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The Use of Linear Measurements for Determining Growth Rate & Size in Cattle

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THE USE OF LINEAR MEASUREMENTS FOR DETERMINING GROWTH RATE AND SIZE IN CATTLE

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GROWTH RATE AND SIZE IN CATTLE

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ABSTRACT

The calves born in the 1979 and 1980 calf crops at Sam Sells and Sons' Polled Hereford Farm in Moultrie, Georgia, were used in a study comparing immature body measurements with subsequent growth. The measurements taken at birth included weight, front leg length, front cannon bone length, and rear cannon bone length. In addition, hip height was measured at one hundred days, seven months, and twelve months of age. Weight was taken at seven months, twelve months and fifteen months of age.

The data were analyzed in four groups according to year of birth and sex. Coefficients of correlation were determined for all measurement combinations. Birth measurements alone accounted for an insignificant amount of the variability in twelve-month weight. Among the four groups studied, seven-month weight showed inconsistent associations to height and weight at twelve and fifteen months of age. This was due primarily to the amount of environmental influences involved in weight at seven months. Multiple regression analyses were conducted using twelve-month weight as a dependent variable and immature body measures as independent variables. An equation using one hundred-day hip height alone

accounted for seventy-six percent of the variability in twelve-month weight. Another equation including two independent variables, one hundred-day hip height and seven-month weight, accounted for eighty percent of the variability in twelve-month weight. When twelve-month height was used for a dependent variable, one hundred-day hip height and rear cannon bone length at birth accounted for seventy percent of the variability.

The coefficients of correlation and multiple regression equations reported in this study support the fact that linear measurements are a more consistent measure of size in immature calves than weight alone. Also, linear measurements show little or no variation due to environmental conditions such as age of dam, unpartitioned maternal ability and physiological changes associated with puberty. The findings support the hypothesis that immature linear skeletal measurements are accurate predictors of subsequent growth in Polled Hereford cattle.

CHAPTER I

INTRODUCTION

For many years cattlemen have used visual appraisal as a tool for predicting genetic potential in livestock. In the history of American beef cattle production, cattlemen have often made mating decisions solely on the basis of visual observation; however, the introduction of scientific agriculture has convinced the contemporary beef cattle breeder of the need to become more efficient and more accurate in his selection of breeding animals.

During the last three decades, consumers have placed increased emphasis upon beef cuts with a high ratio of muscle to fat. Furthermore, the feedlot operator depends upon growth rate and efficiency of gains for profitable returns on his investment. Therefore, the beef breeder has the challenge of meeting the demands of both the consumer and the feedlot operator.

Cattlemen now have access to objective measurements such as weight and age in a large percentage of the breeding animals in the United States. However, use of weight and age alone cannot sufficiently predict the type of cattle needed to satisfy today's market demand. Because of the increasing interest in carcass cutability and the high cost of feeding cattle, other phenotypic parameters such as linear measures of skeletal size are needed to help recognize growth, efficiency of gain and composition of the end product. The use of linear measurements may increase the accuracy of selecting cattle that will meet the consumers' requirements while obtaining fast, efficient growth and finish at a desirable weight and size. In combination with weight and age, linear measurements may improve the accuracy of describing a calf's maturity pattern and thus his potential for future growth.

The purpose of this paper is to compare and discuss certain weights and measures in order to determine their relationship to each other and to determine their association with growth rate and maturity pattern.

CHAPTER II

LITERATURE REVIEW

Weight differences among beef cattle are of economic importance, however accurate and feasible methods of appraising genetic differences in growth must be determined in order for breeders to obtain maximum progress in increasing growth and efficiency through selection (Swiger et al. 1968). Healy (1979) found that a combination of skeletal measurements and weight gave a more accurate indication of size than weight alone, because the environment, unless severe enough to cause stunting, plays a much smaller role in determining skeletal size than does body weight.

There have been many studies involving linear measurements and predicting the carcass merit of live beef calves, however, this information is of limited value in discussion of skeletal measurements and subsequent growth. Therefore the literature referred to in this study is restricted to the work concerned with skeletal measurements and growth.

Birth Measurements. Because of the long generation interval in cattle, it is of great importance to determine an individual's genetic potential as early in life as possible. In a study conducted by Flock et al. (1962), seven linear body measurements including height at withers, depth of chest, length of body, heart girth, circumference of cannon bone and round were taken on 1,425 calves within twenty-four hours of birth. Type scores at birth, weaning weights and preweaning average daily gains were calculated. The study concluded that the correlation between birth weight and preweaning gain may justify selecting on the basis of higher birth weights; however, any increase in birth weights should be critically examined with respect to calving ease. It was also determined that type at birth had a low association with weaning performance. Wither height was determined to be the best predictor of gain, with a phenotypic correlation of .33 in Angus and .35 in Herefords, but at the same time indicated poorer prospect for type at weaning. Also, muscling, heart girth and round measurements had no advantage over skeletal measurements, such as height at withers and body length. The greatest source of variation of birth traits was due to year effects. Sex of calf also played a small role in the variation of birth traits. Bull calves were from 4.2 to 5.5 pounds heavier and consistently had larger linear measurements. Bernard and Hidiroglou (1968) also found bulls to be both longer bodied and taller than heifers. They also concluded that age of dam played a significant role in the skeletal size of calves at birth. Ludwig (1980) showed that dams within the ages of four to nine years of age were mature cows. Cows within this age produced calves which did not vary significantly from the average of 73.95 pounds for heifers and 79.9 pounds for bulls. Furthermore, Ludwig (1980) found that younger dams, two and three years of age, had calves that weighed significantly less at birth.

Preweaning Measurements. There is a limited amount of literature available with preweaning weights and measures. The primary reason for this seems to be the difficulty in obtaining accurate and consistent measurements of young calves. The major factor contributing to inaccurate measurements of preweaning performance is the age of dam, Flock et al. (1962). Flock et al. (1962) found a marked increase in the preweaning performance of calves from four-year-old dams as compared to three-year-old dams. He also found that month of birth and sex of calf contributed to the variability in preweaning performance. On the average, January calves tended to gain more slowly than March or April calves, and bull calves gained significantly faster than heifer calves.

Brown et al. (1973b) considered the relationship between overall size, shape and ten body measurements at four and eight months to feedlot performance for 550 Hereford and Angus bulls. Immature body shapes were associated with subsequent performance on test, and more than one shape showed positive relationshps to efficiency and rate of gain on test. The taller bulls were longer in all measurements at four and eight months, and narrow bulls of both breed groups at four and eight months were observed to eat more feed and weigh more than the shorter, wider bulls. Four months marked a mid-point for preweaning growth and also represented growth at a period when the calf was most dependent on milk. The genetic correlations estimated from Hereford bulls for preweaning gain and four-month body measurements were all positive and large except for body weight which was not significantly different from zero (P<.01). The magnitude of these correlations indicate that the genes having a positive effect on width of loin, width of hips and depth of body had the greatest effect on preweaning gain. Height at the withers had a moderate to high coefficient of correlation with preweaning gain. Of the skeletal measurements, those associated with width at four months were the most closely associated with early gaining ability. Brown et al. (1973b), in considering four-month measurements and postweaning 140-day test gain, found genes influcencing height, depth of flank and length of body at four months to have the greatest effect on postweaning 140-day test gain. For Hereford bulls the two dimensions most likely to influence visual scores, height and length, were highly correlated to postweaning 140-day test gain. Also, genetic correlations involving four-month measures and pre-and post-weaning gains indicate that Hereford bulls which gained rapidly on 140-day test were structurally longer for all dimensions at four months than Hereford bulls with poor gains.

Phenotypic correlations were also calculated to determine the relationship between four-month measurements, preweaning gain and four feedlot traits. Body weight, width of shoulders, width of loin and heart girth circumference were the most highly correlated with preweaning gain for both breed groups. However, any one of these traits alone was responsible for only a small portion of the variability in preweaning gain. For two of the feedlot traits, test gain and feed consumed, the results were similar. The phenotypic correlations between these two traits and each of the ten four-month measurements were positive but small. The phenotypic correlations between feed conversion and each of the ten four-month measurements were small and did not significantly differ from zero. Final weight on test was the only feedlot trait that showed phenotypic correlations of any significant magnitude when compared with the ten four-month measurements. All the correlations were positive, with weight at four months having the greatest phenotypic correlation in both breed groups.

Weaning Measurements. In dealing with weaning measurements, Brown et al. (1973a) determined that the genetic expression of growth measured at eight months represented various degrees of restricted environmental conditions. Environmental effects contributing to this variation include non-partitioned maternal influences, weaning stress, and physiological changes associated with puberty. Because environmental factors influence weight to a much greater extent than skeletal dimension, the use of frame measurements to evaluate growth would seem reasonable (Brody, 1945). In agreement, Brown and Shrode (1971) concluded "the body measurement and body composition traits appear to be of value as a means of obtaining an accurate description of the true growth potential of beef calves."

Brown et al. (1973b) found several eight-month measurements to have a positive influence on preweaning gain. The phenotypic correlation between heart girth circumference and preweaning gain was .80 for Herefords and .73 for Angus. Height at the hips at eight months showed a slightly larger genetic correlation with preweaning gain than did height at the withers. The same was true for height at hips and height at the withers at four months. The phenotypic correlations indicate that height at hips accounted for three times as much variation in preweaning gain of Angus bulls as did wither height. This could be due to the inconsistency of measuring height over the withers. Healey (1979) stated that height over a calf's hooks is the single most accurate skeletal measurement. This is true because it is measured over a solid ball and socket linkage that is less prone to flex.

Of the four feedlot traits studied by Brown et al. (1973b), only three showed any significant relationship to the ten eight-month measurements. Test gain showed a .32 phenotypic correlation with eight-month body weight in Hereford bulls. For Angus bulls test gain had a phenotypic correlation of .34 with both hip height and body length at eight months. Of the ten eight-month measurements, body weight for the Herefords and body weight and hip height for the Angus were the most highly correlated with test gain. The phenotypic correlations were greater in magnitude between the final test weight and the ten eight-month measurements than any of the other three feedlot traits. Eight-month body weight and heart girth circumference showed the highest correlations with final test weight for both breed groups.

Yearling Measurement and Beyond. There are several reasons why postweaning measurements may be advantageous for improving the accuracy of selection of beef cattle. First, one year of age represents a time when growth can be evaluated relatively free of maternal effects, and secondly, at this time the growth of bulls is somewhat parallel to that of steers at market weight. There are, however, some environmental effects that may influence growth from weaning to a year of age. Postweaning energy intake, general health, parasites and weather conditions all may affect postweaning growth, but these effects can be kept relatively uniform among members of a contemporary group. These environmental conditions affect weight more than linear skeletal measurements which suggests that linear measurements could be a very reliable predictor of growth (Brody, 1945). Bernard and Hidiroglou (1968) found that at one year of age the coefficient of correlation between height at withers and body length was about .90. However, the correlation between height at withers and body weight was .54, and the correlation between body length and body weight was .58. Stone (1978), in a study of elite Angus cattle, concluded that for Angus heifers, wither height, hip height and length were highly correlated (greater than .70) with weight at one year. In Angus bulls at one year of age wither height and hip height had a coefficient of correlation of .88 and .88, respectively, with weight. Length had a correlation of .73 with weight at one year. Furthermore, there was a significant difference between the sexes for wither height, hip height, length, fat thickness, and weight at one year of age. Ternan (1959) found the correlation between wither height and height at the hooks was very high. Also Brown and Shrode (1971) used one year of age as a time to observe differing growth patterns between the sexes. They found differences for all measured traits between the sexes were larger at one year of age than at any earlier age. They concluded that the variation could be attributed to physiological differences, differences in the affect of puberty and to certain other environmental factors.

Stone (1978) found that for a group of Angus bulls between twenty and thirty months of age, hip height had a .80 correlation with weight and wither height had a .79 correlation with weight. He also concluded that wither height had a slightly higher correlation with body length than did hip height (.65 and .60 respectively). Calo et al. (1973) evaluated post-weaning growth in a group of pedigree-selected Holstein bulls. It was found that the bulls grew rapidly from six to twenty-four months of age. At approximately thirty-six months, the growth rate began to level off; however, body weight continued to show some increase until eight years and eleven months of age. The bulls attained twenty-one percent of their mature weight at six months, thirty-seven percent at twelve months, forty-six percent at fifteen months and eighty-six percent at thirty-six months of age. The correlations between body weight at different and successive ages for bulls are all positive indicating that animals heavy at an early age tended to be heavy at later ages. Neville et al. (1978) concluded that hip height began to plateau between twenty-four and twenty-seven months of age with a slight upturn starting about thirty-six months of age. There was no indication that a plateau had been reached by thirty-nine months of age. For body weight, Angus and Polled Hereford tended to plateau between twenty-seven and thirty-three months of age after which there was a slight increase for both breeds.

Black et al. (1938) concluded that the ratio of weight to height at the withers gave the highest correlation with performance. From this he concluded that height at the withers was a more reliable source of information regarding true genetic growth rate than was weight. In agreement, Brown and Shrode (1971) concluded that linear measurements added much to the credibility of cattle performance records. Furthermore, Brody (1945) concluded that weight and age alone could not be used to effectively represent the genetic potential of an individual for growth and that, of all linear measurements possible, wither height was the best measure of true genetic size. However, Brody did not consider hip height which other researchers (Brown et al. [1973b], Stone 1978) found to be equally as accurate as a predictor of size and wither height.

CHAPTER III

MATERIALS AND METHODS

The data for this study were collected from the 1979 and 1980 calf crops of Sam Sells and Sons' Polled Hereford Farm at Moultrie, Georgia. There were 174 calves in the study--ninety males and eighty-four females. The calves were all from spring calving cows, and records were collected on the calves from birth until fifteen months of age.

Weight and three linear measurements were taken within the first thirty-six hours after birth. Hip height was measured at one hundred days, and weight and hip height measurements were taken at seven, twelve and fifteen months. In each case the measurements were chosen on the basis of ease and accuracy of measuring.

Birth weight was measured with a simple set of feed scales that could be accurately handled by one man. Length of front leg and length of front and rear cannon bones were the three linear measurements evaluated at birth. Establishing specific points that would provide repeatable measurements was important in the evaluation of linear measurements. Considerable effort was taken to be sure each calf was measured at exactly the same location in regard to the skeleton. First, the front leg was held straight, with no bend at the knee, and the front leg was measured from the elbow joint, just behind the forearm, to the bottom of the front foot. Next, the front leg was bent at the knee and the front cannon bone was measured from the bend in the knee to the center of the fetlock joint. Finally, the rear cannon bone was measured from the top of the hock to the center of the fetlock joint. These were not exact cannon bone measurements, but they were measured in this manner because the measurement point could be uniformly identified from calf to calf, thus reducing the error in measuring a large number of calves. Hip height was not used at birth because of the difficulty involved in obtaining accurate measurements.

Hip height was evaluated at one hundred days and at seven, twelve and fifteen months. Hip height was measured at the hook bones because this measurement is the single most accurate linear skeletal measurement (Healey 1979). This is true because it involves measuring over a solid ball and socket linkage that is less likely to flex. The device used for measuring hip height provided a quick and accurate measurement. It involved modification of the covered working alley which was already used for the routine management of the cow herd. The modifications included the addition of a completely level concrete floor in the first ten feet of the working alley behind the head gate. Next, pipe was used to build a track suspended from the ceiling directly over the working alley and parallel to the floor. A standard retractable metal rule was attached to another pipe which could move freely down the track over the working alley. This allowed the tape measure to be centered directly over the point that was to be measured regardless of the body length of the animal.

Coefficients of correlation were obtained using standard statistical procedure. An analysis of variance was conducted in order to recognize differences among years and among sexes. In addition, a stepwise multiple regression procedure was used. In this procedure selected immature measures were used as independent variables in an attempt to predict dependent variables which consisted of several more mature measures which are critical in beef cattle production. This stepwise procedure provided a method of determining which independent variable accounted for the greatest amount of variability in the dependent variable. The remaining variable that accounted for the greatest portion of the residual variability entered the equation next with this procedure, and the procedure continued until all independent variables were fitted.

CHAPTER IV

RESULTS AND DISCUSSION

In order to describe each group to be studied, the means and standard deviations for all measurements are shown in Table 1. An analysis of variance was conducted to determine differences between groups. The data were divided into four groups to assure a more accurate statistical analysis. The four groups included fifty 1979 bulls, thirty-four 1979 heifers, forty 1980 bulls and fifty 1980 heifers. The data were studied in this manner because there was a statistically significant difference between years and between sexes. Furthermore, hip height at one hundred days was not measured in 1979, and the 1980 study was concluded before the calves reached fifteen months of age.

The only significant difference between years was observed with the twelve-month weight of the bulls ($P<.01$). The 1979 bulls weighed significantly more than the 1980 bulls because the 1979 bulls were fed ad libitum, while the 1980 bulls were fed on a restricted intake regime.

Significant differences between sexes were observed for several of the traits measured. First, and in agreement with Bernard and Hidiroglou (1968), Flock et al. (1962) and

TABLE 1

Means and Standard Deviation of all Measurements Studied

Year	Sex	Birth Weight	Front Leg Length[a]	Cannon Bone Length[a] Front	Cannon Bone Length[a] Rear	100-Days Ht.
1979	M	75.00 ± 10.47	18.41 ± .78	6.95 ± .47	11.01 ± .38	
1979	F	65.87 ± 10.62	18.17 ± .47	6.91 ± .44	11.10 ± .13	
1980	M	74.00 ± 10.39	18.67 ± .60	6.26 ± .24	11.28 ± .49	36.35 ± 1.84
1980	F	71.16 ± 7.96	18.65 ± .56	6.26 ± .29	11.29 ± .45	35.15 ± 1.78

[a]Measured within 36 hours after birth.

7-Months		12-Months		15-Months	
Weight	Hip Height	Weight	Hip Height	Weight	Hip Height
598.94 ± 66.56	43.15 ± 1.34	957.85 ± 100.46	47.71 ± 1.49	1,118.13 ± 93.05	49.53 ± 1.38
550.00 ± 72.38	42.94 ± 1.46	697.50 ± 79.41	45.18 ± 1.28	729.68 ± 80.39	46.29 ± 1.31
619.65 ± 88.15	44.25 ± 1.69	780.39 ± 137.28	47.15 ± 1.80		
562.84 ± 66.62	43.90 ± 1.60	693.60 ± 93.06	46.49 ± 1.44		

Ludwig (1980), the bulls were significantly larger at birth than the heifers: 9:13 pounds in 1979 (P<.05) and 2.84 pounds in 1980 (P<.10). In 1980 the bulls were significantly (P<.01) taller at the hips than the heifers when measured at one hundred days of age. For both years, seven- and twelve-month weights were significantly (P<.01) greater for bulls than for heifers. And in 1979 the bulls were significantly (P<.01) larger than the heifers for height at twelve and fifteen months and for weight at fifteen months.

Tables 2, 3, 4 and 5 show the coefficients of correlation of selected traits for each group. In agreement with Flock et al. (1962), measurements taken at birth had limited value for predicting subsequent growth. Among the traits measured at birth, front cannon bone length had the most consistently strong associations with more mature measurements of size. In contradiction with Flock et al. (1962), preweaning gain as represented by weight at seven months had a very low association with birth weight. Thus, increasing birth weight may not significantly influence weight at seven months. The data for the 1980 males and females indicate that the heavier calves at birth were also larger framed. The coefficients of correlation between linear measurements taken at birth were significantly high, which agrees with Healey (1979) that the skeleton is constant and proportional. Thus, as one bone increases in length the others increase proportionately.

For both males and females in the 1980 group, hip height at one hundred days showed a strong association with

TABLE 2

Coefficients of Correlation Among Body Measurements for 1979 Males

Measurement	(9)	(8)	(7)	(6)	(5)	(4)	(3)	(2)	(1)
1. Birth Wt.[a]	-.28	.26	-.09	.10	.29	.24	.43	.36	1.00
2. Front Leg[a]	.71	.27	.44	.01	.55	.19	.67	1.00	
3. Front Cannon[b]	.68	.47	.42	.35	.33	.39	1.00		
4. 7-Month Wt.	.41	.74	.42	.84	.50	1.00			
5. 7-Month Ht.[b]	.47	.50	.58	.33	1.00				
6. 12-Month Wt.	.57	.85	.61	1.00					
7. 12-Month Ht.[b]	.90	.69	1.00						
8. 15-Month Wt.	.73	1.00							
9. 15-Month Ht.[b]	1.00								

[a]Measurements were taken within 36 hours of birth.

[b]Height measured at the hips.

TABLE 3

Coefficients of Correlation Among Body Measurements for 1979 Females

Measurement	(9)	(8)	(7)	(6)	(5)	(4)	(3)	(2)	(1)
1. Birth Wt.[a]	.40	.36	.23	.16	.28	.07	.14	-.03	1.00
2. Front Leg[a]	.20	-.05	.31	.30	-.20	.28	-.06	1.00	
3. Front Cannon[a]	.52	-.12	.17	-.27	.09	.42	1.00		
4. 7-Month Wt.	.42	.72	.55	.75	.60	1.00			
5. 7-Month Ht.[b]	.54	.69	.67	.70	1.00				
6. 12-Month Wt.	.75	.96	.81	1.00					
7. 12-Month Ht.[b]	.89	.79	1.00						
8. 15-Month Wt.	.75	1.00							
9. 15-Month Wt.[b]	1.00								

[a]Measurements were taken within 36 hours of birth.

[b]Height measured at the hips

TABLE 4

Coefficients of Correlation Among Body Measurements for 1980 Males

Measurements	(9)	(8)	(7)	(6)	(5)	(4)	(3)	(2)	(1)
1. Birth Wt.[a]	.29	.28	.24	.04	.45	.78	.79	.82	1.00
2. Front Leg[a]	.61	.37	.44	.10	.52	.96	.75	1.00	
3. Front Cannon[a]	.45	.45	.45	.34	.59	.73	1.00		
4. Rear Cannon[a]	.72	.49	.46	.17	.68	1.00			
5. 100-days Ht.[b]	.80	.87	.57	.61	1.00				
6. 7-Months Wt.	.40	.71	.80	1.00					
7. 7-Months Ht.[b]	.55	.56	1.00						
8. 12-Months Wt.	.77	1.00							
9. 12-Months Ht.[b]	1.00								

[a]Measurements were taken within 36 hours of birth.

[b]Height measured at the hips.

TABLE 5

Coefficients of Correlation Among Body
Measurements for 1980 Females

Measurement	(9)	(8)	(7)	(6)	(5)	(4)	(3)	(2)	(1)
1. Birth Wt.[a]	.04	.16	.14	.36	-.19	.42	.23	.56	1.00
2. Front Leg[a]	.25	.12	.30	.31	-.03	.73	.54	1.00	
3. Front Cannon[a]	.29	.21	.32	.33	.06	.56	1.00		
4. Rear Cannon[a]	.34	.30	.26	.23	.07	1.00			
5. 100-Days Ht.[b]	.71	.78	.39	.53	1.00				
6. 7-Months Wt.	.70	.79	.40	1.00					
7. 7-Months Ht.[b]	.56	.37	1.00						
8. 12-Months Wt.	.81	1.00							
9. 12-Months Ht.[b]	1.00								

[a]Measurements were taken within 36 hours of birth.

[b]Height measured at the hips.

the linear measurements taken at birth, but a low correlation, .45 for males and -.19 for females, with birth weight. Furthermore, hip height at one hundred days showed a high correlation with weight and height at twelve months. For the 1980 males, hip height at one hundred days accounted for twenty-five percent more variability in twelve-month weight than did seven-month weight and sixteen percent more variability than twelve-month height. Weight at seven months had a relatively inconsistent association with other traits in the study due to the significant environmental effect on seven-month weight as outlined by Brown et al. (1973b). Hip height at one hundred days was a more consistent measurement with less environmental influence than seven-month weight, which is now used for evaluating young cattle. Also, as discussed by Brown et al. (1972a and b), four months of age represents a point at which the calf's total nutrient intake is from the dam's milk; therefore, this could be a more accurate point to measure the milking ability of the dam than at 205 days. Because of the long generation interval in cattle an accurate method of selection at an earlier age could increase the rate of genetic progress. Also, this is the time when other management practices such as vaccinating, dehorning and castrating can be done without a weight loss from additional weaning stress.

In 1979, seven-month weight accounted for the greatest amount of the variability in twelve-month weight, seventy percent in the males and fifty-six percent in the females.

Also in 1979, birth weight had an extremely low association with fifteen-month weight and height. Among the birth measurements of the 1979 males, front leg length had a correlation of .71 with fifteen-month height and the front cannon bone had a correlation of .47 with fifteen-month weight. Of the more mature traits, twelve-month height had the greatest correlation with fifteen-month height and twelve-month weight had the highest correlation with fifteen-month weight.

A multiple regression equation was used to predict twelve-month weight using selected immature body size parameters as independent variables. In 1979 both groups were deleted from the multiple regression analysis because the number of complete records was too few to conduct an accurate and statistically valid analysis. In the two 1980 groups, twelve-month weight and twelve-month height were used as dependent variables because twelve months is the age at which heifers and bulls are conventionally selected or culled from the breeding herd. Several combinations of independent variables were selected according to their ease of measurement and age at which they were measured. An attempt was made to find the most immature combination of traits that would yield a more accurate prediction of twelve-month weight and height than the conventional 205-day measurements.

For the 1980 bulls, linear measurements at birth, when used as independent variables, were accurate predictors of one hundred-day hip height with a multiple R^2 of .75; but the same linear measurements, even in combination with birth weight, were poor predictors of subsequent growth. Another equation including one hundred-day hip height, birth weight, and front cannon bone length at birth was used to predict twelve-month weight as shown in Table 6. In this equation one hundred-day hip height accounted for seventy-six percent of the variability in twelve-month weight, and the addition of birth weight and front cannon bone length measured at birth did not significantly reduce the residual variability.

In another equation, twelve-month weight remained the dependent variable and one hundred-day hip height, seven-month weight and seven-month hip height were used as independent variables (Table 7). One hundred-day hip height and seven-month weight accounted for eighty percent of the variability, but the inclusion of seven-month hip height gave no significant reduction in residual variability. The conventional measurement used to predict twelve-month weight is seven-month weight. A regression equation (Table 8) calculated with seven-month weight alone accounts for a significant amount of variability in twelve-month weight (R^2 = .50); however, it does not account for as much variability as one hundred-day hip height (R^2 = .76). A study conducted by Brown et al. (1973b) and Tables 2, 3, 4 and 5 show inconsistent relationships between seven-month weight due to an unrestricted environmental effect on seven-month weight.

Seven-month height had a low association with height at other ages. This does not coincide with the results of Healey (1979). The reason for this discrepancy is not clear,

TABLE 6

Multiple Regression Equation for Predicting Twelve-Month Weight for the 1980 Bulls

Model	Y Intercept	b values for Birth Wt.	Front Cannon	Ht. 100[a]	R	R Square
M_1	-1120.41			54.37	.87	.76
M_2	-1153.58	-1.62		58.58	.88	.78
M_3	-1196.62	-1.95	15.47	57.75	.88	.78

TABLE 7

Multiple Regression Equation for Predicting Twelve-Month Weight for the 1980 Bulls

Model	Y Intercept	b values for Ht. 100[a]	Wt. 7[b]	Ht. 7[c]	R	R Square
M_1	-1120.41	54.37			.87	.76
M_2	-973.69	43.69	.38		.90	.81
M_3	-557.86	45.27	.57	-13.44	.91	.82

TABLE 8

Multiple Regression Equation for Predicting Twelve-Month Weight for the 1980 Bulls

Model	Y Intercept	Wt. 7[b]	R	R Square
M_1	100.99	1.08	.79	.63

[a]100-day hip height.

[b]7-month weight.

[c]7-month height.

TABLE 9

Comparison of Regression Equations to Predict the Dependent Variable Twelve-Month Weight

		Independent Variables					
		Ht. 100		Wt. 7		Ht. 100, Wt. 7	
Calf	Actual Wt. 12	$\hat{Y}$	Deviation	$\hat{Y}$	Deviation	$\hat{Y}$	Deviation
M 1	1010	1027	+17	1007	- 3	1056	+29
M 2	1050	1027	-23	999	- 51	1052	+ 2
M 51	1035	1027	- 8	922	-113	1022	-13
M 52	910	891	-19	1007	+ 3	906	- 4
M 59	780	796	+16	771	- 9	777	- 3
M 64	835	823	-12	826	- 9	820	-15
M 70	810	850	-40	806	- 4	835	+25
M 81	630	673	+43	718	+ 88	654	-83
M500	925	891	-34	743	-181	842	-83
M 86	700	728	+28	850	+150	754	+54
Average deviation =			24		61		25

Wt. 12 = twelve-month weight

Ht. 100 = 100-day height

Wt. 7 = seven-month weight

and more work needs to be done in order to more accurately analyze the effect that variation in age at measuring, environment and sample size have upon accuracy of linear measurements.

The three multiple regression equations (Tables 6, 7 and 8) that gave the highest multiple coefficient of determination for predicting twelve-month weight were evaluated for their accuracy in estimating twelve-month weight (Table 9). Ten 1980 bull calves were selected at random, and measurements selected from their performance records were used in the equation in order to compare the accuracy of the estimated Y to the actual twelve-month weight. From this comparison it is evident that twelve-month weight may be accurately predicted and the calves accurately ranked at one hundred days of age. On the average, when using one hundred-day hip height alone, twelve-month weight was estimated to within twenty-four pounds per head of the actual twelve-month weight and the deviations had a range of only thirty-five pounds. When seven-month weight was used in the equation alone, the average deviation was sixty-one pounds per head with a range of one hundred and seventy-eight pounds; and when the two traits were used together as independent variables the deviations averaged twenty-five pounds per head and had a range of eighty pounds. However, the combination of one hundred-day hip height and seven-month weight accounted for four percent more of the variability in twelve-month weight in the regression analysis and should be a more accurate predictor of twelve-month weight than one hundred-day height alone. The similarities in the accuracy of the two regression equations may be a reflection of the small random selection. In ranking the calves in order of actual and estimated twelve-month weight, one hundred-day hip height was again the most accurate by ranking the calves in almost the same order as they ranked according to their actual twelve-month weight. When using seven-month weight as the independent variable, ranking by the estimated Y value resulted in significantly different rankings. In this case the fourth heaviest calf according to the actual weight ranked ninth according to estimated weight and the ninth heaviest calf according to the actual weight ranked fifth according to the estimated weight.

Healey (1979) and Brown et al. (1973a) determined that weight alone did not provide an accurate description of size in cattle. For this reason, several multiple regression equations were calculated using immature body measurements as independent variables to predict twelve-month height. Multiple regression calculations showed that combinations of linear skeletal measurements were the best predictors of twelve-month height. The multiple regression equation that best predicted twelve-month height is shown in Table 10. Records from randomly selected calves were used in this equation to calculate estimated twelve-month heights, and the average deviation from actual height was .78 inches per calf.

From the information derived in this study concerning the relationship between immature body measurements and

TABLE 10

Multiple Regression Equation for Predicting Twelve-Month Height of the 1980 Bulls

Model	Y Intercept	Rear Cannon	Ht. 100[a]	R	R Square
M_1	22.78		.67	.80	.64
M_2	19.51	.90	.48	.83	.70

[a]One hundred-day hip height.

subsequent growth, the conclusion may be drawn that growth rate and more mature sizes can be accurately estimated with the use of immature measurements of skeletal size and weight. These data gave evidence that critical points in the selection program such as twelve-month height and weight can be accurately predicted by one hundred days of age. Furthermore, there is a possibility that one hundred-day weight may be a more accurate measure of the dam's milking ability than seven-month weight. Also, seven-month weight was determined to be a poor predictor of growth due to the amount of variability caused by the environment.

CHAPTER V

SUMMARY

The purpose of this study was threefold in nature. The first portion involved a study of the relationships between selected immature body measurements at various ages. Next, a relationship between immature body parameters and subsequent growth was determined. Finally, multiple regression equations were calculated using twelve-month height and weight as dependent variables.

There was a strong association between weight and linear skeletal measurements taken at the same age. There was no significant relationship between birth weight and height and weight at later ages. Linear skeletal measurements at birth had a strong association with hip height measured at one hundred days, and hip height measured at one hundred days had a strong association with twelve-month weight and height.

Weight at seven months had an inconsistent association with other measurements. This is probably a result of unrestricted environmental influences on seven-month weight.

In regard to the multiple regression equations, those involving one hundred-day hip height were the best predictors of twelve-month height and weight. When twelve-month weight was used as a dependent variable, one hundred-day hip height alone accounted for seventy-six percent of the variability. When seven-month weight was the only independent variable, only fifty percent of the variability was explained, but an equation using both one hundred-day hip height and seven-month weight accounted for eighty percent of the variability in twelve-month weight. The multiple regression equation involving one hundred-day hip height and rear cannon bone length at birth was the best predictor of twelve-month height. This equation had a multiple R of .84 and explained seventy percent of the variability in twelve-month height.

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