 2.51 lb over this period of time. Average daily gain in Hereford bulls ranged from 2.97 to 1.83 lb/day (Table XXXII) from 180 to 510 days of age with an average gain of 2.42 pounds. Figures 2 and 6 show the change in average daily gain over time and growth curve for weight, respectively, for Hereford and Angus bulls from 180 to 540 days of age. Predicted values obtained from the actual data for hip height, scrotal circumference, and weight for Hereford and Angus bulls are reported in Appendix Tables XXXIX and XL.

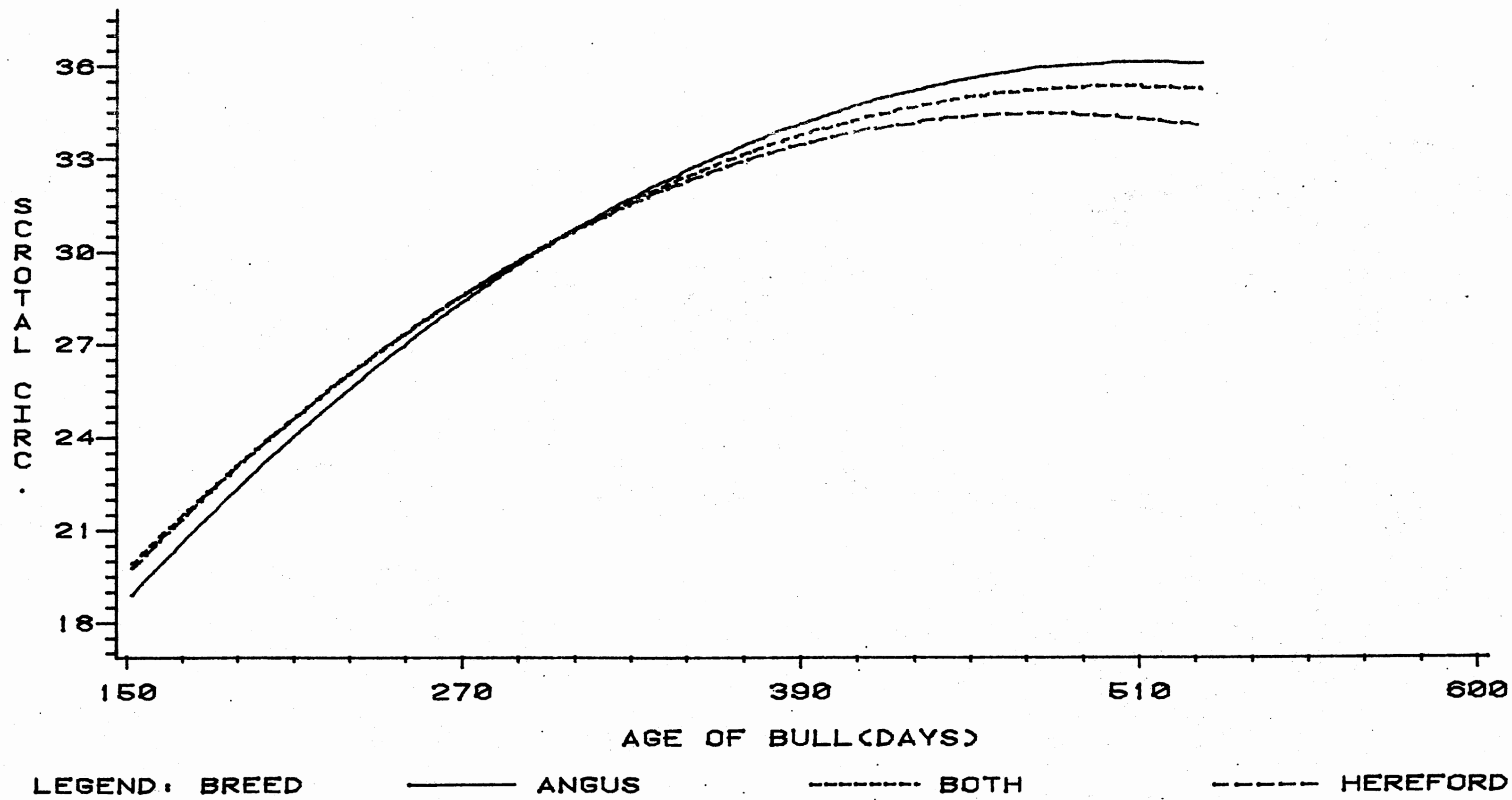

Figure 5. Predicted Scrotal Circumference Growth Curves (cm) in Hereford and Angus Bulls

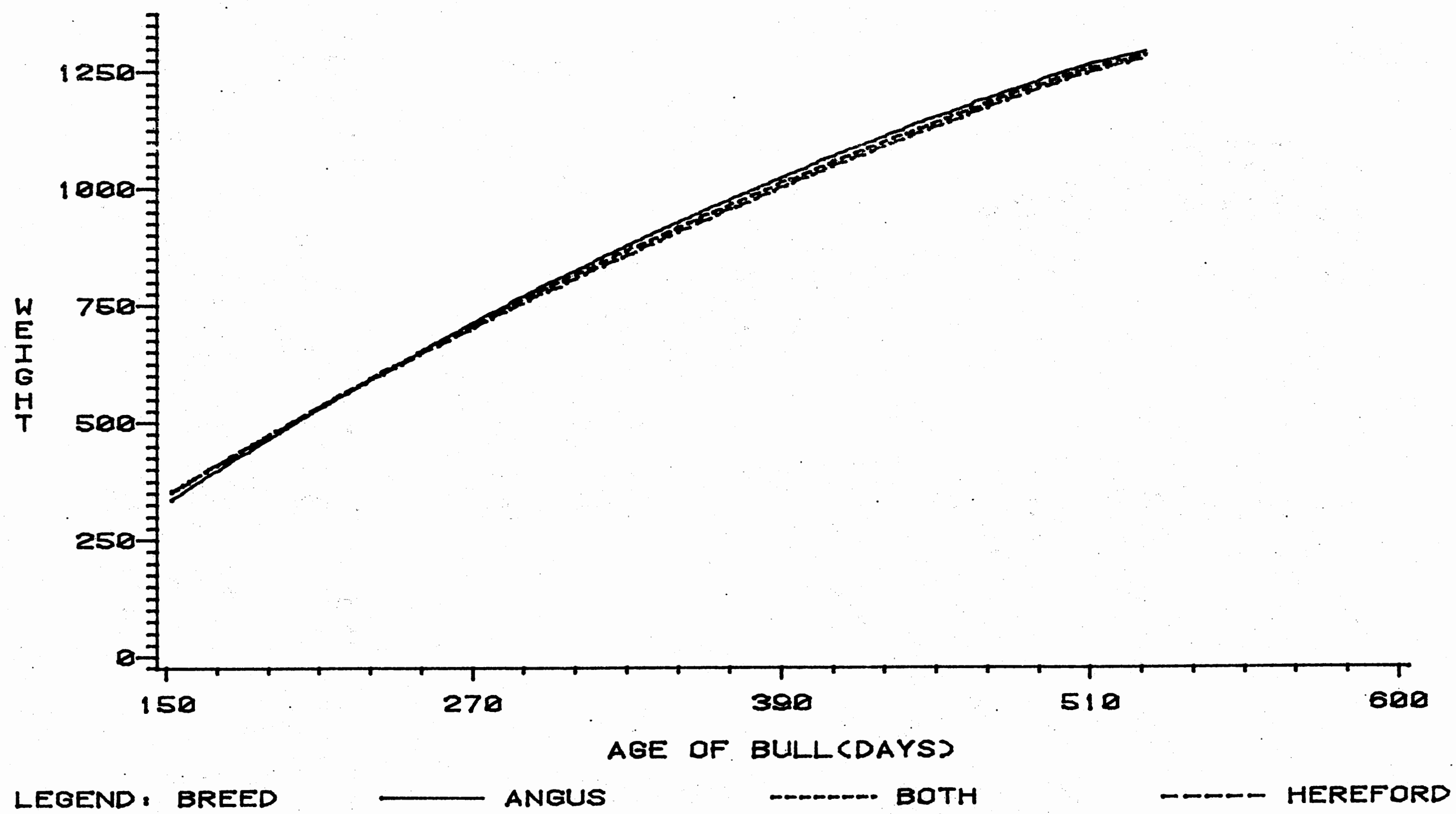

Figure 6. Predicted Average Daily Gain Growth Curves (lb) in Hereford and Angus Bulls

CHAPTER VII

SUMMARY

Study I

Performance data and testicular measurements from 497 Hereford, Polled Hereford, Angus, Brangus, and Charolais bulls were made during the period from December 19, 1979 through April 2, 1981 at Oklahoma Beef, Incorporated. The on-test age of these bulls were approximately seven months and they remained on-test for 140 days.

When breed comparisons were made, Charolais bulls were taller, heavier, faster gaining, trimmer and possessed larger rib eye areas than the other breeds. Hereford, Polled Hereford, and Angus bulls on-test and off-test hip heights were similar with Brangus and Charolais being significantly taller. Hip height growth rate per day was the same ($P>.10$) for all breeds averaging .0328 in/day. Average daily gain were very similar for Charolais, Polled Hereford, Angus, and Brangus bulls ranging from 3.58 to 3.37 lb/day with Hereford bulls being significantly lower with an average gain of 3.18 lb/day.

Angus bulls had the largest on-test scrotal circumference measurement followed by Brangus, Charolais, Hereford, and Polled Hereford. These measurements ranged from 27.7 to 25.6 centimeters. Brangus, Angus, and Charolais were all similar in their off-test scrotal circumference measurement (average 35.3 cm) with Hereford and Polled Hereford being smaller (P<.05) averaging 33.3 centimeters. Brangus and Charolais bulls had the fastest scrotal circumference growth rate of .062 and .059 cm/day, respectively, while Hereford, Polled Hereford, and Angus were all similar with an average of .053 cm/day.

Off-test fat thickness measurements were similar for Angus, Polled Hereford and Angus bulls (average .44 in) followed by Hereford (.38 in) and Charolais (.21 in). The rib eye area of Charolais bulls was larger (P<.05) than that of the other breeds. Rib eye area measurements of 15.1, 13.5, 13.0, 12.6, and 12.5 were recorded for Charolais, Angus, Hereford, Brangus, and Polled Hereford bulls, respectively.

Hereford, Polled Hereford, Angus, Brangus, and Charolais bulls showed an increase in on-test and off-test scrotal circumference as frame size increased when bulls were classified by groups according to their on-test frame size. Pooled within class correlation coefficients of .43, .39, .32, .35, and .56 were recorded between on-test hip height and on-test scrotal circumference on Hereford, Polled Hereford, Angus, Brangus and Charolais bulls, respectively. When bulls were classified by groups according to their off-test frame size, no significant relationship between on-test or off-test scrotal circumference and frame size was observed, although those bulls with larger scrotal circumferences tended to increase as frame size increased. Pooled within class correlation coefficients of .25, .33, .28, .23, and .12 were recorded between off-test hip height and off-test scrotal circumference for Hereford, Polled Hereford, Angus, Brangus and Charolais bulls, respectively. However, when weight was held constant in the model, the relationship between hip height and scrotal circumference was zero. Scrotal circumference growth rate was not associated with frame size classification for any breed. Pooled within class correlation coefficients tended to be zero or slightly negative between on-test or off-test hip height and scrotal circumference growth rate. Correlations between on-test scrotal circumference and on-test weight were generally high, averaging .62, while correlations were lower between off-test scrotal circumference and off-test weight (average .38) for all breeds. Correlations between on-test scrotal circumference and scrotal circumference growth rate were very highly negative (average -.66) while correlations between off-test scrotal circumference and scrotal circumference growth rate were moderately positive, averaging .39.

All breeds showed those bulls that were heavier increased in weight as frame size increased. Pooled within class correlation coefficients were high, averaging .67, between on-test hip height and on-test weight for all breeds. Hereford, Polled Hereford, Angus, and Brangus bulls that were heavier increased in off-test weight as frame size increased while Charolais bulls did not. Correlations between off-test height and off-test weight were moderate to high (average .56) for all breeds, while correlations between on-test or off-test hip height and average daily gain were low to moderate, averaging .14 and .33, respectively.

Overall, all breeds showed an increase in hip height growth rate as off-test frame size increased when bulls were classified into groups by their off-test frame size. However, when bulls were classified into groups by their on-test frame size, a decrease in hip height growth rate was observed as frame size increased. Pooled within class correlation coefficients between hip height growth rate and on-test hip height were moderately negative, averaging -.36, for all breeds while similar correlations between hip height growth and off-test hip height were moderately positive, averaging .31.

Overall no difference was observed between fat and frame size. Correlations between fat and other performance traits and scrotal measurements were generally low, with the highest correlation coefficient being between fat and off-test weight with an average of .31.

Hereford, Polled Hereford, Angus, Brangus, and Charolais bulls all showed an increase in rib eye area as frame size increased. Pooled within class correlation coefficients between rib eye area and off-test weight were high, averaging .73, for all breeds. In addition, the correlations between rib eye area and off-test hip height were averaging .47. However, when weight was held constant, the correlation between rib eye area and off-test hip height were very low and nonsignificant.

Study II

Seasonal differences and growth rates were studied on 60 Hereford and Angus bulls born in the spring and fall calving seasons at Oklahoma State University. Both the spring and fall-born bulls were fed and handled exactly alike. Hip height, scrotal circumference, and weight measurements were taken over the two, 10-month studies.

Temperatures below 30^{o}F had a significant influence on scrotal circumference; therefore, adjustment factors of -1.92 and -1.05 cm were calculated for Hereford and Angus bulls, respectively. Season of birth had no influence on scrotal circumference for either Hereford or Angus bulls, although scrotal circumference tended to increase as weight increased. Season of birth had an influence on hip height and weight in Angus bulls. Angus bulls born in the spring were 1.26 in taller, 66.4

lb heavier, and .93 cm larger in scrotal circumference. Hereford bulls did not show a difference in hip height, scrotal circumference, or weight between the spring- and fall-born bulls.

Hip height growth rate showed a linear decline from 6 to 17 months of age in both Hereford and Angus bulls. Hip height growth rate from 180 to 365 days of age ranged from .0373 to .0277 in/day (average .0325 in/day) on Hereford bulls and from .0373 to .0270 in/day averaging .0321 in/day on Angus bulls. Hip height growth rate from 365 to 510 days of age ranged from .0267 to .0183 in/day (average .0222 in/day) on Hereford bulls and from .0247 to .0163 in/day averaging .0207 in/day on Angus bulls.

Overall, scrotal circumference growth rate showed a linear decline from 180 to 510 days of age for both breeds. Hereford bulls scrotal circumference growth rate ranged from .0790 to -.0067 cm/day from 180 to 520 days of age with an average growth rate of .0543 cm/day up to 13 months of age. Scrotal circumference growth rate on Angus bulls ranged from .0843 to .0040 cm/day from 180 to 510 days of age with an average of .0602 cm/day up to 13 months of age.

Average daily gain was faster for Angus bulls at the start of the test than Herefords, but slowed down much faster than Hereford bulls later in the test period. Angus bulls' average daily gain ranged from 3.23 to 1.80 lb/day (average 2.51 lb/day) from 180 to 510 days of age and Hereford bulls ranged from 2.97 to 1.83 lb/day averaging 2.42 lb/day.

In general, performance traits and scrotal circumference tend to differ between breeds and between different frame sizes. Further study is warranted on the influence of season, preweaning effects of dam and nutrition on growth rates and frame size and skeletal size and growth rates prior to weaning and after 365 days of age.

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APPENDIX

TABLE XXXIV

ON AND OFF TEST DATES OF PERFORMANCE TESTED BULLS

Breed	Group	On Test Date	Off Test Date
Brangus	1	1-17-80	5-20-80
	2	6-24-80	11-18-80
	3	9-23-80	2-18-81
Angus	1	1- 7-80	5-10-80
	2	1- 7-80	6-11-80
	3	3- 3-80	8-12-80
	4	5-10-80	10- 8-80
	5	6-18-80	11-11-80
	6	7-28-80	12- 9-80
	7	9-16-80	2-11-81
	8	10-14-80	3-11-81
Hereford	1	12-19-79	5-26-80
	2	6-13-80	10-28-80
	3	7-28-80	12-22-80
	4	9-30-80	2-25-81
	5	10-28-80	3-25-81
Polled Hereford	1	6-25-80	11-18-80
	2	9-23-80	2-18-81
	3	11-25-80	4- 2-81
Charolais	1	5-21-80	10-16-80

TABLE XXXV

ANALYSIS OF VARIANCE FOR HIP HEIGHT, SCROTAL CIRCUMFERENCE, AND WEIGHT IN HEREFORD AND ANGUS BULLS

Source	df	Hip Height (in)	df	Scrotal Circumference (cm)	df	Weight (lb)
Breed	1	.779*	1	95.354**	1	73848.9**
Season of year	1	65.375**	1	23.34**	1	119487.0**
Breed X Season	1	56.098**	1	19.908	1	229750.4**
Bull within season & Breed	56	10.493**	56	38.233**	56	55644.21**
Age linear	1	162.046**	1	1075.516**	1	1010095.8**
Age quadratic	1	42.184**	1	627.75**	1	169763.5**
Error	654	.146	738	1.365	738	1159.6

*P<.05
**P<.01

TABLE XXXVI

REGRESSION ON AGE[a] FOR HIP HEIGHT, SCROTAL CIRCUMFERENCE, AND WEIGHT ON HEREFORD AND ANGUS BULLS

	Hip Height (in)	6-17 Scrotal Circumference (cm)	Weight (lb)	6-12 Hip Height (in)	12-17[b] Hip Height (in)
Intercept	33.5749*	3.52896*	187.2390*	33.61411*	36.54893*
Linear	.051027*	.127088*	3.8680*	.056294*	.037779*
Quadratic	-3.42498^{-05}*	-.000127*	-.002060*	-3.23185^{-05}*	-1.96091^{-05}*

*P<.05
[a]Age in days
[b]Month of age

TABLE XXXVII

PREDICTED HIP HEIGHT, SCROTAL CIRCUMFERENCE, AND WEIGHT IN HEREFORD AND ANGUS BULLS

	Month of Age				
	6-17			6-12	12-17
Month	Hip Height (in)	Scrotal Circumference (cm)	Weight (lb)	Hip Height (in)	Hip Height (in)
6	41.65	22.29	442	41.62	
7	42.78	24.62	535	42.75	
8	43.85	26.71	623	43.83	
9	44.86	28.58	708	44.84	
10	45.81	30.22	789	45.20	
11	46.69	31.63	866	46.69	
12	47.51	32.81	940	47.53	47.61
13	48.27	33.77	1010	48.31	48.30
14	48.97	34.49	1076		48.96
15	49.61	34.99	1138		49.58
16	50.18	35.26	1197		50.17
17	50.70	35.29	1251		50.72

TABLE XXXVIII

PREDICTED DAILY GROWTH RATE IN HEREFORD AND ANGUS BULLS

	Age Linear			Age Quadratic	
Months[a]	Hip Height Growth Rate in/day	Scrotal Circumference Growth Rate cm/day	ADG lb/day	Hip Height Growth Rate in/day	Hip Height Growth Rate in/day
6-7	.0377	.0777	3.06	.0377	
7-8	.0333	.0697	2.94	.0357	
8-9	.0357	.0633	2.82	.0340	
9-10	.0313	.0547	2.69	.0320	
10-11	.0297	.0473	2.57	.0293	
11-12	.0273	.0393	2.45	.0280	
12-13	.0253	.0320	2.32	.0260	.0230
13-14	.0233	.0240	2.20		.0220
14-15	.0210	.0167	2.08		.0206
15-16	.0193	.0090	1.95		.0193
16-17	.0170	.0013	1.83		.0186

[a]Month of age

TABLE XXXIX

PREDICTED HIP HEIGHT, SCROTAL CIRCUMFERENCE, AND WEIGHT IN ANGUS BULLS

	Month of Age				
Month	Hip Height (in)	6-17 Scrotal Circ. (cm)	Weight (lb)	6-12 Hip Height (in)	12-17 Hip Height (in)
6	41.8 ± .066	21.49 ± .157	432 ± 5.0	41.3	
7	42.9 ± .058	24.02 ± .138	530 ± 4.4	42.6	
8	43.9 ± .051	26.31 ± .120	623 ± 3.8	43.8	
9	44.9 ± .043	28.40 ± .102	711 ± 3.2	44.9	
10	45.8 ± .036	30.17 ± .085	796 ± 2.7	45.9	
11	46.7 ± .029	31.74 ± .070	875 ± 2.2	46.8	
12	47.5 ± .025	33.06 ± .057	950 ± 1.8	47.6	
13	48.3 ± .021	34.15 ± .050	1021 ± 1.6		48.2
14	48.9 ± .021	34.99 ± .049	1088 ± 1.6		48.9
15	49.6 ± .024	35.59 ± .057	1149 ± 1.8		49.5
16	50.1 ± .029	35.96 ± .069	1207 ± 2.2		50.1
17	50.6 ± .035	36.08 ± .084	1260 ± 2.7		50.6

TABLE XL

PREDICTED HIP HEIGHT, SCROTAL CIRCUMFERENCE, AND WEIGHT IN HEREFORD BULLS

Month	Month of Age				
	Hip Height (in)	6-17 Scrotal Circ. (cm)	Weight (lb)	6-12 Hip Height (in)	12-17 Hip Height (in)
6	41.7 ± .051	22.21 ± .166	441 ± 4.8	41.6	
7	42.8 ± .045	24.59 ± .145	532 ± 4.2	42.7	
8	43.8 ± .039	26.71 ± .125	618 ± 3.6	43.8	
9	44.8 ± .033	28.58 ± .105	702 ± 3.1	44.8	
10	45.8 ± .027	30.18 ± .088	732 ± 2.6	45.8	
11	46.7 ± .023	31.54 ± .074	858 ± 2.2	46.6	
12	47.5 ± .020	32.63 ± .066	931 ± 1.9	47.5	
13	48.3 ± .020	33.46 ± .064	1000 ± 1.9		48.4
14	49.0 ± .022	34.04 ± .071	1066 ± 2.1		49.0
15	49.7 ± .026	34.37 ± .084	1129 ± 2.4		49.6
16	50.3 ± .031	34.40 ± .100	1188 ± 2.9		50.2
17	50.8 ± .037	34.20 ± .119	1243 ± 3.4		50.8

VITA

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Master of Science

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