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To the Graduate Council:

I am submitting herewith a thesis written by Joe W. High, Jr. entitled "Relationship of Body Measurements to Genotypes for Bovine Dwarfism as Estimated from X-Ray of the Lumbar Vertebrae." I recommend that it be accepted for nine quarter hours of credit in partial fulfillment of the requirements for the degree of Master of Science, with a major in Animal Husbandry.

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RELATIONSHIP OF BODY MEASUREMENTS TO GENOTYPES FOR BOVINE DWARFISM AS ESTIMATED FROM X-RAY OF THE LUMBAR VERTEBRAE

A THESIS

Submitted to
The Graduate Council
of
The University of Tennessee
in
Partial Fulfillment of the Requirements
for the degree of
Master of Science

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by

Joe W. High, Jr.

August 1955

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Joe W. High, Jr.

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CHAPTER I

INTRODUCTION

An inherited type of dwarfism has become frequent enough in beef cattle to cause breeders much concern. Many of these dwarfs die at birth and those that do live have a poor life expectancy. Most of these dwarfs are very susceptible to bloat and many of them develop a breathing difficulty leading to the common name of "snorter" dwarf. Even at so-called maturity, they do not approach a desirable market weight or finish.

This snorter type of dwarfism is found in at least two of the major beef breeds. No data are available with respect to the over-all frequency of this type dwarfism in these two breeds. However, limited reports indicate this condition has become a serious economic problem in many herds. Probably the greatest loss to the purebred breeder is the reputation damage caused by occurrences of dwarfism in his herd.

The snorter type of dwarfism seems to be conditioned by a simple recessive autosomal gene. If this is true, cattle are of three kinds as far as this condition is concerned: non-carrier (normal phenotypically and genotypically homozygous for the dominant normal allele of the dwarf gene), carrier (normal phenotypically and genotypically heterozygous for the dwarf gene) and dwarf (dwarf phenotypically and genotypically homozygous for the recessive dwarf gene). Being a simple recessive, this gene for dwarfism can be passed on by normal appearing cattle. For example, a herd of grade Hereford cows at the University

of Tennessee were mated to two Hereford bulls that were (unknown at the time but later proved to be) heterozygous for this dwarfism. This cow herd was apparently predominantly clean (non-carrier), since no dwarfs occurred from these matings. All thirteen heifers raised from these matings were mated to a son of one of the previous bulls used. This bull also proved to be heterozygous. Three dwarfs, approximately twenty-three per cent of the offspring, resulted from these matings. Although this per cent is higher than would be expected from unselected second generation heifers (actually twelve and one-half per cent of the offspring would be expected to be dwarfs, providing the dams of the heifers were non-carriers), it does illustrate how rapidly the frequency of this type of dwarfism can unknowingly be increased in two generations.

Since dwarfs do not go back into the breeding herd, the incidence of this dwarfism condition would be rather low in an unselected population of normal cattle. For example, if forty per cent of the bulls mated every generation to unselected heifers were carriers, the occurrence of dwarfs would level off around three per cent of the total offspring. If a carrier bull were used every generation on unselected heifers, the occurrence of dwarfs would level off around fourteen and one-half per cent. A maximum of twenty-five per cent dwarfs would be expected if the bull and all the females mated to him were carriers. Due to chance the actual occurrence of dwarfs might deviate greatly from expectations in particular herds in some years.

Purpose

The apparent increase in frequency of this type of dwarfism suggests that normal animals heterozygous for this hereditary characteristic are favored in the selection of breeding stock. The characteristics leading to this possible selective advantage are not known. Recent emphasis in research on the problem has been directed toward finding some means of distinguishing normal homozygous (non-carrier) from normal heterozygous (carrier) cattle. In cooperation with Iowa State College, studies of X-ray pictures of the lumbar vertebrae of young calves were made at the University of Tennessee in an effort to make this distinction. Assuming the X-ray was correct in distinguishing carrier from non-carrier calves, body measurements were made of the calves X-rayed in an effort to make a similar and cheaper distinction. The purpose of this paper is to present a partial analysis of the data collected in Tennessee during 1954 in connection with this study.

Review of Literature

Several different hereditary types of dwarfism have been reported in beef cattle. Lush (1930) reported on an hereditary short-leggedness found in Hereford cattle in Texas. His report indicated this short-leggedness was the result of a single dominant gene inherited in simple Mendelian manner. Short-leggedness was the only phenotyphic characteristic that distinguished these cattle from normal Hereford cattle.

Stonaker et al. (1944) described an inherited type of compactness

in Shorthorn cattle. Extreme compactness of the body and shortness of the long bones were characteristic of this condition. Later data presented by Stonaker (1954) indicated that a similar condition in Hereford cattle (commonly referred to as "comprest" Herefords) was due to an incompletely dominant gene. Homozygotes were an extreme type of dwarf. Results of work reported by Chambers et al. (1954) indicated either that the genes responsible for dwarfism in "comprest" Herefords and the one producing the snorter dwarf in Hereford and Angus cattle are alleles or that many of the "comprest" cattle in this test also carried the recessive snorter dwarf gene found in non-comprest cattle.

Stumpy, a recessive achondroplasia in Shorthorn cattle, was reported by Baker et al. (1950). A curly hair coat, small switch, bowed front legs and inability to put on finish were characteristic of this condition. Another morphological type of dwarfism apparently conditioned by a simple recessive gene was reported in Angus cattle by Baker et al. (1954). Up to about three months of age this type of dwarf usually exhibited exceptionally compact, low-set thick bodies, with short, wide heads. However, this type dwarf usually did not gain and fatten normally and after a few months did not show the same thickness and degree of finish as they had at an earlier age. The head also appeared relatively longer and narrower than at an earlier age.

Elings (1953) mentions there may be six or more genes causing dwarfism among the three major beef breeds. According to Lush and Hazel (1954) most of these genes are so rare that they have little economic importance. However, Lush emphasized that one particular type of

inherited dwarfism (the so-called snorter) has become frequent enough in beef cattle to cause an economic problem.

This inherited type of dwarfism was first described by Johnson et al. (1950). He reported this condition to be inherited as a monofactorial autosomal recessive in Hereford cattle. Similar observations in Hereford cattle were reported by Gregory et al. (1951), Carroll et al. (1951), and Lindley et al. (1951). Later reports on test matings by Pahnish et al. (1954) and by Lush and Hazel (1954) were in agreement with earlier observations on the type of inheritance.

Gregory et al. (1953) mentioned that this type of dwarfism is present in Angus and Shorthorn cattle. However, no details were given. Crossbred dwarfs from Hereford-Angus matings at the University of Tennessee (1954) gave evidence that this dwarfism was conditioned by the same gene in both breeds.

In general, the following abnormalities were reported as characteristic of the snorter type of dwarfism at birth: undershot lower jaw, comparatively short, broad heads, a protrusion of the eyes and tongue, apparent muscular weakness, incoordinated locomotion, faulty equilibrium, proportionately short forecannons, and sometimes knuckling pasterns. These characteristics were variable in degree and did not always persist for an extended period of time. Many of these dwarfs died soon after birth and those that did live to maturity were reported to be very susceptible to bloat.

Other characteristics of the snorter dwarf that may or may not have been present at birth, but that usually developed during the three

months following birth were: marked mid-forehead prominence, blocky appearance, forced respiration, low weight for age, an inclination to bloat, and a lack of thriftiness. According to Pahnish et al. (1954) these conditions, along with incoordinated locomotion, protrusion of the lower jaw, and proportionately short forecannons usually persisted throughout life. However, he reported that both sexes attained the ability to fatten after two years of age.

Lush and Hazel (1954) stated that cattle are of three kinds as far as the snorter type dwarf gene is concerned: normal, carriers and dwarfs. Lush listed six theoretically possible matings and gave the expected genotypic and phenotypic ratios of each mating. Since the incidence of this type of dwarfism has become rather frequent in many lines and herds of beef cattle, Lush suggested the possibility that animals which are normal but carriers of the gene might be favored in the selection of breeding stock. His suggestion is in agreement with those made by earlier investigators. However, no data have been published confirming this suggestion.

Lush and Hazel (1954) discussed and gave the limitations of several methods by which this dwarfism might be controlled or eliminated in beef herds. The following is a list of those methods:

1. Clean-up by pedigree.
2. Clean-up by progeny test.
3. Clean-up by discarding close relatives of dwarfs.
4. Clean-up by recognizing carriers.

Studies of recent investigators have been directed toward the latter method.

Lush et al. (1952) and Gregory et al. (1952) reported their unsuccessful attempts to distinguish by visual inspection normal (non-carrier) animals from animals which were proved carriers of the dwarf gene. A more objective method for making this distinction was reported by Gregory et al. (1952). Briefly, this distinction was based on statistical analysis of head profile measurements made with a precision instrument called a profilometer. Gregory et al. (1954) reported this method to be highly accurate. However, other tests of this method reported by Pahnish et al. (1954) and Stonaker et al. (1954) did not confirm Gregory's high estimates of accuracy.

Lush and Hazel (1954) listed bulginess of the forehead, X-ray pictures, blood tests, hormone activity and body measurements as plausible clues that are now being tested experimentally in an effort to separate carriers from non-carrier animals.

Recently, studies of X-ray pictures of the lumbar vertebrae of young calves and body measurements were initiated at Iowa State College in an effort to make this distinction. The University of Tennessee, in cooperation with Iowa State College, has participated in these studies.

Experimental Procedure

Body Measurements

Body measurements were made of the 1954 progeny of three Hereford bulls that had sired dwarf calves. The progeny of bulls I and II were out of a purebred herd of horned Hereford cows. This herd had been randomly divided into two breeding herds and mated to bulls I and II,

respectively. The progeny of bull III were out of a cow herd made up of purebred and grade horned Herefords. These cows were purchased from a different breeder, but from the same general area as were many of the cows mated to bulls I and II. Apparently these cow herds were predominately clean (dwarf-free) since no dwarfs occurred from these matings.

Table I lists the body measurements taken and gives the reference points from which each measurement was made. All of the body measurements, except skin thickness, were made to the nearest tenth of a centimeter. The skin thickness was measured to the nearest one-twentieth of a centimeter. The linear body measurements were made with calipers mounted on a meter stick. The meter stick was graduated into tenths of a centimeter. The circumference and round measurements were made with a steel tape, also graduated to the nearest tenth of a centimeter. A small metal caliper, on which the nearest twentieth of one centimeter could be estimated, was used for skin measurements.

Protrusion of the lower jaw was estimated by putting the tip of the thumb against the outer surface of the upper pad and at the same time pressing the inside of the thumb against the lower incisors. The distance from the tip of the thumb to the teeth imprint was estimated to the nearest half of one centimeter. Weight was recorded to the nearest pound. Other data recorded at the time of each measurement included scores for type, condition and sex development.

All the calves were measured at birth or within a few days after birth. A schedule was set up to measure the calves every 28 days beginning before the oldest calf reached one month of age. This schedule

TABLE I

LIST OF BODY MEASUREMENTS AND REFERENCE POINTS OF MEASUREMENT

1. Wither height	Along line perpendicular to ground just posterior to elbow joint. Calipers.
2. Chest depth	On same line as height measurement. Calipers.
3. Chest height	On same line as height measurement. By subtraction, 1 - 2.
4. Body length	Anterior edge of shoulder point to posterior edge of pin bone. Calipers.
5. Rump length	Anterior edge of hook bone to posterior edge of pin bone. Calipers.
6. Coupling length	Anterior edge of hook bone to posterior edge of last rib. Calipers.
7. Width shoulder	Widest point in shoulders. Calipers.
8. Width forerib	Widest point in depression behind shoulders. Calipers.
9. Width loin	Midway in coupling. Calipers.
10. Width hooks	Calipers.
11. Width pins	Calipers.
12. Depth twist	Top of rump to twist. Calipers.
13. Head length	Top of poll to muzzle. Calipers.
14. Muzzle length	Level top of eyes to muzzle. Calipers.
15. Head width	Widest part of head just above eyes. Calipers.
16. Muzzle width	Widest part of muzzle. Calipers.

TABLE I

LIST OF BODY MEASUREMENTS AND REFERENCE POINTS OF MEASUREMENT
(CONTINUED)

17. Teeth (if undershot)	Distance, teeth to pad with mouth shut. Ruler.
18. Length cannon bone (metacarpus)	On posterior surface of front leg, accessory carpal bone to top of dewclaw. Calipers.
19. Length of forearm (ulna)	On posterior surface of front leg, accessory carpal bone to "elbow" (olecranon). Calipers.
20. Length of upper arm (humerous)	Anterior edge of shoulder point to posterior point of elbow. Calipers.
21. Length metatarus	Point of hock (tuber calcis) to top of dewclaw. Calipers.
22. Length tibia	Point of hock to anterior edge of stifle joint (patella). Calipers.
23. Length stifle to pins	Anterior edge of stifle to posterior edge of pin bone. Calipers.
24. Circumference cannon bone	At smallest point. Tape.
25. Circumference Heart	At narrowest point just behind shoulders. Tape.
26. Circumference paunch	At largest point of barrel. Tape.
27. Circumference rear flank	Just anterior to hooks. Tape.
28. Round measurement	Patella to patella. Tape.
29. Tail length	Attachment to end of tail proper (do not include switch). Tape.
30. Skin thickness	Double thickness of skin over midrib halfway down side. Small caliper.

TABLE I

LIST OF BODY MEASUREMENTS AND REFERENCE POINTS OF MEASUREMENT
(CONTINUED)

31. Type score	Medium = 7. Good = 10. Choice = 13. Fancy = 16.
32. Condition score	Commercial = 7. Good = 10. Choice = 13. Prime = 16.
33. Sex development score	A subjective evaluation of apparent masculinity or femininity as these terms are ordinarily used by judges. To be especially emphasized in case of bulls. Score as 1, 2, 3, 4, or 5 with 3 representing hypothetical average development for age, 5 exceptional and 1 poor.

was followed, except in a few instances, until the measurements were terminated just prior to weaning.

The calving period extended from the last of January through the middle of May. The calves ranged in age from nine to slightly less than six months when the measurements were terminated the latter part of October.

For measurement, the calves were haltered and allowed to stand in as nearly natural positions as possible. This was not always an easy accomplishment. However, most calves became more docile each time they were handled.

Most of the measurements were taken by two animal husbandmen[1]; however, some of the birth measurements were taken by a herdsman. Early measurements were repeated several times in order for the two men to become oriented on the proper reference points of each measurement. During this training period the repeatability for a particular measurement was checked by each technician, also the repeatability between technicians was checked. These checks were made by observation and no formal statistics were run to confirm them. From observation, most of the skeletal measurements were highly repeatable. However, some measurements, such as depth of twist, coupling length and width of pins, were more variable.

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[1]The measurements were taken by Dr. E. J. Warwick, regional coordinator of Project S-10 "Beef Cattle Breeding" for the Southern Region, and Dr. H. J. Smith, Associate Professor of Animal Husbandry at the University of Tennessee.

After this initial orientation period measurements were not repeated unless they were obviously out of line with previous ones taken. This was due to the large number of calves measured and to the limited time available for taking the measurements.

X-Ray Procedure

In addition to the body measurements, X-ray pictures of the lumbar vertebrae of each calf were made, usually within two weeks after birth. The exposures were made with a portable X-ray machine with a fifty milliamp and ninety kilo-volt capacity. The calves were tied and placed on their side. A dark cloth around their eyes was very effective in quieting them down. Two or more exposures were made of the lumbar vertebrae on a slow film. The time of each exposure varied with the calf's loin width and the kilo-voltage used. It usually ranged from one to three and one-half seconds. Although this amount of time is comparatively long, surprisingly few films were ruined due to movement of the calf. The milli-amperage was usually held constant at forty, while the kilo-voltage varied from seventy to eighty-five. A distance of thirty inches between the X-ray tube and the film was used.

With the X-ray machine used, two weeks was about the maximum calf age at which a readable exposure could be taken. This was due primarily to the increasing amount of muscular tissue surrounding the vertebrae. Also, a masking effect was produced by some internal organ or organs. This effect, along with the increased muscle tissue, gave the bone outline a hazy appearance. Limited anatomical studies indicated this masking effect was due to the rumen on the left and liver on the right side

of the vertebrae. The severity of this effect was variable between calves, but increased with age and size of the calf. In recent work, the addition of a cone, grid and the use of fast film cut the time of exposure down considerably and increased the quality of exposures made on larger calves. Techniques are still being studied in an effort to make readable exposures of calves over two weeks of age.

At the time these exposures were made it was not known if the structure of the bone at the points of differentiation changed with age. In later work not reported in this thesis, readable pictures of calves made at weekly intervals up to a month of age, show slight, but probably real, changes at the points of differentiation. However, in calves X-rayed to date, recovery by one month of age has not been great enough to change the original classification in any case.

Method of Classification

The X-ray exposures were classified on the basis of a method used by Dr. L. N. Hazel of Iowa State College. Dr. Hazel classified some of the exposures and the remainder were classified by the two previously mentioned animal husbandmen and third animal husbandman[2]. The men were taught the principles of this method by Dr. Hazel.

Dr. Hazel's method of classification was based almost entirely on the ventral body outline of the lumbar vertebrae. Other factors such as density lines and proportional length of the vertebrae were taken into

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[2]J. M. Griffith, Assistant Animal Husbandman of the University of Tennessee.

consideration. However, they had little effect on the final classification.

If the ventral body outline of the lumbar vertebrae gave a smooth, curved line appearance with no irregular protrusions, the animal was classified as a C (clean, or non-carrier - see Figure 1). The ventral vertebrae outline of an animal classified as a B (carrier) showed small teat-like projections or irregular protrusions (see Figure 2). The general outline of the B type vertebrae, except for the protrusions, appeared more straight lined than those of the C type. However, this was variable. Also, some of the B type vertebrae showed density lines which might be an indication of some inward force or pressure. Except in extreme cases only two or three of the six lumbar vertebrae showed these characteristics. The remaining vertebrae were normal. The B type classification was divided into seven sub-divisions, B_2 through B_8, depending on the number of vertebra that appeared abnormal and the number and size of the protrusions. The vertebrae of the B_2 animals approached that of the C type animals. The break between the C and B_2 types exposures was not very clear cut, indicating an overlap between the two.

The A, or dwarf, vertebrae appeared proportionately short in comparison with a C or B type vertebrae. A very pronounced double protrusion was characteristic of the A type ventral body outline of all six lumbar vertebrae (see Figure 3). The posterior and anterior epiphysis of the vertebrae body of dwarfs were more developed than those of the B and C type calves. A considerable number of dwarfs were X-rayed and their pictures were rather easily distinguished from those of the most

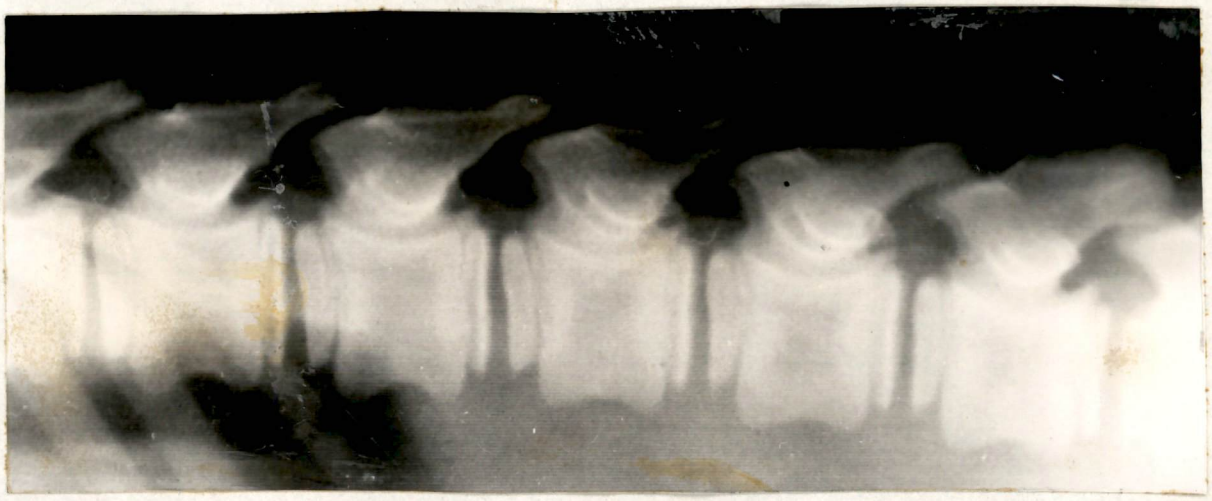


Figure 1. C Type Vertabrae.

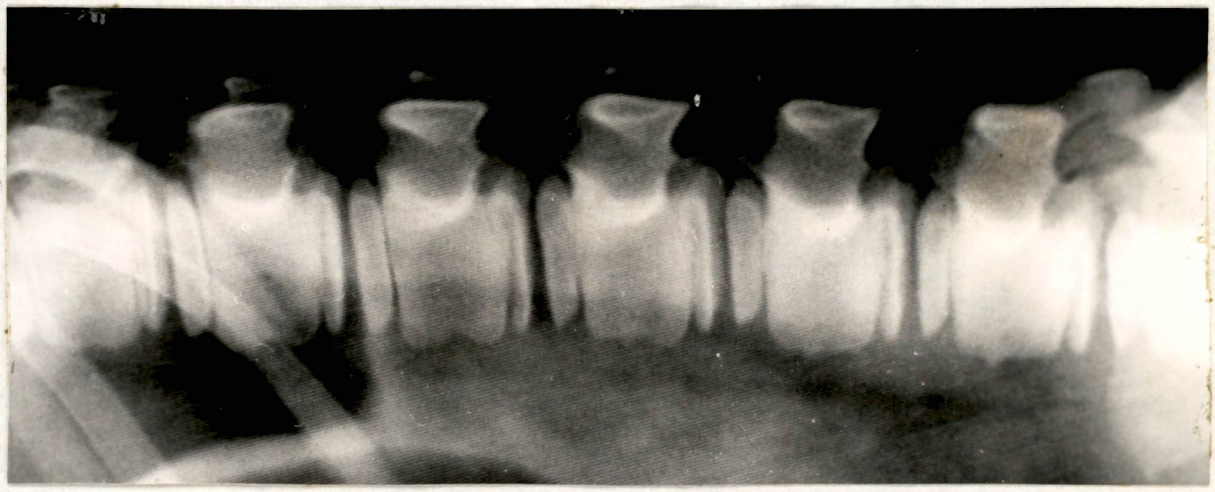


Figure 2. B Type Vertabrae.



Figure 3. A Type Vertabrae.

extreme B type pictures, indicating a clean break between these two classifications.

Animals with non-readable X-ray exposures were classified as questionable. Non-readable exposures were due primarily to the large size of the calves at the time the exposures were made. Exposures of two nervous calves were ruined due to movement. The measurements of calves whose X-ray exposures were questionable were not included in the analysis. The measurements of four other B type calves, a male and three females, sired by bull I were not included in the analysis of body measurements. One calf died and the other three were transferred to another station shortly after birth. Two other calves, a B type male and a C type female, sired by bull II were not included in the analysis. The growth of the former was considered abnormal since it was out of a poor milking cow and weighed only two hundred and ten pounds at weaning. The latter was transferred to another station.

The exposures were first classified by the men independently. Their classifications were then compared and those not in agreement were rechecked and a final classification was collectively made.

CHAPTER II

RESULTS AND DISCUSSION

Table II gives the progeny of each bull by sex and X-ray classification. Since the calves were all progeny of bulls which had sired dwarfs and since the cow herds were thought to be free of the gene for dwarfism, the assumption of a mono-factorial recessive as the mode of inheritance leads to the expectation that, on the average, half the calves should be carriers and half non-carriers. Chi square and probability for deviation of X-ray ratios from expected ratios are given in Table II.

The ratio of carrier to non-carrier in the progeny of bull II deviated somewhat from the expected ratio; however, this deviation was within the limits of chance, with a probability between twenty and thirty per cent. The ratios of the other two bulls were approximately the same as the expected ratios.

In order to get some initial information on growth rates and differences between calves with C and B type X-rays, a preliminary study was made of six measurements. The six measurements used were found to be some of the more discriminating ones in earlier work at Iowa State College. These measurements, including weight, loin width, head length, cannon length, and body length were summarized by X-ray classification and sex. This summary included measurements from birth to six months of age at monthly intervals. The measurements taken nearest a given month of age were used as the measurements for that age respectively.

TABLE II

X-RAY CLASSIFICATION OF CALVES BY SIRES

Sire	Total No. of Calves	X-ray classification				Chi** Square	Probability
		Dwarfs	Carriers	Non-carriers	Questionable*		
I	22	0	10	9	3	0.052	.80 < P <.90
II	22	0	7	12	3	1.316	.20 < P <.30
III	17	0	7	8	2	0.067	.70 < P <.80
Total	61	0	24	29	8	.472	.40 < P <.50

*X-ray pictures not readable. These calves omitted from Chi square calculations.

**An expected fifty-fifty ratio of carriers to non-carriers was assumed.

This summary is given in Table V of the appendix.

The averages of each measurement at any given age up to six months were greater for the C type than that of the B type animals, except in a few instances where the averages were the same. This was true in both sexes.

The over-all average of these measurements by months of age was plotted on a graph to determine the effects of age on each measurement (see Figure 4). Observation of this graph indicated growth rates for these measurements, with the exception of cannon length, were apparently linear up to six months of age. Further analysis indicated cannon growth was curvilinear up to ninety-three days of age. At this age cannon growth leveled off rather abruptly and was linear to six months of age.

With this information, it was decided to select an age at which to standardize each measurement in order to put them on a comparable basis. The use of a standard age rather than a standard weight was debatable, for the weights of calves are influenced by many factors. However, the dams of these calves were randomly divided into the various breeding herds. Even if selection had been practiced in mating the cows there was no way of knowing what the X-ray classification of a particular cow's offspring would be. Thus, assuming there was no difference between the B type and C type calves within sex, the weights of these calves would tend to balance out at a given age. Another reason, though probably not a justifiable one, was that standard ages had not been used in the analysis of earlier work at Iowa State College.

EFFECTS OF AGE ON CERTAIN BODY MEASUREMENTS

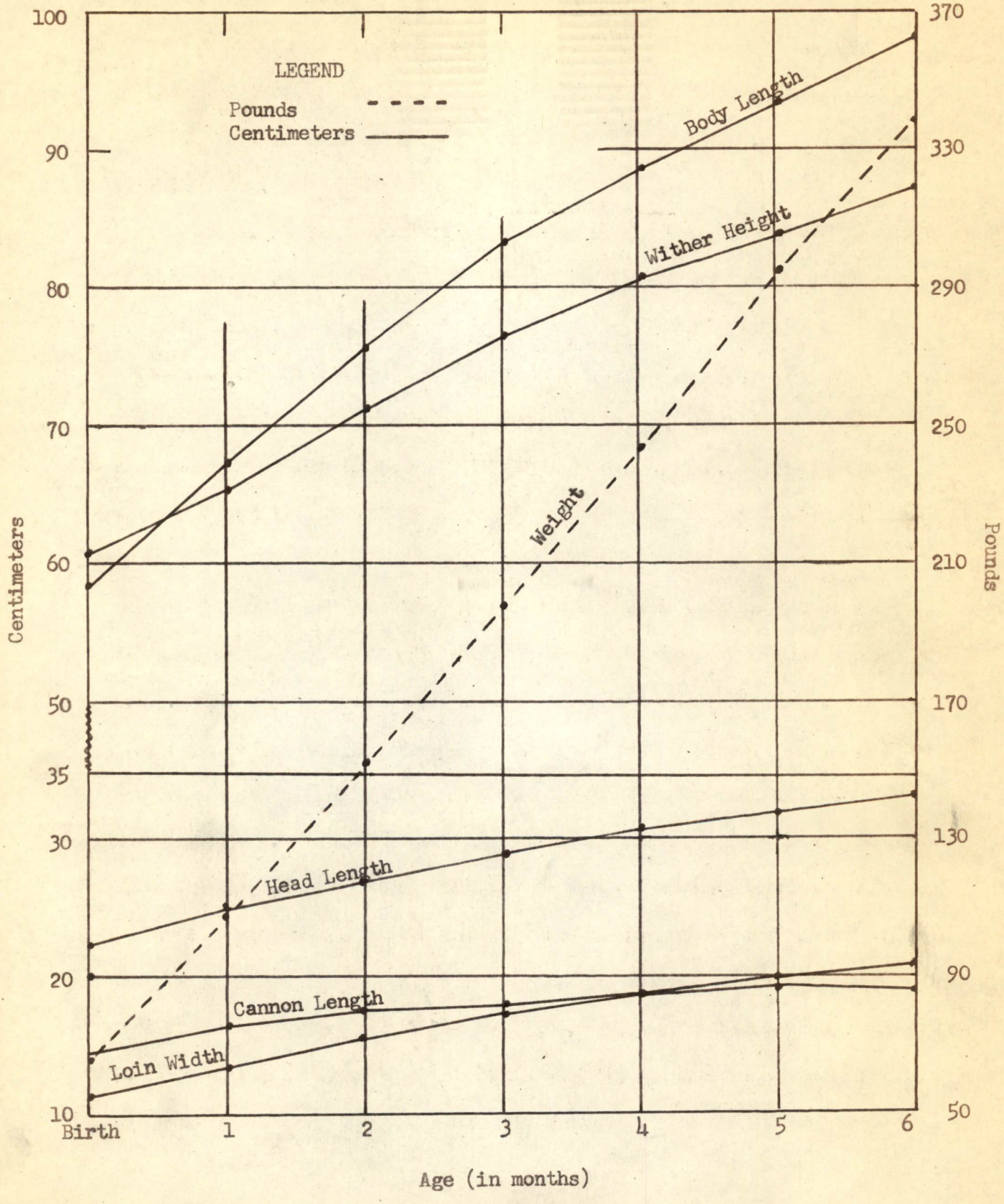


Figure 4

Figure 4 indicated the measurements were linear, or nearly so, up to six months of age; therefore, selection of a standard age would seem arbitrary up to this age. Observation of the average measurement differences between the C type and B type calves indicated that in general these differences increased slightly with age. A standard age of five months was selected because some of the youngest calves were slightly less than six months of age when the measurements were terminated; therefore, five months was the oldest age at which a measurement of these calves could be bracketed.

Body measurements including weight, wither height, loin width, head length, head width, cannon length, cannon circumference, tibia length, stifle to pins lehgth, paunch circumference, round measurement, tail length, shoulder width, and body length were standardized to five months of age by averaging the measurements taken nearest four, five and six months of age. Type scores were also summarized by this method. In a few cases where measurements were not taken near five months of age an average of the four and six months measurements was used. The average obtained from this method was a rough one. However, the amount of human error encountered in taking the measurements was reduced. Due to the large amount of data, a more precise method was prohibitive for this thesis.

The five-month averages of these measurements were summarized by X-ray classification and sex (see Table VI of the appendix). The overall averages of this summary are given in Table III.

Weight was the largest measurement difference between the B type

TABLE III

AVERAGES OF BODY MEASUREMENTS STANDARDIZED TO FIVE MONTHS OF AGE AND GROUPED ACCORDING TO X-RAY CLASSIFICATION AND SEX

	Weight	Wither Height	Loin Width	Head Length	Head Width	Cannon Length	Tibia Length	Stifle to pins Length	Cannon Circum.	Paunch Circum.	Round Meas.	Tail Length	Shoulder Width	Body Length	Av. Type Grade
							B Type - Males								
Total:	3172[a]	922.5	213.4	352.0	180.1	200.9	379.6	382.5	159.1	1467	780.9	498.7	309.8	1011.2	126.0
Av.	288.0	83.9	19.4	32.0	16.4	18.3	34.5	34.8	14.5	133	71.0	45.3	28.2	91.9	11.5
							C Type - Males								
Total:	5289	1448.4	341.0	548.9	278.2	322.5	597.6	613.1	252.0	2308	1257.0	792.2	499.5	1615.1	191.1
Av.	311.1	85.2	20.1	32.3	16.4	19.0	35.2	36.1	14.8	136	73.9	46.6	29.4	95.0	11.2
							B Type - Females								
Total:	2169	649.7	150.8	246.4	127.1	143.4	269.6	271.8	110.3	1029	559.3	358.0	223.0	736.0	95.4
Av.	271.0	81.2	18.8	30.8	15.9	17.9	33.7	34.0	13.8	129	69.9	44.8	27.9	92.0	11.9
							C Type - Females								
Total:	3089	928.1	217.0	347.0	175.7	207.2	384.2	384.8	153.5	1441	792.8	517.0	312.3	1042.1	128.5
Av.	289.9	84.4	19.7	31.5	16.0	18.8	34.9	35.0	14.0	131	72.1	47.0	28.4	94.7	11.7
							Dwarfs - Female								
Total:	396	141.9	29.4	57.2	32.1	28.2	58.4	58.2	26.0	254	122.2	74.3	49.6	153.1	
Av.	198	71.0	14.7	28.6	16.0	14.1	29.2	29.1	13.0	127	61.1	37.2	24.8	76.6	
							Dwarfs - Male								
Total:	409	145.9	29.4	56.4	31.9	29.2	58.6	57.7	27.9	243	128.9	83.2	52.3	157.7	
Av.	204	73.0	14.7	28.2	16.0	14.6	29.3	28.8	14.0	122	64.4	41.6	26.2	78.8	

[a]All measurements in centimeters except weight which is in pounds.

and C type calves in both sexes. These weight differences were not significant in either sex because of the variation within a classification. Wither height differences between the B and C type females were highly significant. There was no significant difference between the two classifications in either sex for loin width, cannon length, tibia length and body length. The average differences between the other measurements were so small that no test of significance was made. However, the average of each measurement of the B type calves was intermediate between the respective average measurements of the dwarf and C type calves.

The smaller average measurements of the B type calves, such as head length, cannon length, and tibia length, are characteristics which are desirable in beef cattle. The slightly higher type scores of the B type calves would suggest that a slightly higher per cent of B type calves would be favored over C type calves in the selection of breeding stock.

For further studies of the data, a table of ratios was set up by X-ray classification and sex using the five-month averages of all calves for each measurement. A study of this table (Table VII of the appendix) indicated that most of the ratios between measurements of the B type calves were intermediate between respective measurement ratios of the dwarf and C type calves. In almost every case the size of the differences in ratios between the B and C type calves was proportionally smaller than differences in one or both of the actual measurements. This would suggest that most differences were related to size and that on a

proportionate basis there was little difference between the measurements of the B type and C type calves.

From this ratio table, five measurements were selected for further study in an effort to find significant differences between the B type and C type calves. The ratios of these measurements in the B type calves were intermediate between the respective measurement ratios of the dwarf and C type calves. Observation of actual measurement differences between B type and C type calves and the variance of a measurement within each classification was considered in selecting these five measurements. Previous measurements used in work at Iowa State College were also considered.

Discriminate functions as developed by Fisher (1936) were calculated for each sex using the five measurements selected, including weight, loin width, head length, cannon length and body length, in efforts to see if an optimum weighting of measurements would group the calves in the same fashion as did the X-rays. Discriminate functions weight a number of factors in such a way that maximum differentiation is given between two groups where there is overlap in each single factor.

Table IV gives the results of this analysis by X-ray classification and sex. Discriminant functions for the B and C types were significant and highly significantly different in males and females, respectively. Figure 5 gives the frequency distributions of functions by X-ray type and sex. There was considerable overlap between the B and C type male calves. However, there was almost complete separation of the

TABLE IV

DISCRIMINATE FUNCTION VALUES

Specification	Calf No.	Body measurements*					Discriminate Function**
		Weight	Loin Width	Head Length	Cannon Length	Body Length	
		Function weights					
		1.00	-8.91	-119.3	169.0	13.58	
B Type - Males	7	327[a]	20.6	33.0	19.2	96.1	434.5
	11	390	21.4	34.7	20.0	99.4	405.3
	28	280	19.4	30.9	17.3	92.3	322.4
	35	283	19.1	31.8	18.0	95.5	379.6
	38	263	17.9	30.6	18.0	91.3	476.1
	37	243	17.1	29.6	17.3	84.6	393.0
	A459	307	20.2	33.1	18.3	96.3	276.6
	G482	322	20.2	32.6	18.5	97.3	383.7
	A534	222	18.7	30.3	18.3	84.0	455.9
	A547	237	19.1	32.0	18.0	84.4	204.5
	A548	298	19.7	33.4	18.0	90.0	108.9
	Total	3172	213.4	352.0	200.9	1011.2	3840.5
	Av.	288.0	19.4	32.0	18.3	91.9	349.5
C Type - Males	15	342	23.1	33.3	20.1	97.6	549.1
	26	313	19.3	32.7	18.8	95.2	401.9
	27	275	18.2	31.2	18.3	90.9	447.3
	33	383	20.8	34.6	19.5	102.0	373.3
	6	253	19.1	30.7	18.8	90.8	581.8
	9	295	20.0	32.1	18.5	93.4	391.9
	21	280	19.0	31.6	19.1	92.9	554.9
	23	208	17.0	28.4	17.0	88.1	533.5
	24	262	17.8	29.6	18.9	90.8	741.6
	34	345	19.8	33.0	18.6	97.1	354.0
	A451	377	22.7	34.9	19.6	100.0	310.3
	G451	230	17.6	30.1	18.1	85.6	477.6
	A455	375	22.5	33.5	19.5	98.7	444.4
	G486	405	22.4	34.9	19.5	110.2	434.9
	A491	303	19.7	32.5	18.3	94.4	326.7
	G508	365	23.0	34.6	21.4	101.0	661.1
	A550	278	19.0	31.2	18.5	86.4	412.9
	Total	5289	341.0	548.9	322.5	1615.1	7997.2
	Av.	311.1	20.1	32.3	19.0	95.0	470.4

TABLE IV

DISCRIMINATE FUNCTION VALUES (CONTINUED)

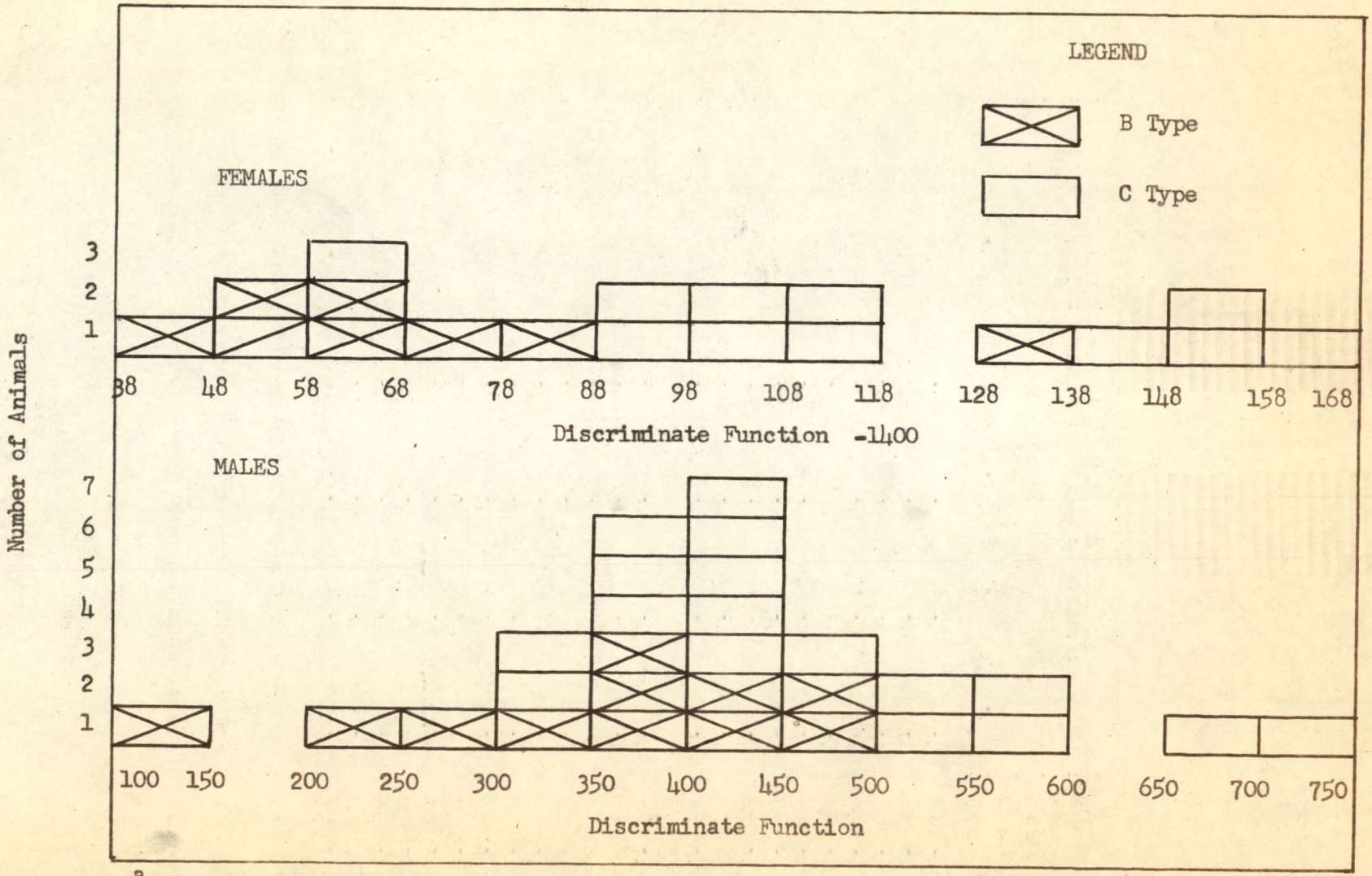
Specification	Calf No.	Body measurements*					Discriminate Function**
		Weight	Loin Width	Head Length	Cannon Length	Body Length	
		Function weights					
		1.00	1.01	15.62	50.55	3.64	
B Type - Females	29	328	20.2	32.6	17.8	97.3	1455.6
	8	257	18.7	30.1	17.4	92.2	1447.2
	10	292	20.5	30.9	18.0	93.4	1461.2
	16	298	19.6	31.1	19.2	97.0	1531.2
	31	268	17.4	31.0	17.7	93.5	1468.9
	39	197	16.3	29.5	17.0	84.8	1448.3
	A458	322	21.0	31.9	18.5	95.6	1480.6
	A481	207	17.1	29.3	17.8	82.2	1466.9
	Total	2169	150.8	246.4	143.4	736.0	
	Av.	271	18.8	30.8	17.9	92.0	1461.0
C Type - Females	3	283	20.6	31.3	18.5	93.3	1501.5
	4	303	20.0	31.9	18.5	95.4	1497.9
	17	277	19.2	32.5	18.9	95.8	1554.1
	30	277	18.3	31.0	18.0	91.1	1467.2
	36	355	20.3	33.2	19.0	101.5	1514.0
	1	315	19.5	31.6	19.1	96.1	1513.6
	5	235	18.8	30.1	19.0	91.6	1548.0
	13	322	20.7	33.2	19.6	96.0	1557.7
	19	235	19.1	29.6	18.1	93.2	1500.8
	22	262	18.7	30.1	18.7	89.4	1497.8
	A503	325	21.8	32.5	19.8	98.7	1564.8
	Total	3089	217.0	347.0	207.2	1042.1	
	Av.	289.9	19.7	31.5	18.8	94.7	1520.4

*Measurements standardized to five months of age.

**Sum of the five weighted measurements for each calf.

[a]All measurements in centimeters except weight which is in pounds.

Distribution of Calves According to Their Discriminate Function[a]



[a] Sum of five weighted body measurements including loin width, head length, cannon length, body length and weight.

Figure 5

B and C type female calves. The functions of only two calves, one from each X-ray classification appear to be out of place in the female classification. The B type calf had the longest and the C type calf had the shortest cannon in their respective classifications. Since cannon length was the most heavily weighted measurement, the function of these calves was very much affected.

It should be pointed out that these functions were both developed and tested on the same set of measurements. For a fully valid test, testing would have to be on a different set of calves. However, significant difference between the measurement functions of the B and C type calves in both sexes would indicate some relationship between these body measurements and X-ray classifications. Assuming the X-ray is correct in distinguishing carrier from non-carrier animals, these data would indicate that body measurements of the females could be used with fair accuracy to make this distinction. However, the amount of overlap between the measurement functions of the B and C type males in this study would limit the use of body measurements in making this distinction between male animals.

These calves will have to be progeny tested and the application of these methods tested on other animals before any conclusive statements can be made with regard to the validity of these methods as a means of distinguishing carrier from non-carrier calves.

CHAPTER III

SUMMARY

X-ray pictures were made of the lumbar vertebrae of young calves in an effort to distinguish animals heterozygous for the snorter dwarf gene from animals homozygous for the normal allele of the dwarf gene. Assuming the X-ray technique was correct in making this distinction, body measurements were made of the calves X-rayed in an effort to make a similar and cheaper distinction. These calves were the 1954 progeny of three Hereford bulls that had sired dwarf calves. The progeny of these bulls were out of purebred and grade horned Hereford cows. These cows were apparently predominately clean (non-carriers), since no dwarfs occurred from these matings.

On the basis of their X-ray pictures the calves were classified as non-carriers, carriers or dwarfs, according to a method used by Dr. L. N. Hazel of Iowa State College. The ratio of non-carrier to carrier calves according to X-ray classifications were approximately the same as the expected ratios.

The body measurements were standardized to five months of age and summarized by X-ray classifications and sex. Averages of this summary indicated that the X-ray type carriers had slightly higher type scores and such desirable beef characteristics as shorter heads, cannons and tibias than did the X-ray type non-carriers. These data suggest that a slightly higher per cent of X-ray type carriers would be favored over X-ray type non-carriers in the selection of breeding stock.

A discriminate function was applied to five body measurements including weight, loin width, head length, cannon length and body length. These functions gave significant difference between the non-carrier and carrier type classifications in both sexes. These significances suggest a relationship between X-ray classifications and the measurements analyzed. With the exception of two calves, the separation of carrier from non-carrier females according to measurement functions was identical with the separation given by X-ray classifications. However, there was considerable overlap between the measurement functions and the X-ray classifications of the male calves. Assuming the X-ray is correct in distinguishing carrier from non-carrier animals, the overlap of the measurement functions for the male calves would limit the use of body measurements for making this distinction between male calves.

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APPENDIX

TABLE V

SUMMARY OF BODY MEASUREMENTS AT MONTHLY INTERVALS FROM BIRTH TO SIX MONTHS OF AGE BY X-RAY CLASSIFICATION AND SEX

Calf No.	Loin width						
	Birth	1 mo.	2 mo.	3 mo.	4 mo.	5 mo.	6 mo.
	B Type - Males						
7	11.2[a]	13.2	17.0	19.2	19.8	22.0	20.0
11	11.5	14.8	25.5	18.3	20.0	22.2	22.1
28	12.0	14.5	16.0	17.5	19.5	19.9	19.2
35	11.5	13.1	15.7	17.2	17.5	19.0	20.8
38	14.4	13.2	15.2	16.2	17.2	17.4	19.2
37	11.2	11.9	13.9	15.8	16.4	16.6	18.4
A459	10.6	12.3	14.8	18.0	18.3	18.8	23.6
G482	10.6	12.8	14.5	16.7	18.6	20.5	21.5
A534	10.0	13.3	13.6	14.0	18.1	18.5	19.6
A547	11.3	11.8	14.5	16.1	17.5	18.9	19.3
A548	10.2	13.0*	15.8	17.9	18.5	19.2	20.2
Total:	124.5	143.9	176.5	186.9	201.4	213.0	223.9
Av.	11.3	13.1	16.0	17.0	18.3	19.4	20.4
	C Type - Males						
15	12.2	16.5	17.6	19.9	22.6	23.6	23.2
26	10.4	13.2	14.8	16.0	18.5	19.0	20.4
27	11.6	12.0	14.8	17.5	17.0	18.7	18.9
33	12.7	14.8	17.8	19.8	18.7	20.2	23.5
6	9.9	12.2	15.1	17.4	18.7	19.0	19.6
9	10.5	13.2	16.3	17.2	19.8	20.3	20.0
21	13.6	12.8	14.5	16.1	17.9	19.1	20.0
23	9.4	12.2	14.0	14.8	16.5	17.0	17.6
24	9.9	11.6	13.3	15.3	17.8	17.3	18.4
34	13.0	15.2	23.3	19.9	19.0	19.4	21.1
A451	10.6	12.4	15.8	18.0	20.8	22.5	24.7
G451	9.8	10.8	13.7	14.3	15.7	17.3	19.8
A455	10.6	12.5	16.6	19.2	19.8	22.8	24.8
G486	13.3	16.1	17.8	19.3	19.9	20.5	24.4
A491	9.9	11.8	14.4	15.8	18.9	18.8	21.3
G508	12.2	15.3	19.2	20.0	21.5	23.1	22.8
A550	12.3	13.5*	14.8	18.2	18.8*	19.4	19.6
Total:	191.9	226.1	273.8	298.7	321.9	338.0	360.1
Av.	11.3	13.3	16.1	17.6	18.9	19.9	21.2
Grand Total:	316.4	370.0	450.3	485.6	523.3	551.0	584.0
Av.	11.3	13.2	16.1	17.3	18.7	19.7	20.9

TABLE V

SUMMARY OF BODY MEASUREMENTS AT MONTHLY INTERVALS FROM BIRTH TO SIX MONTHS OF AGE BY X-RAY CLASSIFICATION AND SEX (CONTINUED)

Calf No.	Loin width						
	Birth	1 mo.	2 mo.	3 mo.	4 mo.	5 mo.	6 mo.
	B Type - Females						
29	11.3	13.0	14.8	16.3	18.8	19.7	21.0
8	10.3	12.7	15.6	15.9	17.9	19.3	18.8
10	10.4	14.7	16.2	19.2	20.1	20.5	20.9
16	12.4	14.7	17.3	18.8	20.4	18.3	20.0
31	10.8	12.0	14.6	14.9	17.2	16.2	18.8
39	11.6	12.5	13.6	16.2	15.5	14.6	18.8
A458	10.0	13.0	16.4	17.9	19.7	21.9	21.3
A481	9.6	10.0	12.1	13.2	15.4	16.8	19.0
Total	86.4	102.6	120.6	132.4	145.0	147.3	158.6
Av.	10.8	12.8	15.1	16.5	18.0	18.4	19.8
	C Type - Females						
3	10.4	13.6	15.8	16.1	21.0	20.5	20.3
4	11.3	14.0	15.5	19.0	19.3	20.0	20.8
17	12.7	15.5	15.6	17.5	18.8	18.7	20.0
30	11.3	11.8	13.2	15.4	16.9	17.7	20.2
36	11.9	15.0	17.7	19.7	18.8	20.0	22.2
1	10.6	14.6	14.7	17.0	18.5	19.5	20.4
5	11.2	12.5	13.6	17.0	18.0	19.4	19.1
13	11.6	14.8	16.6	19.4	20.6	21.2	20.2
19	12.5	12.6	10.5	16.1	19.0	19.2	19.1
22	13.1	13.0	14.3	16.0	18.4	18.3	19.8
A503	11.3	15.8	19.0	19.5	20.8	21.8*	22.8
Total	127.9	153.2	157.0	192.7	210.1	216.4	224.9
Av.	11.6	13.9	14.3	17.5	19.1	19.7	20.4
Grand Total	214.3	255.8	277.6	325.1	355.1	363.7	383.5
Av.	11.3	13.5	14.6	17.1	18.7	19.1	20.2
Grand Total Males and Females	530.7	625.8	727.9	810.7	878.4	914.7	976.5
Av.	11.3	13.3	15.5	17.2	18.7	19.5	20.6

TABLE V

SUMMARY OF BODY MEASUREMENTS AT MONTHLY INTERVALS FROM BIRTH TO SIX MONTHS OF AGE BY X-RAY CLASSIFICATION AND SEX (CONTINUED)

Calf No.	Head length						
	Birth	1 mo.	2 mo.	3 mo.	4 mo.	5 mo.	6 mo.
	B Type - Males						
7	23.3	24.5	28.9	30.7	31.4	33.5	34.0
11	23.1	27.0	28.8	31.7	33.3	35.1	35.7
28	22.9	24.5	27.1	28.9	29.6	31.3	31.8
35	21.8	25.3	26.8	28.3	30.9	31.7	32.7
38	21.3	24.1	26.8	27.5	29.3	30.6	32.0
37	20.3	24.6	25.2	27.1	28.6	29.5	30.6
A459	22.4	23.6	27.4	28.9	30.6	33.1	35.6
G482	21.8	24.1	26.5	28.3	30.3	32.8	34.6
A534	31.8	24.6	25.8	27.0	29.4	31.0	30.6
A547	22.7	24.0	27.3	29.1	30.4	31.7	32.4
A548	22.8	25.3*	27.8	30.3	31.6	33.0	33.8
Total	244.2	271.6	298.4	317.8	335.4	353.3	363.8
Av.	22.2	24.7	27.1	28.9	30.5	32.1	33.1
	C Type - Males						
15	23.1	26.5	28.6	30.9	31.0	33.4	35.4
26	22.8	25.3	27.5	29.7	31.4	32.6	34.0
27	22.6	24.4	25.7	28.6	29.8	31.4	32.5
33	24.9	26.0	30.6	32.0	32.4	34.5	36.0
6	21.1	22.1	26.9	28.2	30.0	30.3	31.8
9	22.9	24.2	27.9	29.8	31.5	31.7	33.0
21	22.7	24.6	26.8	29.2	30.3	31.9	32.6
23	20.1	22.5	24.2	25.8	26.5	28.9	29.8
24	30.7	23.5	24.9	27.7	28.0	29.5	31.2
34	23.1	26.7	29.3	30.0	31.3	33.1	34.6
A451	21.4	26.1	28.4	31.4	33.0	33.9	37.8
G451	20.5	23.9	24.2	26.2	28.1	29.8	32.3
A455	21.3	24.2	27.5	29.3	31.2	33.4	35.9
G486	24.2	27.2	28.2	31.8	33.0	34.3	35.5
A491	22.1	22.8	26.3	28.0	30.4	32.4	34.6
G508	24.3	26.8	30.0	32.5	33.4	34.3	34.8
A550	22.6	24.6*	26.5	29.1	29.8*	30.6	31.7
Total	380.4	423.2	463.5	500.2	521.1	546.0	573.5
Av.	22.4	24.9	27.3	29.4	30.7	32.1	33.7
Grand Total	624.6	694.8	761.9	818.0	856.5	899.3	937.3
Av.	22.3	24.8	27.2	29.2	30.6	32.1	33.5

TABLE V

SUMMARY OF BODY MEASUREMENTS AT MONTHLY INTERVALS FROM BIRTH TO SIX MONTHS OF AGE BY X-RAY CLASSIFICATION AND SEX (CONTINUED)

Calf No.	Head length						
	Birth	1 mo.	2 mo.	3 mo.	4 mo.	5 mo.	6 mo.
	B Type - Females						
29	22.0	23.6	26.0	28.0	30.0	31.2	34.1
8	20.7	22.4	26.8	27.2	29.0	29.9	31.4
10	21.5	25.3	26.4	29.0	29.5	30.8	32.3
16	21.8	25.7	27.2	30.1	30.5	30.8	32.1
31	22.8	23.8	25.4	26.9	30.5	31.0	31.5
39	22.9	24.0	25.2	26.6	28.6	29.0	31.0
A458	21.4	23.6	27.0	28.1	30.5	31.8	33.5
A481	21.6	21.6	24.3	25.8	27.5	28.7	31.7
Total	174.7	190.0	208.3	221.7	236.1	243.2	257.6
Av.	21.8	23.7	26.0	27.7	29.5	30.4	32.2
	C Type - Females						
3	21.7	23.8	25.8	27.2	30.5	31.5	32.0
4	23.0	24.0	26.4	29.5	31.3	31.3	33.1
17	23.7	26.4	28.5	30.2	31.6	32.0	34.0
30	22.6	23.2	25.3	27.4	29.7	31.3	33.1
36	22.2	26.4	28.2	29.6	31.9	33.2	34.6
1	22.0	24.5	26.0	28.6	31.0	31.2	32.7
5	23.0	23.2	23.9	27.5	29.0	30.4	31.0
13	24.0	26.8	29.6	31.1	32.5	33.6	33.6
19	21.5	24.2	25.5	26.9	28.3	29.5	30.9
22	22.0	24.5	26.4	27.7	29.0	30.0	31.3
A503	22.0	26.0	27.8	29.9	31.8	32.5*	33.2
Total	247.7	273.0	293.4	315.9	336.6	346.5	358.5
Av.	22.5	24.8	26.7	28.7	30.6	31.5	32.6
Grand Total	422.4	463.0	501.7	537.6	572.7	589.7	616.1
Av.	22.2	24.4	26.4	28.3	30.1	31.0	32.4
Grand Total Males and Females	1047.0	1157.8	1263.6	1355.6	1429.0	1489.0	1553.4
Av.	22.3	24.6	26.9	28.8	30.4	31.7	33.1

TABLE V

SUMMARY OF BODY MEASUREMENTS AT MONTHLY INTERVALS FROM BIRTH TO SIX MONTHS OF AGE BY X-RAY CLASSIFICATION AND SEX (CONTINUED)

Calf No.	Cannon length						
	Birth	1 mo.	2 mo.	3 mo.	4 mo.	5 mo.	6 mo.
				B Type - Males			
7	14.0	16.1	18.5	19.2	19.7	19.6	18.3
11	14.9	16.3	17.2	18.2	19.9	20.6	19.5
28	14.3	15.6	17.8	16.7	16.8	18.0	17.1
35	15.5	17.4	15.7	18.2	18.3	17.6	18.2
38	14.0	16.8	17.8	18.0	18.1	18.0	17.9
37	14.2	15.8	16.2	17.3	17.4	16.8	17.7
A459	15.0	16.7	17.0	18.4	16.9	18.7	19.4
G482	15.0	15.2	16.7	16.9	17.4	19.2	19.0
A534	14.8	17.0	17.5	18.0	18.3	18.3	18.3
A547	14.8	16.3	16.8	17.5	17.8	18.0	17.9
A548	15.2	16.0*	16.8	18.1	18.1	18.1	17.8
Total:	161.7	179.2	188.0	196.5	198.7	202.9	201.1
Av.	14.7	16.3	17.1	17.9	18.1	18.4	18.3
				C Type - Males			
15	14.9	18.4	18.4	18.9	20.4	19.9	20.0
26	15.3	16.4	17.2	16.9	18.2	19.6	18.6
27	12.9	15.5	16.3	17.4	18.1	19.0	17.7
33	15.5	17.2	19.1	19.7	19.5	20.0	19.0
6	14.7	15.5	17.3	18.3	18.6	19.1	18.6
9	14.5	16.3	16.1	17.8	19.3	18.3	18.0
21	14.9	14.9	17.0	18.2	19.4	19.5	18.4
23	12.9	15.7	16.0	16.1	16.8	17.7	16.5
24	13.6	15.6	16.8	17.5	18.1	19.1	19.6
34	15.1	17.1	17.4	17.9	18.3	19.0	18.6
A451	14.5	16.3	18.3	18.7	19.0	19.4	20.5
G451	14.6	15.1	15.0	15.6	16.4	17.4	18.5
A455	16.0	17.0	18.2	19.3	19.2	19.9	19.4
G486	17.5	17.8	18.5	19.5	19.1	18.8	20.2
A491	14.2	15.2	16.8	16.6	18.4	18.3	18.3
G508	16.8	17.8	20.1	19.6	20.5	21.4	21.5
A550	16.2	16.5*	16.8	18.5	18.3*	18.1	18.9
Total:	254.1	279.3	295.3	306.5	317.6	324.5	322.3
Av.	14.9	16.4	17.4	18.0	18.7	19.1	19.0
Grand Total:	415.8	458.5	483.3	503.0	516.3	527.4	523.4
Av.	14.8	16.4	17.3	18.0	18.4	18.8	18.7

TABLE V

SUMMARY OF BODY MEASUREMENTS AT MONTHLY INTERVALS FROM BIRTH TO SIX MONTHS OF AGE BY X-RAY CLASSIFICATION AND SEX (CONTINUED)

Calf No.	Cannon length						
	Birth	1 mo.	2 mo.	3 mo.	4 mo.	5 mo.	6 mo.
	B Type - Females						
29	14.8	14.7	16.8	15.6	18.5	18.5	17.6
8	14.3	14.1	16.9	16.7	17.6	17.7	17.0
10	12.4	16.2	18.0	18.0	18.5	18.5	17.0
16	14.4	17.8	17.3	19.1	19.3	19.7	18.8
31	14.3	16.1	17.3	16.4	18.6	16.7	17.8
39	15.1	16.2	16.2	18.1	17.3	16.8	16.8
A458	14.2	15.2	17.8	18.7	18.3	19.3	17.9
A481	13.7	14.5	15.0	15.2	17.1	17.9	18.5
Total	113.2	124.8	135.3	137.8	145.2	145.1	141.4
Av.	14.1	15.6	16.9	17.2	18.1	18.1	17.7
	C Type - Females						
3	13.6	15.8	15.8	18.2	18.0	18.7	18.8
4	14.1	15.3	15.8	18.2	19.3	17.8	18.4
17	14.3	16.8	16.9	16.8	18.7	18.8	19.2
30	15.9	16.0	16.2	18.5	18.0	17.5	18.2
36	16.4	18.6	19.2	19.5	19.5	18.8	18.8
1	14.6	15.4	16.5	18.4	19.6	18.8	18.8
5	12.5	16.2	17.3	18.7	19.3	20.0	17.7
13	13.8	16.8	17.5	18.8	19.3	19.6	19.9
19	13.2	15.2	17.0	16.6	17.8	18.7	17.8
22	13.4	17.0	17.6	18.4	18.5	18.7	18.9
A503	13.3	17.8	18.5	18.1	19.6	19.8*	20.1
Total	155.1	180.9	187.8	200.2	207.6	207.2	206.6
Av.	14.1	16.4	17.1	18.2	18.9	18.8	18.8
Grand Total	268.3	305.7	323.1	338.0	352.8	352.3	348.0
Av.	14.1	16.1	17.0	17.8	18.6	18.5	18.3
Grand Total Males and Females	669.6	764.2	806.4	841.5	869.1	879.7	871.4
Av.	14.2	16.3	17.2	17.9	18.5	18.7	18.5

TABLE V

SUMMARY OF BODY MEASUREMENTS AT MONTHLY INTERVALS FROM BIRTH TO SIX MONTHS OF AGE BY X-RAY CLASSIFICATION AND SEX (CONTINUED)

Calf No.	Weight						
	Birth	1 mo.	2 mo.	3 mo.	4 mo.	5 mo.	6 mo.
	B Type - Males						
7	75	100	184	240	290	355	335
11	84	155	188	260	320	410	440
28	71	115	153	210	235	295	310
35	75	108	136	165	245	275	330
38	64	93	130	155	235	255	300
37	63	88	120	150	210	250	270
A459	70	89	143	187	250	290	380
G482	55	111	150	195	245	340	381
A534	50	90	105*	120	185	222	260
A547	65	85	125	180	202	224	250
A548	66	113*	160	220	250	280	315
Total:	738	1147	1594	2082	2667	3196	3571
Av.	67.1	104.3	144.9	189.3	242.5	290.5	324.6
	C Type - Males						
15	72	145	198	250	285	365	375
26	70	107	145	210	240	330	370
27	78	100	134	180	220	285	320
32	87	130	220	250	330	380	440
6	56	77	143	175	205	265	290
9	64	92	178	215	245	300	340
21	70	99	146	195	230	290	320
23	36	78	109	155	165	210	250
24	55	91	130	180	205	270	300
34	79	150	180	230	280	345	410
A451	72	97	160	225	290	380	460
G451	55	66	98	129	175	225	290
A455	60	99	170	232	295	370	460
G486	114	164	215	295	333*	370	440
A491	56	72	126	177	230	305	375
G508	56	155	230	320	335*	350	380
A550	85	110*	135	205	233*	262	295
Total:	1165	1832	2717	3623	4296	5302	6115
Av.	68.5	107.8	159.8	213.1	252.7	311.9	359.7
Grand Total:	1903	2979	4311	5705	6963	8498	9686
Av.	68.0	106.4	154.0	203.8	248.7	303.5	345.9

TABLE V

SUMMARY OF BODY MEASUREMENTS AT MONTHLY INTERVALS FROM BIRTH TO SIX MONTHS OF AGE BY X-RAY CLASSIFICATION AND SEX (CONTINUED)

Calf No.	Weight						
	Birth	1 mo.	2 mo.	3 mo.	4 mo.	5 mo.	6 mo.
	B Type - Females						
29	63	93	137	205	230	290	360
8	50	77	143	175	205	265	300
10	58	123	158	200	240	310	325
16	77	143	182	220	250	310	335
31	58	91	124	155	240	265	300
39	70	87	100	120	145	195	250
A458	63	94	154	205	250	320	395
A481	45	52	81	111	150	200	270
Total	484	760	1079	1391	1810	2155	2535
Av.	60.5	95.0	134.8	173.8	226.2	269.4	316.9
	C Type - Females						
3	62	95	131	161	230	290	330
4	71	104	146	225	255	315	340
17	79	114	154	195	225	280	325
30	59	79	100	145	250	265	315
36	87	147	205	245	315	350	400
1	76	112	145	184	260	325	360
5	62	82	111	170	195	240	270
13	76	140	180	230	260	330	375
19	55	92	120	155	180	240	285
22	68	106	138	170	210	275	300
A503	58	135	180	240	290	325*	360
Total	753	1206	1610	2120	2670	3235	3660
Av.	68.5	109.6	146.4	192.7	242.7	294.1	332.7
Grand Total	1237	1966	2689	3511	4480	5390	6195
Av.	65.1	103.5	141.5	184.8	235.8	283.7	326.1
Grand Total Males and Females	3140	4945	7000	9216	11443	13888	15881
Av.	66.8	105.2	148.9	196.1	243.5	295.5	337.9

TABLE V

SUMMARY OF BODY MEASUREMENTS AT MONTHLY INTERVALS FROM BIRTH TO SIX MONTHS OF AGE BY X-RAY CLASSIFICATION AND SEX (CONTINUED)

Calf No.	Wither height						
	Birth	1 mo.	2 mo.	3 mo.	4 mo.	5 mo.	6 mo.
	B Type - Males						
7	61.6	65.5	76.5	81.5	87.5	89.5	88.0
11	63.2	75.0	78.3	84.0	88.0	82.5	95.5
28	59.7	64.0	69.5	75.5	79.0	82.5	84.7
35	64.4	68.5	72.4	77.5	80.5	86.9	85.2
38	60.4	65.0	70.5	75.0	79.4	81.9	86.1
37	58.5	62.1	65.7	72.5	75.2	81.0	82.1
A459	63.6	65.5	73.0	76.5	81.3	85.7	89.0
G482	60.8	67.0	72.3	75.2	81.8	86.3	90.0
A534	57.8	63.0	65.5*	68.0	77.5	80.4	79.0
A547	60.6	63.0	68.7	75.5	76.0	78.5	79.5
A548	61.5	66.5*	71.5	80.0	82.3	84.6	85.0
Total:	664.1	725.1	783.9	841.2	888.5	929.8	944.1
Av.	60.4	65.9	71.3	76.5	80.8	84.5	85.8
	C Type - Males						
15	59.0	72.0	79.0	83.2	87.0	88.9	93.5
26	65.3	67.0	72.5	76.4	81.4	84.0	90.4
27	61.3	65.5	69.0	74.0	78.5	80.0	84.7
32	67.7	69.5	82.5	86.0	86.4	91.0	96.0
6	60.2	60.4	70.9	74.0	77.5	80.5	86.0
9	61.2	64.0	75.4	77.0	83.0	85.0	88.2
21	61.4	64.0	74.0	79.0	83.0	83.0	88.2
23	53.5	60.0	65.0	70.0	72.1	77.5	80.0
24	58.9	64.5	69.1	75.1	81.0	81.5	87.6
34	63.6	70.0	74.2	78.6	79.7	85.3	90.5
A451	64.5	66.0	73.0	79.5	85.5	91.0	93.5
G451	59.0	59.5	64.5	69.0	72.5	77.2	84.2
A455	62.5	65.5	74.0	81.0	84.3	87.5	92.5
G486	66.0	72.5	78.5	85.5	87.6*	89.7	95.3
A491	59.7	60.5	66.5	72.7	78.5	82.3	86.8
G508	67.0	75.0	79.4	86,7	87.6*	88.5	93.5
A550	63.0	66.0*	69.2	75.5	77.9*	80.4	83.3
Total:	1053.8	1121.9	1236.7	1323.2	1383.5	1433.3	1514.2
Av.	62.0	66.0	72.7	77.8	81.4	84.3	89.1
Grand Total:	1717.9	1847.0	2020.6	2164.4	2272.0	2363.1	2458.3
Av.	61.4	66.0	72.2	77.3	81.1	84.4	87.8

TABLE V

SUMMARY OF BODY MEASUREMENTS AT MONTHLY INTERVALS FROM BIRTH TO SIX MONTHS OF AGE BY X-RAY CLASSIFICATION AND SEX (CONTINUED)

Calf No.	Wither height						
	Birth	1 mo.	2 mo.	3 mo.	4 mo.	5 mo.	6 mo.
	B Type - Females						
29	58.8	62.5	68.0	73.8	79.0	81.0	85.2
8	57.8	59.0	68.5	73.2	75.5	80.0	81.7
10	58.7	67.5	71.0	76.0	80.5	83.0	85.1
16	59.8	72.0	73.5	77.0	83.0	83.6	84.7
31	60.9	64.0	71.0	73.2	79.0	81.9	86.0
39	58.2	63.5	66.0	69.5	73.5	74.6	80.9
A458	62.0	64.0	69.0	75.0	79.5	84.0	87.7
A481	57.1	57.5	62.0	68.5	72.5	78.3	83.5
Total	473.3	510.0	549.0	586.2	622.5	646.4	674.8
Av.	59.2	63.7	68.6	73.3	77.8	80.8	84.3
	C Type - Females						
3	60.4	65.5	69.0	74.5	82.1	83.5	87.0
4	61.7	64.0	68.5	77.5	82.5	83.3	85.8
17	62.1	67.0	71.0	77.4	81.5	83.0	84.1
30	58.9	61.0	67.0	71.5	79.5	84.3	88.0
36	65.8	74.0	79.0	83.5	87.0	90.0	97.0
1	63.3	64.5	70.0	74.0	81.5	87.0	86.6
5	60.7	63.0	68.4	77.0	79.5	80.0	84.0
13	60.5	68.5	76.2	80.0	83.5	86.5	89.0
19	55.7	67.5	70.0	78.0	78.5	81.3	86.4
22	58.3	65.0	70.5	73.5	78.7	79.0	84.2
A503	59.0	68.0	76.0	80.0	84.4	86.7*	89.0
Total	666.4	720.8	785.6	843.9	898.7	924.6	961.1
Av.	60.6	65.5	71.4	76.7	81.7	84.1	87.4
Grand Total	1139.7	1230.8	1334.6	1430.1	1521.2	1571.0	1635.9
Av.	60.0	64.8	70.2	75.3	80.1	82.7	86.1
Grand Total Males and Females	2857.6	3077.8	3355.2	3594.5	3793.2	3934.1	4094.2
Av.	60.8	65.5	71.4	76.5	80.7	83.7	87.1

TABLE V

SUMMARY OF BODY MEASUREMENTS AT MONTHLY INTERVALS FROM BIRTH TO SIX MONTHS OF AGE BY X-RAY CLASSIFICATION AND SEX (CONTINUED)

Calf No.	Body length						
	Birth	1 mo.	2 mo.	3 mo.	4 mo.	5 mo.	6 mo.
	B Type - Males						
7	64.0	66.4	82.5	90.0	92.0	98.0	98.3
11	63.1	76.0	85.6	91.4	95.1	100.0	103.0
28	60.7	67.5	76.0	82.9	87.0	91.5	98.4
35	58.2	70.3	74.7	83.0	90.0	93.4	103.0
38	53.8	65.5	72.0	78.7	87.8	91.0	95.0
37	54.6	62.5	70.5	73.5	80.5	82.2	91.2
A459	56.0	67.1	76.0	79.2	91.1	94.6	103.3
G482	57.5	68.0	79.5	86.6	92.2	97.9	102.0
A534	53.6	65.8	68.4*	71.1	80.4	86.0	85.6
A547	55.5	58.4	69.5	77.8	79.2	80.5	88.3
A548	55.0	63.2*	71.5	83.0	86.3	89.3	90.7
Total	632.0	730.7	826.2	897.2	961.6	1004.4	1058.8
Av.	57.5	66.4	75.1	81.5	87.4	91.3	96.3
	C Type - Males						
15	61.0	77.0	83.3	91.0	92.0	96.3	104.5
26	65.2	68.0	78.0	83.9	90.0	93.0	102.5
27	58.5	67.0	76.2	81.5	86.5	89.0	97.3
32	63.1	75.0	86.5	92.0	96.0	104.0	106.0
6	54.5	56.8	75.6	83.5	89.5	90.5	91.8
9	59.1	65.4	80.3	90.0	89.5	94.4	96.4
21	59.3	64.0	74.5	84.5	88.0	93.0	97.2
23	51.2	65.5	69.5	78.6	83.2	86.2	95.0
24	53.0	61.6	73.1	79.0	84.0	92.0	96.4
34	62.2	75.7	80.6	86.9	87.7	100.0	103.5
A451	60.3	68.1	80.0	91.0	93.0	103.0	104.0
G451	52.5	59.0	62.0	73.9	77.1	87.7	92.0
A455	56.5	65.7	79.0	85.3	92.8	97.0	106.4
G486	68.5	80.3	86.5	94.6	100.3*	106.0	114.5
A491	56.2	56.5	71.5	80.2	85.7	95.6	102.0
G508	63.3	80.5	88.2	95.4	97.2*	99.0	103.0
A550	62.2	67.4*	72.7	84.8	87.1*	89.5	83.3
Total	1006.6	1153.5	1317.5	1456.1	1519.6	1616.2	1695.8
Av.	59.2	67.9	77.5	85.7	89.4	95.1	99.8
Grand Total	1638.6	1884.2	2143.7	2353.3	2481.2	2620.6	2754.6
Av.	58.5	67.3	76.6	84.0	88.6	93.6	98.4

TABLE V

SUMMARY OF BODY MEASUREMENTS AT MONTHLY INTERVALS FROM BIRTH TO SIX MONTHS OF AGE BY X-RAY CLASSIFICATION AND SEX (CONTINUED)

Calf No.	Body length						
	Birth	1 mo.	2 mo.	3 mo.	4 mo.	5 mo.	6 mo.
	B Type - Females						
29	56.0	62.0	72.3	82.0	85.0	91.5	102.0
8	55.3	61.4	74.8	83.1	89.2	92.0	95.3
10	52.9	71.4	75.0	81.5	88.6	92.8	98.9
16	60.7	76.2	80.8	87.0	92.5	98.7	99.7
31	55.5	66.4	74.0	78.0	89.5	94.7	96.4
39	57.7	63.5	69.0	75.0	79.5	84.0	91.0
A458	58.0	65.7	78.0	84.5	89.8	95.0	102.0
A481	53.3	56.9	61.5	71.8	75.5	80.5	90.5
Total:	449.4	523.5	585.4	642.9	689.6	729.2	775.8
Av.	56.2	65.4	73.2	80.4	86.2	91.1	97.0
	C Type - Females						
3	56.4	63.2	74.3	82.0	87.6	94.0	98.4
4	60.5	62.0	74.5	87.0	91.0	93.6	101.5
17	61.0	70.0	78.4	87.0	89.0	96.5	102.0
30	57.7	62.5	69.1	79.0	85.9	90.4	97.0
36	62.0	77.0	83.7	90.3	96.5	103.0	105.0
1	61.4	69.8	76.5	82.4	91.5	97.0	99.9
5	55.5	63.5	69.7	83.5	87.5	91.5	95.8
13	62.0	75.0	80.8	89.0	93.0	95.5	99.5
19	54.9	62.8	71.0	81.0	89.0	92.3	98.5
22	56.0	68.3	71.9	82.0	83.3	88.6	96.4
A503	56.9	71.5	83.0	87.8	94.4	98.7*	103.0
Total:	644.3	745.6	832.9	931.0	988.7	1041.1	1097.0
Av.	58.6	67.8	75.7	84.6	89.9	94.6	99.7
Grand Total:	1093.7	1269.1	1418.3	1573.9	1678.3	1770.3	1872.8
Av.	57.6	66.8	74.6	82.8	88.3	93.2	98.6
Grand Total Males and Females	2732.3	3153.3	3562.0	3927.2	4159.5	4390.9	4627.4
Av.	58.1	67.1	75.8	83.6	88.5	93.4	98.5

[a]All measurements in centimeters except weight which is in pounds.

*Average of measurements bracketing this age.

TABLE VI

BODY MEASUREMENTS STANDARDIZED TO FIVE MONTHS OF AGE AND GROUPED ACCORDING TO X-RAY CLASSIFICATION AND SEX

Calf No.	Body Measurements: Weight	Wither Height	Loin Width	Head Length	Head Width	Cannon Length	Tibia Length	Stifle to pins Length	Cannon Circum.	Paunch Circum.	Round Meas.	Tail Length	Shoulder Width	Body Length	Av. Type Grade
							B Type - Males								
7	327[a]	88.3	20.6	33.0	17.1	19.2	36.4	37.0	15.2	133	75.1	46.3	29.2	96.1	12.3
11	390	92.0	21.4	34.7	17.2	20.0	37.3	37.8	16.1	144	78.9	47.3	31.8	99.4	12.7
28	280	82.0	19.4	30.9	16.1	17.3	34.5	33.6	14.7	126	72.7	44.5	28.7	92.3	12.3
35	283	84.2	19.1	31.8	16.2	18.0	34.1	34.2	13.8	128	68.5	46.9	27.8	95.5	9.7
38	263	82.5	17.9	30.6	15.4	18.0	33.3	33.9	13.8	125	67.9	41.4	26.3	91.3	10.0
37	243	79.4	17.1	29.6	15.5	17.3	33.6	34.2	14.5	125	69.2	44.3	28.0	84.6	12.3
A459	307	85.3	20.2	33.1	16.9	18.3	34.2	35.9	14.5	136	74.6	44.8	27.7	96.3	11.0
G482	322	86.0	20.2	32.6	16.7	18.5	33.6	34.9	14.3	142	71.0	46.4	29.0	97.3	10.7
A534	222	79.0	18.7	30.3	16.0	18.3	32.5	32.0	13.9	126	64.7	40.8	25.9	84.0	12.0
A547	237	79.0	19.1	32.0	16.0	18.0	34.7	33.8	13.9	136	66.2	46.8	27.2	84.4	11.0
A548	298	84.8	19.7	33.4	17.0	18.0	35.4	35.2	14.4	146	71.8	49.2	28.2	90.0	12.0
Total:	3172	922.5	213.4	352.0	180.1	200.9	379.6	382.5	159.1	1467	780.9	498.7	309.8	1011.2	126.0
Av.	288.0	83.9	19.4	32.0	16.4	18.3	34.5	34.8	14.5	133	71.0	45.3	28.2	91.9	11.5
							C Type - Males								
15	342	89.8	23.1	33.3	16.1	20.1	36.5	36.8	15.1	133	77.7	49.3	31.5	97.6	11.7
26	313	85.3	19.3	32.7	16.6	18.8	35.1	35.1	14.8	134	72.2	47.5	28.3	95.2	11.3
27	275	81.1	18.2	31.2	15.9	18.3	34.0	33.8	14.2	127	67.9	45.3	28.2	90.9	11.3
33	383	91.1	20.8	34.6	16.7	19.5	38.0	38.8	15.3	142	78.7	51.2	30.1	102.0	11.0
6	253	81.3	19.1	30.7	15.4	18.8	33.8	35.0	14.2	124	68.3	41.4	27.9	90.8	10.0
9	295	85.4	20.0	32.1	14.9	18.5	36.1	35.9	14.0	136	75.3	45.5	28.2	93.4	11.0
21	280	84.7	19.0	31.6	16.1	19.1	35.7	35.9	14.5	132	71.9	45.5	28.4	92.9	10.7
23	208	76.5	17.0	28.4	15.0	17.0	33.9	33.1	13.8	114	69.2	41.0	24.9	88.1	11.0
24	262	83.4	17.8	29.6	15.8	18.9	35.6	36.1	14.4	124	72.2	43.8	28.4	90.8	11.0
34	345	85.2	19.8	33.0	16.6	18.6	35.0	36.6	15.2	141	77.3	47.9	31.7	97.1	12.0
A451	377	90.0	22.7	34.9	18.1	19.6	36.2	39.3	16.0	151	76.7	50.3	32.8	100.0	11.7
G451	230	78.0	17.6	30.1	15.9	18.1	32.7	32.4	13.7	125	65.7	41.4	25.0	85.6	10.7
A455	375	88.1	22.5	33.5	17.9	19.5	35.6	36.0	15.7	151	79.7	47.8	33.7	98.7	12.7
G486	405	93.2	22.4	34.9	17.4	19.5	39.0	40.0	16.2	154	83.5	56.7	32.2	110.2	10.3
A491	303	82.5	19.7	32.5	16.4	18.3	33.1	35.7	15.1	132	78.3	47.6	28.8	94.4	12.3
G508	365	91.0	23.0	34.6	17.2	21.4	31.4	38.8	15.4	150	73.0	41.8	32.0	101.0	10.7
A550	278	81.8	19.0	31.2	16.2	18.5	31.9	33.8	14.4	138	69.4	48.2	27.4	86.4	11.7
Total:	5289	1448.4	341.0	548.9	278.2	322.5	597.6	613.1	252.0	2308	1257.0	792.2	499.5	1615.1	191.1
Av.	311.1	85.2	20.1	32.3	16.4	19.0	35.2	36.1	14.8	136	73.9	46.6	29.4	95.0	11.2

TABLE VI

BODY MEASUREMENTS STANDARDIZED TO FIVE MONTHS OF AGE AND GROUPED ACCORDING TO X-RAY CLASSIFICATION AND SEX
(CONTINUED)

Calf No.	Body Measurements														
	Weight	Wither Height	Loin Width	Head Length	Head Width	Cannon Length	Tibia Length	Stifle to pins Length	Cannon Circum.	Paunch Circum.	Round Meas.	Tail Length	Shoulder Width	Body Length	Av. Type Grade
							B Type - Females								
29	328	83.5	20.2	32.6	16.7	17.8	33.8	35.3	15.1	136	76.6	47.2	30.3	97.3	13.7
8	257	79.1	18.7	30.1	15.8	17.4	33.8	33.7	13.3	127	69.3	43.9	27.2	92.2	12.0
10	292	82.9	20.5	30.9	16.2	18.0	33.8	35.1	13.9	131	74.7	43.9	29.6	93.4	13.3
16	298	83.8	19.6	31.1	15.9	19.2	34.7	36.6	14.4	134	76.0	45.5	29.9	97.0	12.0
31	268	82.3	17.4	31.0	15.8	17.7	34.4	34.5	13.4	128	67.8	43.5	27.2	93.5	11.0
39	197	76.3	16.3	29.5	14.3	17.0	32.0	30.9	12.7	110	62.5	43.7	25.0	84.8	9.7
A458	322	83.7	21.0	31.9	17.0	18.5	34.6	34.5	14.8	140	73.4	47.1	29.5	95.6	13.0
A481	207	78.1	17.1	29.3	15.4	17.8	32.5	31.2	12.7	123	59.0	43.2	24.3	82.2	10.7
Total	2169	649.7	150.8	246.4	127.1	143.4	269.6	271.8	110.3	1029	559.3	358.0	223.0	736.0	95.4
Av.	271	81.2	18.8	30.8	15.9	17.9	33.7	34.0	13.8	129	69.9	44.8	27.9	92.0	11.9
							C Type - Females								
3	283	84.2	20.6	31.3	16.2	18.5	34.6	35.7	13.4	134	71.9	46.8	28.4	93.3	12.3
4	303	83.9	20.0	31.9	16.5	18.5	34.6	34.6	14.3	132	73.3	46.7	29.5	95.4	12.7
17	277	82.9	19.2	32.5	15.8	18.9	34.4	34.5	14.0	134	71.2	47.5	28.1	95.8	12.0
30	277	83.9	18.3	31.0	16.2	18.0	35.0	35.4	13.3	130	66.8	47.5	25.9	91.1	11.0
36	355	91.3	20.3	33.2	16.0	19.0	37.1	37.3	14.8	137	76.0	50.6	29.7	101.5	11.7
1	315	85.0	19.5	31.6	16.4	19.1	35.4	34.1	14.1	138	75.5	46.7	30.2	96.1	13.0
5	235	81.2	18.8	30.1	15.0	19.0	33.9	33.8	12.8	122	65.9	43.2	26.2	91.6	10.3
13	322	86.3	20.7	33.2	15.9	19.6	36.1	36.0	15.2	136	78.0	48.3	29.1	96.0	12.3
19	235	82.1	19.1	29.6	14.9	18.1	34.4	34.2	13.1	114	67.5	45.9	26.2	93.2	10.0
22	262	80.6	18.7	30.1	16.2	18.7	33.0	33.4	13.9	128	71.3	42.9	28.6	89.4	11.7
A503	325	86.7	21.8	32.5	16.6	19.8	35.7	35.8	14.6	136	75.4	50.9	30.4	98.7	11.5
Total	3089	928.1	217.0	347.0	175.7	207.2	384.2	384.8	153.5	1441	792.8	517.0	312.3	1042.1	128.5
Av.	289.9	84.4	19.7	31.5	16.0	18.8	34.9	35.0	14.0	131	72.1	47.0	28.4	94.7	11.7
							Dwarfs - Females								
59	183	68.8	13.6	27.3	15.7	13.9	27.4	27.9	12.9	120	60.2	37.0	24.0	78.1	
A518	213	73.1	15.8	29.9	16.4	14.3	31.0	30.3	13.1	134	62.0	37.3	25.6	75.0	
Total	396	141.9	29.4	57.2	32.1	28.2	58.4	58.2	26.0	254	122.2	74.3	49.6	153.1	
Av.	198	71.0	14.7	28.6	16.0	14.1	29.2	29.1	13.0	127	61.1	37.2	24.8	76.6	
							Dwarfs - Male								
52	187	72.0	13.9	28.2	15.4	14.4	30.6	28.7	13.2	122	61.2	37.1	24.5	78.9	
G489	222	73.9	15.5	28.2	16.5	14.8	28.0	29.0	14.7	121	67.7	46.1	27.8	78.8	
Total	409	145.9	29.4	56.4	31.9	29.2	58.6	57.7	27.9	243	128.9	83.2	52.3	157.7	
Av.	204	73.0	14.7	28.2	16.0	14.6	29.3	28.8	14.0	122	64.4	41.6	26.2	78.8	

[a]All measurements in centimeters except weight which is in pounds.

TABLE VII

RATIOS OF VARIOUS BODY MEASUREMENTS BY X-RAY CLASSIFICATION AND SEX*

Measurement	X-ray classification	Weight		Wither Height		Loin Width		Head Length		Head Width		Cannon Length		Tibia Length		Stifle to Pins		Cannon Circum.		Paunch Circum.		Round Meas.		Tail Length		Body Length	
		M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F
Weight	A			2.79[a]	2.79	13.87	13.47	7.23	6.72	12.75	12.38	13.97	14.04	6.96	6.78	7.08	6.80	14.57	15.23	1.67	1.56	3.18	3.24	4.90	5.32	2.59	2.58
	B			3.43	3.34	14.84	14.41	9.00	8.80	17.56	17.04	15.74	15.14	8.35	8.04	8.28	7.97	19.86	19.64	2.17	2.10	4.06	3.88	6.36	6.05	3.13	2.95
	C			3.65	3.43	15.47	14.72	9.63	9.20	18.97	18.12	16.37	15.42	8.84	8.31	8.62	8.29	21.02	20.71	2.29	2.21	4.21	4.02	6.68	6.17	3.27	3.06
Wither Height	A					4.97	4.83	2.59	2.48	4.56	4.44	5.00	5.04	2.49	2.43	2.53	2.44	5.21	5.46	.60	.56	1.13	1.16	1.75	1.91	.93	.93
	B					4.32	4.32	2.62	2.64	5.12	5.11	4.58	4.54	2.43	2.41	2.41	2.39	5.79	5.88	.63	.63	1.18	1.16	1.85	1.81	.91	.88
	C					4.24	4.28	2.64	2.68	5.20	5.28	4.48	4.49	2.42	2,42	2.36	2.41	5.76	6.03	.63	.64	1.15	1.17	1.83	1.80	.90	.89
Loin Width	A							.52	.51	.92	.92	1.01	1.04	.50	.50	.51	.51	1.05	1.13	.12	.12	.23	.24	.35	.40	.19	.19
	B							.61	.61	1.18	1.18	1.06	1.05	.56	.56	.56	.55	1.34	1.36	.14	.15	.27	.27	.43	.42	.21	.20
	C							.62	.62	1.23	1.23	1.06	1.05	.57	.57	.56	.56	1.36	1.41	.15	.15	.27	.27	.43	.42	.21	.21
Head Length	A									1.76	1.79	1.93	2.03	.96	.98	.98	.98	2.01	2.20	.23	.23	.44	.47	.68	.77	.36	.37
	B									1.95	1.94	1.75	1.72	.93	.91	.92	.91	2.21	2.23	.24	.24	.45	.44	.71	.69	.35	.33
	C									1.97	1.97	1.70	1.68	.92	.90	.90	.90	2.18	2.25	.24	.24	.44	.44	.69	.67	.34	.33
Head Width	A											1.10	1.13	.55	.55	.56	.55	1.14	1.23	.13	.13	.25	.26	.38	.43	.20	.21
	B											.90	.89	.48	.47	.47	.47	1.13	1.15	.12	.12	.23	.23	.36	.35	.18	.17
	C											.86	.85	.47	.46	.45	.46	1.11	1.14	.12	.12	.22	.22	.35	.34	.17	.17
Cannon Length	A													.50	.48	.51	.48	1.04	1.08	.12	.11	.23	.23	.35	.38	.19	.18
	B													.53	.53	.53	.53	1.26	1.30	.14	.14	.26	.26	.40	.40	.20	.19
	C													.54	.54	.53	.54	1.28	1.34	.14	.14	.26	.26	.41	.40	.20	.20
Tibia Length	A															1.02	1.00	2.09	2.25	.24	.23	.45	.48	.70	.78	.37	.38
	B															.99	.99	2.38	2.44	.26	.26	.49	.48	.76	.75	.37	.37
	C															.98	1.00	2.38	2.49	.26	.27	.48	.48	.76	.74	.37	.37
Stifle To Pins	A																	2.06	2.24	.24	.23	.45	.48	.69	.78	.37	.38
	B																	2.40	2.46	.26	.26	.49	.49	.77	.76	.38	.37
	C																	2.44	2.50	.27	.27	.49	.49	.77	.74	.38	.37
Cannon Circum.	A																			.11	.10	.22	.21	.34	.35	.18	.17
	B																			.11	.11	.20	.20	.32	.31	.16	.15
	C																			.11	.11	.20	.19	.32	.30	.16	.15
Paunch Circum.	A																					1.89	2.08	2.93	3.41	1.55	1.66
	B																					1.87	1.85	2.92	2.88	1.45	1.40
	C																					1.84	1.82	2.94	2.79	1.43	1.38
Round Meas.	A																							1.55	1.64	.82	.80
	B																							1.57	1.56	.77	.76
	C																							1.59	1.53	.78	.76
Tail Length	A																									.53	.49
	B																									.49	.49
	C																									.49	.50

*Five month measurement averages for each X-ray classification within a sex used.

[a]Ratio values obtained by dividing measurements into row measurements staying within the respective x-ray classification and sex.