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I am submitting herewith a dissertation written by Max Franklin Hawkins entitled "Factors Affecting the Subjective Estimate of Structural Soundness in Birth to Market Age Swine." I have examined the final copy of this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Animal Science.

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FACTORS AFFECTING THE SUBJECTIVE ESTIMATE OF STRUCTURAL SOUNDNESS IN BIRTH TO MARKET AGE SWINE

A Dissertation

Presented for the

Doctor of Philosophy

Degree

The University of Tennessee, Knoxville

Max Franklin Hawkins

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ABSTRACT

One hundred eighteen pigs, representing 12 litters, were used to study structural soundness and toe size uniformity. The pigs were sired by either a Hampshire or Duroc boar and the sows were Duroc x Yorkshire, Yorkshire x Duroc, or Landrace x Yorkshire x Duroc crosses. Pigs were cared for by normal and standard management and feeding practices. While in the farrowing house, the floor surface was partly concrete and partly one-half inch steel rods spaced three-eights of an inch apart. The grower-finishing unit had a total concrete floor. Pigs were visually appraised by an experienced evaluator at 1, 7, 14, 21, 60, and 223 days of age. Pigs were first scored for overall soundness and then scored for components of growth and composition, and components of skeletal shape. All scoring was on a 1-15 basis. At the same days of age, each pig was measured, in centimeters, for toe and pad size and the differences between lateral and medial toe measurements were calculated.

The evaluator's scores accounted for more variation among younger pigs and pigs at 223 days of age, while there was less variation in scores at the intermediate time of 60 days of age. The skeletal shape components of foreleg side view, front pastern, and topline and the variable age accounted for 76% of the total variation in overall soundness score.

Pad width and pad depth were more highly associated to overall soundness score than any other foot measures. Calculated differences between lateral and medial toes and pads provided little explanation in the variation of overall soundness score, however, scores for pad width and pad depth did tend to explain the most variation in overall soundness score at all ages, especially at day 223 with R-squares of .26 and .37 respectively.

Growth of the pigs tended to follow the chronological schedule of management and environmental changes. This chronological schedule affected the total variation that the evaluator observed in the population. Litter effect explained 34% of the variation in overall soundness score at birth, however, when litter effect was removed the means of the subjective components remained the same. This would indicate that soundness score is the result of genetics, however, more likely it is influenced by both genetic and environmental components.

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CHAPTER I

INTRODUCTION

Swine produced in the United States have undergone rather drastic genetic changes during the past 30 year period. These changes were brought about, largely, by the shift in demand for lard. The average market hog in 1950 produced a carcass yielding about 40 lbs. of fat trim. This amount was reduced to 31 lbs. in 1960, 21 lbs. in 1970, and about 15 lbs. in 1980. Today, there is an increasing percentage of very lean hogs that will produce carcasses yielding less than 10 lbs. of fat trim. Therefore, as market weight has remained relatively constant over the past 30 years, more than 75% of the fat trim (13% of the body weight) has been genetically replaced by muscle. Furthermore, swine have undergone an increase in growth rate, as Ittner and Huges (1937) reported that pigs averaged 160 lbs. in 180 days; whereas, today, the average market hog will weigh 230 lbs. in the same 180 day period.

These changes have resulted in several dramatic phenotypic changes. Pigs have become taller, longer, larger framed, leaner, and more muscular in appearance with greater bone circumference. Average pigs of today would be what producers call "late maturing" hogs; that is, they will stay considerably leaner while growing to a larger frame size and, in some cases, heavier weights. Also, during this same time period, swine production itself has changed.

Producers subject the pig to a wide variety of environments ranging from dirt or pasture lots to total confinement rearing with slatted flooring. Consequently, hogs have necessarily undergone drastic changes in genetics, phenotype, and environment with an increased demand by the producer that the pig gain rapidly and efficiently, and demand by the packer that the pig yield larger quantities of lean pork.

During this same period, producers have become aware of a crippling disorder that affects the structural soundness, mobility, and performance of their swine. These observations are more frequent among the larger framed, later maturing, faster growing pigs. Producers often refer to this crippling effect as "busted up." Researchers have referred to it as "leg weakness" and found that it is associated with osteochondrosis, a generalized disease of the physeal, epiphyseal, and articular cartilage. Boars, because they grow more rapidly, remain leaner and develop greater frame size, are more often affected by this inability to move freely. Therefore, they are more often culled from the breeding herd as they are unable to heat check, mount, and successfully service sows. This can be a problem also with the gilt or sow if, for structural soundness reasons, she must be culled from the herd at an early age. When the producer must cull the affected stock from his herd, it is of economic concern because he may have fewer pigs born and a smaller number of market hogs to absorb the fixed costs of production.

There have been several postulations as to the cause of the disorder, namely genetics, nutrition, type of rearing, muscle, nerve, growth, and exercise. However, experimental results have been inconclusive with what would appear to have interactive effects. There have been little real help offered the producer in identifying early in life pigs that are likely to become affected since most research efforts have been devoted to the older (postweaning) pigs during the growing-finishing period.

Therefore, the objectives of this research were to: (1) study structural soundness at various ages in swine; (2) identify early signs of unsoundness; and (3) define correlated physiological changes occurring in unsound animals.

CHAPTER II

LITERATURE REVIEW

I. LEG WEAKNESS AND OSTEOCHONDROSIS

Non-infectious musculoskeletal abnormalities have been reported as serious problems in fast growing pigs and particularly breeding stock in the United States (Grondalen and Grondalen, 1974a; Magladery and McDougal, 1950) and in Europe (Duthie and Lancaster, 1964; Grondalen, (1974d); Grondalen, 1976; Nielsen, 1973; Vaughan, 1971). Non-scientific, yet descriptive terms such as "busted-up" or "leg weakness" (Duthie and Lancaster, 1964; Grondalen, 1974e; Vaughan, 1971) have been coined to describe the gross appearance and poorer mobility of affected pigs. Animals suffering from leg weakness have a stiff gait, arched back, variable degree of straightness and/or knuckling over of the joints of the lower portion of the limbs. These pigs walk on the tips of their claws (Duthie and Lancaster, 1964; Vaughan, 1971), and lameness is a common clinical sign in this syndrome. Although leg weakness produces a variety of locomotion and musculoskeletal abnormalities, the pigs are in otherwise normal health.

Studies of pathological lesions of the skeletal system associated with the leg weakness syndrome have shown abnormal changes in the growth areas (physes or epiphyseal plates) and synovial joint cartilages of the skeleton (Grondalen, 1976; Reiland, 1976; Vaughan, 1971). In a four year study, Norwegian investigators (Grondalen, 1974a, 1974b, 1974c, 1974d; Grondalen and Grondalen, 1974a, 1974b; Grondalen and Vangen, 1974; Grondalen, 1976) identified the lesions consistently present in severe cases of leg weakness as those of a disease called osteochondrosis, which is an abnormality of endochondral bone growth. Reiland (1976) reported that, in Sweden, the lesions of osteochondrosis were found in nearly all cases of leg weakness in swine less than 18 months of age. Although the conditions called leg weakness and osteochondrosis are not necessarily synonymous (Grondalen, 1976), osteochondrosis has been reported to be a primary cause of leg weakness in breeding swine (Reiland, 1976). Osteochondrosis in swine is manifested as a generalized disease of the physeal, epiphyseal, and articular cartilage. Osteochondrotic lesions occur at numerous sites throughout the body but have a particular predilection for the distal physis of the ulna, elbow joint, intervertabral joints, and knee joint (Grondalen, 1976; Reiland, 1976; Reiland, 1978a; Vaughan, 1971). The gross and histological morphology of osteochondrotic lesions have been well documented by Grondalen (1974a, 1974d), Reiland (1976), Reiland (1978a), and Vaughan (1971).

II. INFLUENCE OF NUTRITION AND GROWTH ON LEG WEAKNESS AND OSTEOCHONDROSIS

Variations in dietary vitamin A, vitamin D, calcium, phosphorus, and protein have negligible influence on the morbidity of osteochondrosis (Duthie and Lancaster, 1964; Grondalen, 1974e, 1974g; Nielsen, 1973; Nissan, 1980; Rieland, 1978b). However, high caloric intake (by quality and/or quantity of diet) increases the incidence of the condition according to Grondalen (1974e), Olsson and Rieland (1978), and Rieland (1978c). The deleterious effects of a high caloric intake are manifested through increased rate of growth, as shown by Goldspink (1972) and Reiland (1978b). Thus, a very rapid growth rate is generally considered to be an important factor in leg weakness.

Heredity plays an important role as a determinant of the growth potential of an individual and, in turn, osteochondrosis (Reiland et al., 1970). Animals bred for genetically induced slower rates of growth do not develop osteochondrosis (Olsson and Reiland, 1978; Reiland, 1976; Reiland, 1978c). Reiland (1978c) observed that animals fed a restricted diet had no or mild osteochondrosis lesions when compared to animals that were fed ad libitum and slaughtered at the same age. However, Grondalen (1974g) found no significant difference in the morbidity of the osteochondrosis lesions if rapidly growing and slowly growing animals were observed at the same weight rather than at the same age. Increased growth, superior feed efficiency, decreased body fat, and increased muscling represent a few of the characteristics genetically associated with the modern domestic pig and are considered desirable. Reiland et al. (1978) reported a positive correlation between osteochondrosis morbidity and many of the phenotypic traits currently judged desirable in modern swine. Grondalen (1974f) found that unfavorable phenotypic traits were heritable and associated with leg weakness in swine. Disadvantageous joint shape was shown, by Grondalen (1974f), to be genetically associated with leg weakness.

Growth hormone also has been implicated in osteochondrosis because of its association with increased growth rate (Olsson and Reiland, 1978; Reiland, 1976; Reiland, 1978c). Reiland (1978c) emphasized the etiological role of growth hormone in osteochondrosis based on the work of Ringberg Lund-Larsen and Bakke (1975). The latter authors reported that serum levels of growth hormone and somatomedin are higher in strains of pigs that grow rapidly and have low backfat thicknesses than in slower growing pigs. Conversely, Siers and Hazel (1970) and Siers and Swiger (1971) reported that growth hormone serum levels were lower in rapidly growing swine and related the decrease to more rapid utilization of the hormone. In a study of the effects of exogenous estrogen upon the morbidity and severity of osteochondrosis lesions in slaughter pigs (Nakano et al., 1979), no significant difference was observed between the control and treated animals.

III. INFLUENCE OF MUSCLE DEVELOPMENT ON LEG WEAKNESSES AND OSTEOCHONDROSIS

The association of the muscular system with leg weakness was suggested by Thurley (1967) and supported by Grondalen (1974e). Thurley (1967) observed that splay leg in baby pigs was associated with myofibrillar hypoplasia of the skeletal muscles. In the affected muscle fibers, myofibrils were decreased in number (Thurley and Done, 1969), and the ratio of the intracellular to extracellular potassium also was decreased. Patterson et al. (1969) hypothesized muscle weakness resulting from myofibrillar hypoplasia to be a predisposing factor to joint instability and subsequent signs of leg weakness. Histological studies by Ilchmann (1969) and electron microscopic studies by Bergmann and Wesemeir (1970) revealed the presence of the pathological changes within skeletal muscles of slaughter pigs, but the lesions were not significantly correlated with locomotor disabilities of the animals.

IV. INFLUENCE OF BIOMECHANICS ON LEG WEAKNESS AND OSTEOCHONDROSIS

The influence of altered biomechanics appeared to have a diverse influence in the etiologies of leg weakness and osteochondrosis. Regimented and mild exercise has a beneficial influence upon the mobility of rapidly growing swine (Grondalen, 1974e, Perrin and Bowland, 1977; Thurley, 1967). Furugouri and Kawabata (1982) postulated that signs of leg weakness were assumed to be due to poor leg development resulting from lack of exercise. However, Perrin and Bowland (1977) found that exercise had no beneficial influence on the severity of articular lesions. The beneficial effects of exercise upon the limb phenotype have been conjectured to result from strengthening of the muscles of the body (Grondalen, 1974e; Perrin and Bowland, 1977). Exercise loads applied to the forelimb of pigs has produced significant increase in the severity of the lesions of osteochondrosis (Grondalen, 1974e; Walker et al., 1966). Reiland (1978a) considered the biomechanical influence of excessive loading or trauma as the "triggering factor" in the etilogy of osteochondrosis.

Integral to the role of biomechanics in the etiologies of osteochondrosis and leg weakness are the gross anatomical composition of the animal and its related external conformational traits. Miller (1980) used radiography as a tool to determine the most desirable angles between the bones of the major joints of the limbs. He found that as the angulation of the joints became more obtuse, the structural soundness of the animal decreased (leg weakness increased). This inverse relationship presumably caused decreased cushioning or shock absorbing capability of the musculoskeletal system. Studies of the phenotypic characteristics of slaughter pigs indicate that narrow lumbar region, broad hams, great width between the stifle joints, and carcass length have a significant infleucne on locomotor ability (Grondalen, 1974e; van der Wal et al., 1980). Many workers (Fredeen and Sather, 1978; Thurley, 1967; Vaughan, 1971) agreed that differences in leg weakness of the live pig may be visually evaluated, but that the degree of joint damage (severity of osteochondrosis) cannot. Further, gross anatomical evaluation of the bones of the appendicular skeleton indicates that specific gross morphological characteristics of the skeleton (e.g., twist or torsion of the femur or humerus) have a significant influence on the external conformation and locomotor ability of swine (Grondalen, 1974c, 1974e).

V. INFLUENCE OF TOE SIZE ON LEG WEAKNESS AND OSTEOCHONDROSIS

Gross observations of the differences in the size of inside and outside toes of swine are easily made (Lidvall, 1982; Miller, 1980). This difference led the investigators to hypothesize that there were differences in the muscle and bone development of the digits. Kornegay et al. (1981) found that, in cases where the front outside toes of boars were longer than the front inside toes, the condition was due to a positioning effect of the metacarpals. The proximal end of the outside metacarpals was located distal to the proximal end of the inside metacarpals.

In cases of pigs with pad and toe lesions, the worn and irritated areas on the foot may be related to some form of leg weakness. Kornegay et al. (1981) found no relationship between pad scores and bone parameters or growth rate. Their soundness scores were not generally associated with pad scores. Newton et al. (1980) found that the type of slatted floor material had no effect on toe development. Pigs on plastic slats had longer hooves, while pigs on concrete developed narrower soles. Concrete produced the most hoof cracks while concrete and steel produced the least. All foot measures correlated significantly with growth rate. Hoof length and sole length were correlated with foot pad lesions and hoof cracks when pigs housed on various floors were considered together.

VI. GROWTH OF SWINE

Robison (1976) stated that the economic importance of growth rate is clear. A number of studies have established a high positive relationship between gain and efficient feed utilization. Also, a shorter feeding period increases rate of gain, reduces overhead and labor costs, and reduces risk of loss from accident and disease.

Presumably, swine populations can be characterized by their growth patterns. Yet growth is a complicated biological phenomenon with no adequately objective measurement. Growth may be considered as a combination of physical processes such as hyperplasia and hypertrophy which include volumetric development and chemical changes which are responsible for physiological maturation. Thus, growth may be considered in at least two ways: (1) an increase in body mass over time; and (2) changes in form or composition resulting from differential growth rates of component parts. The increase in body mass may be divided chronologically such as prenatal, post-natal to weaning, weaning to slaughter, and growth in the breeding herd (slaughter weight to maturity). Generally, composition is defined in terms of fat, bone, muscle, and internal organs.

Concerning prenatal growth, Ullrey et al. (1965) reported a comprehensive study of the growth of the swine fetus. Skeletal measures and body length generally exhibited a linear relation with age. On the other hand, soft tissues, including body weight, increased in a curvilinear fashion with age. However, for all measures of body composition including soft tissues, it appears that prenatal growth appears nearly linear after 72 days. Correlations between various skeletal measures or body length and age were high (.98).

Several workers have shown a strong negative correlation between litter size and individual prenatal growth. Salmon-Legangeur (1968) states that differential growth of individual organs does not significantly influence total body weight. While this objective appears to be valid prior to 70 days, it appears that after this time most structures are in a linear growth phase.

Actually, very little research has been reported on preweaning growth patterns. Whatley and Quaife (1937) reported on preweaning growth up to 10 weeks of age. Preweaning growth was generally curvilinear, but their growth curve suggested that preweaning growth could be divided into two distinct growth phases. If separated into growth before and after approximately six weeks, growth was essentially linear. It was their thinking that this change in growth may be due to implementation of supplemental feeding at about six weeks of age. Ahlschwede and Robison (1971) suggested that the relation between direct genetic and maternal effects changes from positive to negative at about three weeks of age (the age at which supplemental feed was made available). Their data illustrated that preweaning growth was significantly curvilinear. For the first four weeks growth was nearly linear; whereas, after this time, growth rapidly accelerated.

Retardation of growth due to insufficient food intake initiates a highly complicated chain of responses. Some aspects of development continue relatively unaffected by retardation of somatic growth; whereas, others keep more or less in step with the size of the animal (Robison, 1976). Thus, it appears that early growth patterns may affect physiological maturation and carcass composition.

Postweaning body weight curves have been reported by Donald (1940), Lush and Kincaid (1943), Taylor and Hazel (1955), and Abarca and Tapia (1963). The first two reports showed that a quadratic equation best fits the data. However, Taylor and Hazel (1955) reported linear growth between 134 and 174 days of age with similar slopes for the faster growing one-third and the slower growing one-third of the pigs. Growth between 53 and 346 days was reported to be linear by Abarca and Tapia (1963).

More recently, Quijandria and Robison (1971) and Standal (1973) reported body weight curves. In both cases the quadratic term was significant, the percentage of the variation accounted for was only slightly larger than accounted for by the linear model (less than 1%). The data of Quijandria and Robison (1971) covered the ages 119 to 154 days with a final weight of 82 kg; whereas, Standal (1973) had an age range of 135 to 225 days with final weights up to 130 kg. Using the data of Doornenbal (1971), with an age range of 78 to 210 days and a final weight of 130 kg, a significant quadratic regression was calculated; however, the quadratic term accounted for only 1% of the variance. Thus, it appears that, in swine, the quadratic function is statistically significant but probably of little biological (practical) importance for postweaning gains to about 130 kg.

CHAPTER III

EXPERIMENTAL PROCEDURE

Data for this study were collected from July, 1980 through February, 1981 from experiments conducted at The University of Tennessee Blount Farm, Knoxville, Tennessee.

I. EXPERIMENTAL ANIMALS

One hundred eighteen pigs, representing 12 litters, were used for this study. Pigs were sired by either a Duroc or Hampshire boar, while the sows were Duroc x Yorkshire, Yorkshire x Duroc, or Landrace x Yorkshire x Duroc.

II. MANAGEMENT

During gestation the sows were maintained in half-acre pasture lots and moved to the farrowing house approximately one week prior to farrowing. Within 24 hours after birth of pigs, needle teeth were clipped, birth weights were recorded, and the pigs were individually identified with earnotches. At day three, the pigs received intramuscular iron dextran, and at 10 days of age dirt was placed in the pig area of the farrowing crate to further prevent anemia. Pigs were vaccinated for erysipelas, and the male pigs were castrated at four weeks of age. Pigs were weaned by removing the sows from the crate at 35 days after farrowing. The pigs remained in the crate for an additional two weeks and were then moved to the grower-finishing house where they were kept for the duration of the study.

III. FACILITIES

The farrowing barn contains 24 crates that were 7 feet long and 6 feet wide. The sow area of the crates was 2 feet wide and there was a space 2 foot wide on either side for the pigs. The floors were concrete with the rear 2-1/2 feet slatted with half inch round steel rods spaced three-eights inch apart. Crates were equipped with a feed bowl and automatic waterer for the sows and a 25-pound capacity, 4-hole creep feeder for the pigs.

The grower-finishing house was a pole-type open-front barn, with approximately one-half of the area roofed. The pens were 5 feet wide and 20 feet long with an automatic waterer at the open end and a two-hole self feeder under the roof end. The floor was solid concrete with a 2% slope to a gutter. The pens were scraped and cleaned daily.

IV. FEEDING

At 21 days of age, the pigs were given access to an 18% crude protein creep diet (Table 1). Pigs remained on this diet until they had obtained approximately 75 pounds body weight at which time they were switched to the standard University of Tennessee 15% crude protein diet for finishing to market weight. The pigs remained on this diet until the experiment was completed.

TABLE 1. Eighteen percent crude protein creep diet

Ingredient	Pounds
No. 2 Yellow Corn	681
Soybean Oil Meal (44%)	200
Dehydrated Alfalfa Meal (17%)	100
Dicalcium Phosphate	10
Salt	5
Vitamin Premix[a]	8
Antibiotic[b]	1
Total	1005

[a]Provides an additional to the ration of 400,000 UPS units of vitamin A, 100,000 ICU units of vitamin D-3, 500 IU of vitamin E, 400 mg of riboflavin, 1,000 mg of pantothenic acid, 1,500 mg of niacin, 1,500 mg of vitamin B-12, 100 mg of Vit K, and 20,000 mg of chlorine chloride.

[b]Contains 50 gms per pound of Oxytetracycline.

V. SUBJECTIVE EVALUATION

Pigs were visually appraised by an experienced evaluator at 1, 7, 14, 21, 60, and 223 days of age. A scoring system of 1 to 15 was used to describe the pigs. A list of traits that were subjectively evaluated are presented in Table 2. Descriptions of each trait associated with score values 2, 5, 8, 11, and 14 are shown. Other score values were considered to be slight deviations above or below the score values shown in the table (+ or -). Each scale was predetermined to cover the range of the respective traits in the total swine population. Therefore, the lower or higher values for scores related to some traits were used infrequently in this study.

VI. OBJECTIVE BODY AND FOOT MEASUREMENTS

Each pig was weighed, photographed, and objectively measured on day 1, 7, 14, 21, 60, and 210. All measurements were taken while the pig was manually held, except for day 210, when the pigs were restrained in a tilt table squeeze chute, and the measurements were taken while the pig was inverted.

Objective body measurements are illustrated in Figure 1. All circumference measurements were taken with string and then transferred to a ruler calibrated in centimeters. Circumference of the lower foreleg (CLFL) Was taken at the midpoint of the II, III, IV, and V metacarpals. Circumference of the foreleg (CFL)

TABLE 2. Traits and descriptive values utilized in visually scoring pigs for soundness

	2	5	8	11	14
1. Frame, scale (length)	29"	30"	31"	32"	33"
2. Backfat	1.4+"	1.4-1.2"	1.2-1.0"	1.0-.8"	.8"-
Sow (condition score)	Fat	Fleshy	Average	Poor	Thin
3. Muscle size (LEA)	4.0-	4.0-4.5	4.5-5.0	5.0-6.0	6.0+
4. Muscle design - shape	Very round & tight	Slighty round & tight	Average	Slightly long & loose	Very long & & loose
5. Width (spring of rib, width of walk)	Very narrow	Slightly narrow	Average	Slightly wide	Very wide
6. Depth (volume)	Very shallow	Slightly shallow	Average	Slightly deep	Very deep
7. Topline - design	Very high top	Definite arch	Slightly arched	Level	Flat or swayed
8. Rump structure	Steep rump	Somewhat steep	Normal - some slope (10°-20°)	Slight slope	Level to nearly level
9. Shoulder (top view)	Very tight	Somewhat tight	Normal	Slightly wide	Very wide
10. Shoulder (side view)	Shoulder back-angle of humerus open	Shoulder sloping slightly back	Top of shoulder above foot	Shoulder slightly forward	Shoulder forward-angle of humerus closed
11. Front leg (side view)	Knuckled over at knee	Front leg & knee straight	Knee very slightly back - slight curvature	Knee back - decided curvature	Knee definitely back - leg curved
12. Front pastern	Definitely straight - up on toes	Somewhat straight up on toes slightly	Normal sl. (10°-20°) angle - foot down square	Pastern sloping (20°-35°)	Decided slope - almost walks on dewclaw
13. Front leg (front view)	Knees out, toes in slightly	Straight - toes very slightly in	Normal - toes out at very slight angle (0-3°)	Knees sl. in, moderately toed out	Knees in - feet splayed
14. Rear leg (side view)	Very post legged	Slightly post legged	Normal - some "set" to hock	Slightly sickle hocked	Very sickle hocked

TABLE 2.(Continued)

		2	5	8	11	14
15.	Rear pastern	Definitely straight - up toes	Somewhat straight up on toes slightly	Normal -slight (10°-20°) angle-foot set down square	Pastern sloping (20°-35°)	Decided slope - almost walks on dewclaw
16.	Rear leg (rear view)	Hocks out, feet turned in	Hocks turned slightly out	Normal - hocks very slightly pointed in	Hocks in, feet pointed out	Cow-hocked - hocks almost touching, feet turned out
17.	Toe uniformity (front)	Inside toes decidedly smaller	Inside toes smaller	Inside toes very slightly smaller	Toes same size	Inside toes larger
18.	Toe uniformity (rear)	Inside toes decidedly smaller	Inside toes smaller	Inside toes very slightly smaller	Toes same size	Inside toes larger
19.	Substance of bone	Very light, flat refined bone	Bone somewhat light	Average bone	Greater than average bone	Heavy, coarse round bone
20.	Gait	Short, choppy, stiff difficult gait	Somewhat restricted gait	Acceptable or satisfactory	Rather long, free gait	Loose, fluid, easy-going gait
21.	Looseness of skeleton	Very tight made	Slightly tight and restricted	Average	Somewhat loose	Very loose
22.	Overal soundness score	Unsound	Marginally unsound	Acceptable	Sound	Very sound

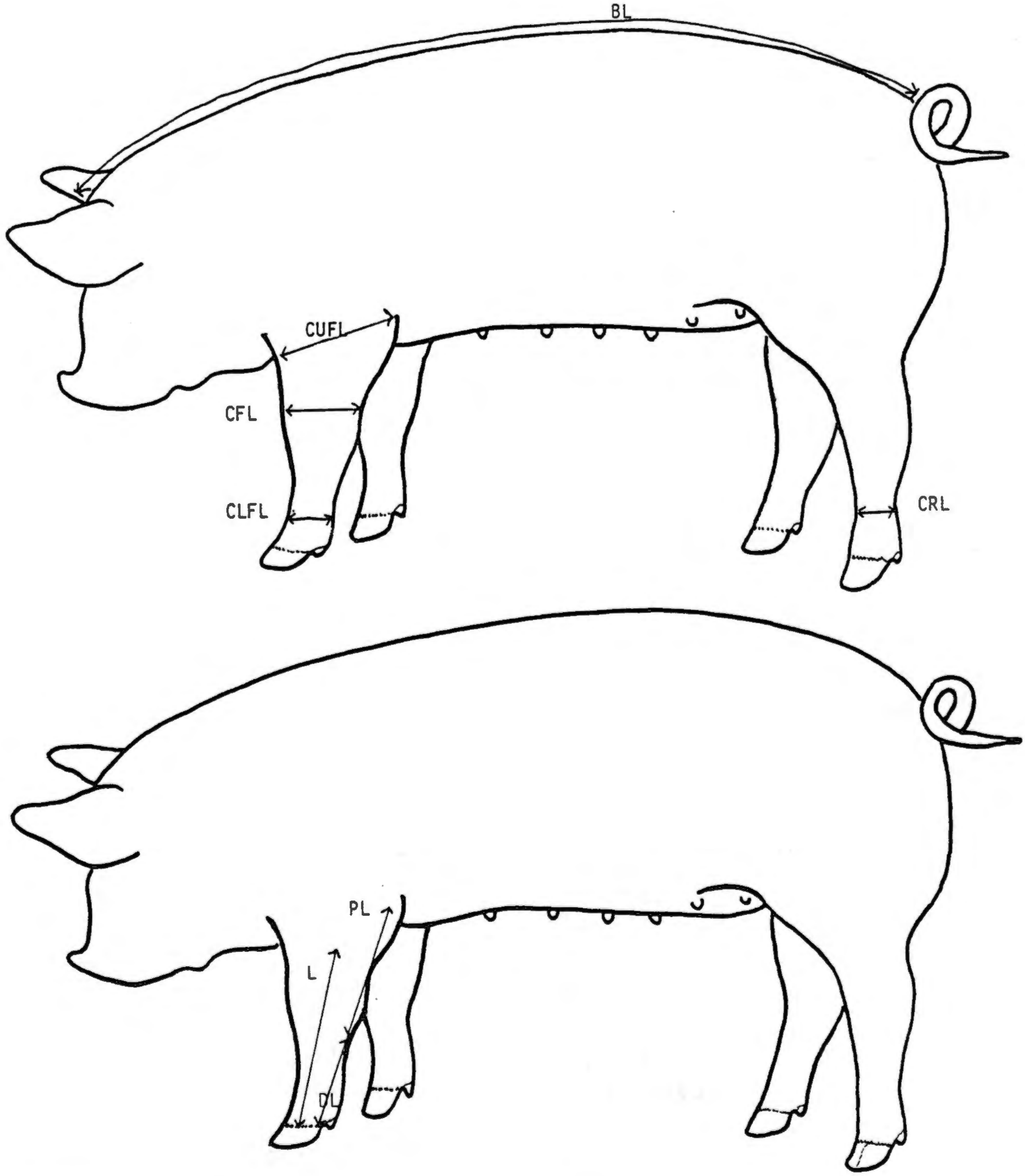

FIGURE 1. Location of objective body measures.

was taken at the midpoint of the radius and ulna. Circumference of the upper foreleg (CUFL) was taken around the humerus, radius, and ulna joint and was an indication of mass. Circumference of the rear leg (CRL) was taken at the midpoint of the II, III, IV, and V metacarpals.

The linear leg measurements were taken with a divider and transferred to a ruler calibrated in centimeters. The distal leg (DL) was measured from the hair line of the hoof to the process of the accessory carpal bone. The proximal leg (PL) was measured from the process of the accessory carpal bone to the tip of the olecranon process. The leg (L) measurement was taken from the hair line of the hoof to the lateral condyle of the humerus.

Body length (BL) was measured with a steel tape from the base of the poll to the root of the tail.

Objective foot measurements are illustrated in Figure 2. The same measurements were taken on each foot. All foot measurements were obtained with the use of a divider and transferred to a ruler calibrated in centimeters.

Toe height (TH) was taken from the most anterior point of the toe to the hair line of the hoof. Toe width (TW), measured on the sole of the toe, was taken from the most lateral point to the most medial point directly anterior to the pad. Toe depth (TD), measured on the sole of the toe, was taken from the most anterior edge of the toe to the most anterior edge of the pad. Pad depth (PD) was measured from the most anterior point to its

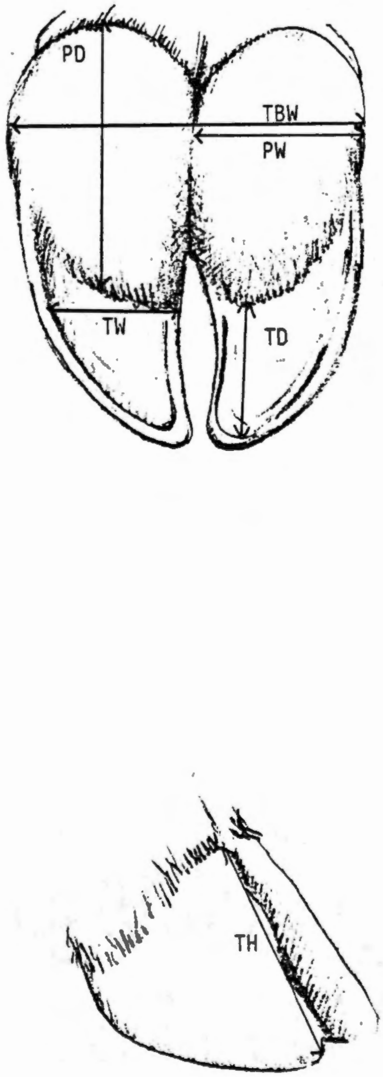

FIGURE 2. Location of objective toe measures.

posterior wear line. Pad width (PW) was taken lateral to medial at its widest point. These measurements were taken on both lateral and medial toes. Total pad width (TPW) was a combination width of both lateral and medial pads and was taken from the lateral point of the lateral pad to the most medial point of the medial pad. Difference variables, by foot, toe height difference (THD), toe width difference (TWD), toe depth difference (TDD), pad depth difference (PDD), and pad width difference (PWD) were calculated by subtracting the medial variable from the lateral variable.

VII. STATISTICAL ANALYSIS

The statistical analysis system of Barr and Goodnight (1979) was used to perform stepwise regression analyses to order and eliminate variables for subsequent analyses. Multiple regression analyses of the subjective scores were then performed on the following model:

$Y = \mu + \text{foreleg sideview}_j + \text{front pastern}_j + \text{topline}_k + \text{error}_{ijk}$, when Y is subjective overall soundness score.

CHAPTER IV

RESULTS AND DISCUSSION

I. RESULTS

Means and standard deviations of subjective overall soundness score and the component scores which were considered to be associated with the overall score are shown in Table 3. Means of overall soundness score increased (pigs were scored more sound) from 7.0 at day 1 to 9.4 at day 21, and then decreased (pigs were scored less sound) to 7.8 at day 223. This increase at intermediate ages followed by a decrease in score magnitude at later ages was observed also in many of the component scores.

Scores of the shoulder, foreleg, and rear leg when viewed from the side, topline, toe uniformity of both front and rear feet, bone size, and scores related to the pig's gait all tended to follow the same pattern as the overall soundness score as age increased. However, the magnitude of the subjective scores of frame size and loin eye area tended to decrease at intermediate ages. The means of scores for fatness, width, depth, slope of rump, shoulder viewed from the top, front view of the legs, and front pasterns tended to fluctuate without an established pattern or to remain constant as age increased from 1 to 223 days. Scores for rear pasterns and rear legs viewed from the rear tended to decrease with age. However, the means at day 1 and day 223 are similar in their description of overall soundness and its component scores.

TABLE 3. Means and standard deviations by age for subjectively evaluated traits

	Age, days					
	01 n = 17	7 n = 101	14 n = 93	21 n = 85	60 n = 64	223 n = 61
Overall soundness score	7.0 ± 3.93	8.8 ± 3.00	8.8 ± 2.55	9.4 ± 2.25	8.5 ± 2.28	7.8 ± 3.83
Component parts:						
Frame size	8.9 ± 3.46	8.6 ± 2.67	8.1 ± 2.16	8.3 ± 2.25	7.9 ± 2.34	9.3 ± 2.88
Fat	7.4 ± 2.45	7.2 ± 2.25	8.2 ± 2.53	7.7 ± 1.57	8.1 ± 1.45	7.5 ± 2.78
Loin-eye area	8.9 ± 2.30	9.0 ± 1.68	7.6 ± 2.33	7.7 ± 1.49	7.7 ± 1.99	9.3 ± 1.87
Muscle design	7.6 ± 2.77	6.8 ± 2.36	8.4 ± 1.66	8.7 ± 2.59	8.9 ± 2.88	7.6 ± 2.85
Width	9.0 ± 2.46	9.5 ± 2.04	7.4 ± 2.61	9.3 ± 1.44	8.9 ± 2.01	9.6 ± 2.31
Depth	9.6 ± 2.62	9.5 ± 2.16	9.7 ± 1.71	9.1 ± 1.77	6.2 ± 2.10	10.0 ± 2.42
Topline	7.4 ± 2.19	7.8 ± 1.95	9.8 ± 2.03	7.2 ± 1.55	6.9 ± 1.91	7.7 ± 2.27
Slope to rump	6.5 ± 2.56	6.8 ± 1.89	6.8 ± 1.54	6.3 ± 1.27	6.3 ± 1.53	6.9 ± 2.97
Shoulder topview	8.7 ± 2.77	9.9 ± 1.95	6.0 ± 1.41	9.1 ± 1.41	8.6 ± 1.66	9.4 ± 2.07
Shoulder sideview	7.1 ± 2.56	8.5 ± 2.63	9.9 ± 2.18	8.4 ± 1.48	7.7 ± 1.65	8.3 ± 2.66
Foreleg sideview	6.2 ± 3.06	8.0 ± 2.88	8.4 ± 1.79	7.8 ± 1.74	7.0 ± 1.80	7.4 ± 3.28
Front pastern	7.4 ± 3.10	8.0 ± 2.12	7.9 ± 1.87	8.2 ± 1.45	7.5 ± 1.32	8.7 ± 2.77
Foreleg frontview	8.4 ± 2.35	9.3 ± 1.43	8.2 ± 1.82	9.4 ± 1.32	9.2 ± 1.29	9.2 ± 1.39
Rear leg sideview	6.7 ± 2.27	8.1 ± 2.41	9.1 ± 1.29	8.2 ± 1.95	8.2 ± 1.97	6.6 ± 2.23
Rear pastern	7.7 ± 2.35	6.9 ± 1.96	8.2 ± 1.90	6.4 ± 1.32	6.3 ± 1.37	6.6 ± 2.39
Rear leg rearview	10.2 ± 1.71	10.6 ± 1.84	6.5 ± 1.53	10.5 ± 1.31	10.4 ± 1.61	8.8 ± 1.59
Toe uniformity-front	8.7 ± 2.28	9.7 ± 2.17	10.7 ± 1.42	8.7 ± 1.99	8.9 ± 1.82	8.0 ± 2.13
Toe uniformity-rear	6.7 ± 2.06	7.1 ± 1.97	9.6 ± 2.54	6.5 ± 1.83	6.9 ± 1.64	5.9 ± 1.86
Bone size	8.7 ± 3.17	9.0 ± 2.55	9.6 ± 2.27	9.3 ± 2.10	8.2 ± 2.45	8.7 ± 1.88
Gait	7.1 ± 3.46	8.5 ± 3.02	9.2 ± 2.50	9.6 ± 2.39	8.3 ± 2.32	7.8 ± 3.52
Looseness	7.0 ± 3.41	8.8 ± 3.08	8.3 ± 2.70	9.7 ± 2.19	8.8 ± 2.49	8.3 ± 3.15
Live weight (kg)	1.6 ± .39	2.6 ± .64	3.7 ± .98	7.0 ± 1.64	13.55± 3.16	123.1 ± 16.77

One possible cause of the trend for the scores to be curvilinear could be that as the pigs increased in age from birth to day 21, they were exercising and stretching their musculoskeletal system. Then, prior to scoring on day 60, the pigs were weaned and the stress associated with weaning and adjusting to a new environment tended to alter their phenotypic expression which resulted in lower subjective scores (indicating greater unsoundness). By day 223, the pigs could have recovered from the stress associated with weaning, and a truer phenotype, with respect to unsoundness, would be expressed, and this change is reflected by the evaluator's scores.

Coefficients of correlation (Table 4) among subjective estimates (scores) of the growth and composition components show similar relationships to those reported in studies where objective measurement of these variables were used. The relationships indicate that as pigs become heavier, they are also subjectively larger, heavier muscled, wider, deeper, and the circumference of their bones increased. Among the component scores, the only negative associations were those of fat thickness with other traits, fat thickness being negatively associated with all other component scores of growth and composition.

The coefficients of correlation of the component scores of growth with overall soundness score showed a definite trend. Although most of the growth and composition scores were related to the overall score at early ages, no significant (P>.05) association

TABLE 4.. Coefficients of correlation among subjective estimates of growth, composition and overall soundness score

Subjective estimates of;	Age, days[a]	Weight	Frame	Fat thickness	Loin Eye Area	Body Width	Body Depth	Bone Size	Overall Soundness Score
Weight	1		.54[b]	-.52	.51	.41	.51	.65	.25**
	7		.56	-.51	.65	.66	.70	.81	.32
	14		.61	-.64	.68	.73	.78	.86	.33
	21		.61	-.37	.45	.67	.72	.79	.23*
	60		.64	-.48	.67	.79	.82	.83	.08ns
	223		.64	-.39**	.02ns	.57	.64	.42**	.12ns
Frame	1			-.36	.51	.52	.72	.69	.24**
	7			-.13ns	.53	.54	.68	.61	.09ns
	14			-.29	.46	.45	.62	.62	.08ns
	21			-.12ns	.32	.38	.55	.56	.06ns
	60			-.08ns	.37	.58	.62	.65	.18ns
	223			-.28	.02ns	.61	.69	.72	.18ns
Fat thickness	1				-.61	-.51	-.49	-.66	-.32ns
	7				-.54	-.59	-.47	-.58	-.41
	14				-.73	-.72	-.59	-.62	-.13ns
	21				-.49	-.51	-.56	-.54	-.03
	60				-.48	-.43	-.39	-.44	.19
	223				.42	-.31*	-.30*	-.05ns	-.25ns
Loin eye area	1					.67	.66	.72	.06ns
	7					.81	.78	.73	.39
	14					.76	.69	.71	.18ns
	21					.61	.60	.56	-.02ns
	60					.72	.71	.65	-.13ns
	223					.29*	.02ns	.14ns	-.27ns
Body width	1						.75	.67	.19*
	7						.79	.77	.43
	14						.78	.78	.18ns
	21						.77	.76	.19ns
	60						.82	.83	.09ns
	223						.62	.66	.25ns
Body depth	1							.74	.19*
	7							.82	.30
	14							.81	.27
	21							.79	.14ns
	60							.81	-.04ns
	223							.66	.19ns
Bone size	1								.32
	7								.45
	14								.24**
	21								.14ns
	60								.03ns
	223								.26ns

*P<.05.

**P<.01.

ns = nonsignificant

[a]There were 117 pigs at age 1, 101 pigs at age 101, 93 pigs at age 14, 85 pigs at age 21, 64 pigs at age 60, and 61 pigs at age 223.

[b]All other coefficients are significant at P<.001.

was observed between any of these component scores and overall soundness score at day 60. Other reports where objective measurements were used have suggested a significant relationship between growth and unsoundness. However, the relationship has been generally restricted to weight and unsoundness. The only growth and composition score significantly ($P<.05$) associated with overall soundness score at day 21 was that of weight. The evaluator tended to observe significant ($P<.05$) associations between growth and composition and unsoundness at days 1, 7, and 14. This suggests that there appeared to be more difference among the pigs with respect to growth and composition component scores than in other indicators of structural unsoundness at early ages and that these affected overall soundness score. This is in agreement with the trend with respect to change in the magnitude of the score values as age increases, shown in Table 3.

Coefficients of correlation among scores for individual skeletal shape components are shown in Table 5. Due to the similarities in the magnitude of component scores at various ages, scores taken on days 1, 60, and 223 were selected to be shown. The highest associations ($P<.001$) at all ages were those between topline, rump, shoulder viewed from the side, foreleg viewed from the side, and front pastern. There was a trend for the coefficients of correlation among the scores of skeletal shape components at the intermediate ages to be smaller than those at younger and older ages.

TABLE 5. Coefficients of correlation among individual skeletal shape components of overall soundness score at selected pig ages

Component scored	Age, Days[a]	Topline	Rump	Shoulder top view	Shoulder side view	Foreleg side view	Front Pastern	Foreleg front view	Rear side view	Rear pastern	Overall soundness score
Topline	1		.55[b]	.03^{ns}	.41	.39	.27	.12^{ns}	.39	.25**	50
	60		.71	.08^{ns}	.46	.35	.39	-.26*	.01^{ns}	.11^{ns}	.45
	223		.67	.52	.39	.37**	.44	.01^{ns}	.36**	.28^{ns}	.49
Rump	1			-.06^{ns}	.33	.25**	.18^{ns}	.08^{ns}	.29	.17^{ns}	.35
	60			-.01^{ns}	.27*	.12^{ms}	.17^{ns}	-.15^{ns}	-.06^{ns}	-.16^{ns}	.25*
	223			.37**	.36**	.41	.39	-.01^{ns}	.42	.55	.51
Shoulder top view	1				.27**	.32**	.40	.09^{ns}	.06^{ns}	.37**	.34**
	60				.09^{ns}	.11^{ns}	.16^{ns}	.09^{ns}	.09^{ns}	.25^{ns}	.09^{ns}
	223				.38*	.31*	.46**	.01^{ns}	.32*	.40*	.41*
Shoulder side view	1					.84	.83	.22*	.56	.62	.83
	60					.71	.57	-.28*	.45**	.29*	.68
	223					.93	.82	-.27^{ns}	.43*	.22^{ns}	.83
Fore leg side view	1						.80	.27*	.47	.61	.86
	60						.82	-.31*	.46	.37*	.75
	223						.84	-.36*	.44*	.30*	.85
Front pastern	1							.24*	.49	.74	.85
	60							-.27*	.46	.12^{ns}	.75
	223							-.23^{ns}	.52**	-.33*	.81
Fore leg Front view	1								.18^{ns}	.23*	.32*
	60								-.07^{ns}	-.20^{ns}	-.21^{ns}
	223								-.02^{ns}	.16^{ns}	-.26^{ns}
Rear leg side view	1									.61	.58
	60									.47	.48
	223									.63	.60
Rear pastern	1										.73
	60										.51
	223										.40*

*$P<.05$.

**$P<.001$.

ns=nonsignificant.

[a]There were 117 pigs at age 1, 64 pigs at age 60, and 61 pigs at age 223.

[b]All other coefficients are significant at $P<.0001$.

Coefficients of correlation between scores of skeletal shape components and overall soundness score show that the scores of topline, rump, shoulder viewed from the side, foreleg viewed from the side, front pastern, and rear leg viewed from the side were positively correlated ($P<.001$) with overall soundness score at all ages. Although these relationships were significant at 60 days of age, they tended to be smaller in magnitude than at other ages. One explanation for this is that there appeared to be less variation in the pigs at day 60 with respect to these traits and with respect to the subjective scores which were associated with these trends.

The score evaluating the degree of the slope of the rump was positively associated with the score indicating arch of the topline. However, slope of rump was negatively associated with view of the shoulder from the top, front view of the foreleg, and rear pastern. Coefficients of correlation between foreleg front view and rear leg side view with other scores varied in magnitude and direction and appeared to be independent of other scores. One observation that was difficult to explain was the negative ($P<.05$) relationship between the front leg scores made while viewing that limb from the front and those made while viewing it from the side.

Coefficients of correlation among subjective estimates of foot conformation, gait, and overall soundness score are presented in Table 6. The correlation between front toe uniformity and rear

TABLE 6. Coefficients of correlation among subjective estimates at foot conformation, gait, and overall soundness

Subjective estimates of:	Age, Days	Front toe uniformity	Rear toe uniformity	Gait	Looseness	Overall soundness score
Front toe uniformity	1[a]		.46[b]	-.07[ns]	-.09[ns]	.07[ns]
	7		.47	.12[ns]	.12[ns]	.14[ns]
	14		.41	.41	.44	.42
	21		.26*	.25*	.30*	.29*
	60		.42**	.19[ns]	.33*	.27*
	223		.41*	.22[ns]	.39*	.27*
Rear toe uniformity	1			.33**	.31*	.31*
	7			.12[ns]	.15[ns]	.16[ns]
	14			.34**	.33*	.35**
	21			.15[ns]	.16[ns]	.14[ns]
	60			.36*	.37*	.39*
	223			.30*	.47**	.36*
Gait	1				.96	.96
	7				.93	.95
	14				.93	.95
	21				.93	.97
	60				.90	.97
	223				.92	.97
Looseness	1					.97
	7					.97
	14					.97
	21					.95
	60					.96
	223					.93

*P<.05.

**P<.001.

[ns]=nonsignificant.

[a]There were 117 pigs at age 1, 101 pigs at age 7, 93 pigs at age 14, 85 pigs at age 21, 64 pigs at age 60, and 61 pigs at age 223.

[b]All other coefficients are significantly different at P<.0001.

toe uniformity was highest, .47 ($P<.0001$), at days 1 and 7, and lowest, .26 ($P<.05$), at day 21. The positive association suggested that front and rear feet develop similarly. Uniformity of the toes of the front feet was not significantly associated with gait at early and late ages, while toe uniformity at the rear feet was correlated ($P<.05$) with looseness and gait at days 60 and 223. Toe uniformity of both front and rear extremities was positively correlated ($P<.05$) with overall soundness score at days 60 and 223. The exceptionally high ($r = .92$ to $.97$) and significant coefficients of correlation ($P<.0001$) among gait, looseness, and overall soundness score indicated that they tend to have similar effects on the overall score and are good indicators of that score.

The score, looseness and gait, was included to express an overall description of the body motion during movement. It was positively and extremely highly correlated with the score of gait and with overall soundness score at all ages. These correlations suggest that these two component scores, gait and looseness, were the most valuable component scores with respect to predicting the overall soundness score.

Means and standard deviations of objective toe and pad measurements are shown in Table 7. There were very small differences between the mean of the lateral toe length measurement and that of the corresponding medial measurement. However, pad width and pad depth were rather consistent, in that the measurements of the lateral toes were generally larger than those of the medial toe at all ages.

TABLE 7. Means and standard deviations of objective toe and pad measurements by age, in cm

Measurement	Age, days 1 N = 117	7 N = 101	14 N = 93	21 N = 85	60 N = 64	223 N = 61
Lateral						
Toe Height	1.04 ± .11	1.10 ± .12	1.26 ± .12	1.63 ± .15	1.92 ± .22	3.70 ± .30
Toe Width	.62 ± .09	.83 ± .11	.99 ± .11	1.13 ± .10	1.39 ± .15	2.51 ± .18
Toe Depth	.53 ± .07	.58 ± .08	.69 ± .09	.77 ± .09	.95 ± .10	2.09 ± .21
Pad Width	.86 ± .13	1.02 ± .11	1.13 ± .13	1.35 ± .11	1.59 ± .15	2.39 ± .20
Pad Depth	.91 ± .14	1.07 ± .15	1.24 ± .13	1.51 ± .14	1.75 ± .17	2.54 ± .33
Medial						
Toe Height	1.06 ± .10	1.09 ± .14	1.25 ± .12	1.61 ± .15	1.93 ± .18	3.52 ± .35
Toe Width	.63 ± .09	.80 ± .09	.95 ± .13	1.12 ± .15	1.32 ± .14	2.29 ± .27
Toe Depth	.56 ± .06	.61 ± .07	.75 ± .62	.80 ± .09	.96 ± .10	1.98 ± .25
Pad Width	.81 ± .12	.99 ± .09	1.09 ± .10	1.28 ± .09	1.53 ± .14	2.19 ± .24
Pad Depth	.83 ± .14	1.04 ± .14	1.71 ± .14	1.44 ± .14	1.65 ± .20	2.53 ± .32
Total Pad Width	1.78 ± .19	2.04 ± .21	2.29 ± .22	2.77 ± .22	3.21 = .25	5.10 ± .35

The greatest expression of the above trend was observed at 223 days of age when the toe height, width, and depth of the lateral and medial toes were 3.70 vs. 3.52, 2.51 vs. 2.29, and 2.09 vs. 1.98 cm, respectively. Pad width and depth of the toes at this age were 2.39 vs. 2.19 and 2.54 vs. 2.53 cm, respectively. It appears that as the pigs become older and heavier there is a tendancy for the medial toe and pad to wear more than the lateral toe and pad.

Means and standard deviations of the calculated differences between the lateral and medial toes are given in Table 8. The larger differences tended to be those between lateral and medial toe width, pad depth and pad width, with the lateral measurement consistently larger than the medial. Since the lateral movement was larger at day 1, it appears that it should continue to be dominant in size from useage and due to the weight it supports. Although the differences in toe height are apparent at birth, they remain small until day 223. This could be due to the wearing off of the toe surface where the measurements were taken.

The major increase in difference between measurements of the lateral and medial toes occurred between day 60 and day 223, and the largest changes were observed in the front feet. This time period represents the greatest stress on the toe due to the increased weight of the pig.

Means and standard deviations of the toe and pad measurements for the front feet are shown in Table 9. The measurements of the

TABLE 8. Means and standard deviations of calculated differences between the lateral and medial toe and pad measurement for individual feet at various ages, in cm

		Age, days					
		1	7	14	21	60	223
Variable	Foot	N = 117	N = 101	N = 93	N = 85	N = 64	N = 61
Toe Height	1[a]	.011 ± .09	.032 ± .16	.003 ± .09	.017 ± .34	.077 ± .15	.060 ± .23
	2	.018 ± .09	.003 ± .18	.019 ± .09	.041 ± .11	.053 ± .17	.156 ± .32
	3	.002 ± .09	.019 ± .12	.009 ± .12	.008 ± .14	-.007 ± .15	.322 ± .26
	4	-.015 ± .09	.008 ± .14	.011 ± .14	.018 ± .11	-.005 ± .15	.180 ± .25
Toe Width	1	.008 ± .08	.005 ± .10	.012 ± .11	.059 ± .17	.087 ± .13	.325 ± .27
	2	.019 ± .07	.023 ± .09	.011 ± .14	.054 ± .11	.087 ± .12	.183 ± .31
	3	-.005 ± .08	.005 ± .09	.018 ± .09	.031 ± .13	.089 ± .16	.263 ± .24
	4	.009 ± .07	.267 ± .44	.365 ± .48	.353 ± .48	.297 ± .46	.082 ± .28
Toe Depth	1	.005 ± .09	.001 ± .08	.001 ± .09	.011 ± .09	.000 ± .12	.039 ± .23
	2	.005 ± .07	-.006 ± .09	.003 ± .09	-.010 ± .09	-.002 ± .11	-.052 ± .26
	3	-.009 ± .07	-.007 ± .13	-.013 ± .09	-.015 ± .10	-.010 ± .11	.037 ± .25
	4	-.032 ± .06	-.019 ± .09	-.065 ± .61	-.028 ± .10	.010 ± .12	.114 ± .23
Pad Depth	1	.033 ± .09	.025 ± .15	.016 ± .13	.014 ± .13	.014 ± .19	.059 ± .81
	2	.076 ± .09	.069 ± .11	.042 ± .14	.079 ± .13	.098 ± .16	.262 ± .83
	3	.110 ± .11	.090 ± .11	.114 ± .12	.125 ± .14	.141 ± .15	.349 ± .28
	4	.082 ± .11	.035 ± .11	.068 ± .11	.075 ± .12	.102 ± .16	.015 ± .36
Pad Width	1	.038 ± .08	.031 ± .08	.049 ± .09	.047 ± .11	.105 ± .12	.136 ± .29
	2	.041 ± .08	.021 ± .11	.009 ± .09	.081 ± .15	.122 ± .14	.138 ± .30
	3	.056 ± .08	.003 ± .09	.026 ± .09	.053 ± .10	.100 ± .17	.253 ± .28
	4	.044 ± .07	.031 ± .09	.035 ± .09	.065 ± .10	.058 ± .12	.195 ± .26

[a]Foot 1 = left front foot, foot 2 - left rear foot, foot 3 = right rear foot, and foot 4 = right front foot.

TABLE 9. Means and standard deviations of objective toe and pad measurements for the front feet by age, in cm

	Age, days					
	1	7	14	21	60	223
Measurement	N = 117	N = 101	N = 93	N = 85	N = 64	N = 61
Lateral						
Toe Height	1.04 ± .11	1.10 ± .12	1.26 ± .12	1.63 ± .15	1.93 ± .22	3.70 ± .30
Toe Width	.62 ± .10	.83 ± .11	.99 ± .11	1.13 ± .10	1.39 ± .15	2.51 ± .18
Toe Depth	.53 ± .07	.59 ± .08	.69 ± .10	.77 ± .09	.95 ± .10	2.09 ± .21
Pad Width	.91 ± .15	1.02 ± .11	1.13 ± .13	1.35 ± .11	1.59 ± .15	2.39 ± .20
Pad Depth	.81 ± .13	1.07 ± .15	1.24 ± .13	1.51 ± .14	1.75 ± .17	2.54 ± .33
Medial						
Toe Height	1.06 ± .11	1.09 ± .14	1.25 ± .12	1.61 ± .15	1.93 ± .18	3.52 ± .27
Toe Width	.64 ± .10	.80 ± .09	.96 ± .13	1.12 ± .15	1.32 ± .14	2.30 ± .27
Toe Depth	.57 ± .06	.61 ± .08	.75 ± .62	.80 ± .09	.96 ± .10	1.98 ± .25
Pad Width	.81 ± .13	.99 ± .10	1.10 ± .10	1.28 ± .09	1.53 ± .14	2.19 ± .24
Pad Depth	.83 ± .14	1.03 ± .14	1.17 ± .15	1.44 ± .14	1.65 ± .20	2.53 ± .32
Total Pad Width	1.78 ± .20	2.04 ± .21	2.29 ± .22	2.77 ± .22	3.21 ± .25	5.10 ± .35

front feet were selected for more detailed study since unsoundness is more frequently associated with front feet. The larger differences between lateral and medial toe measurements at early ages were those of pad width and pad depth. The lateral toe was not always dominant (largest) at these early ages. However, the lateral toe was larger with respect to all measurements at day 223. This suggests that the size of the lateral and medial pad remains similar from birth to market. Whereas, in the comparison of lateral and medial toe measurements, the medial toe was slightly larger at birth, but significantly smaller at market age.

Pooled means and standard deviations for toe and pad measurements of the front feet are shown in Table 10. The larger standard deviations, indicating more variation, are those of pad width, pad depth, and total pad width. The variation, expressed as standard deviations, of differences between lateral and medial toes increased with age, and the largest standard deviation was observed at day 223. Toe width differences has the largest standard deviations at days 1, 7, 21, and 60, whereas pad width had the largest standard deviation at day 223. This suggests that differences in width would be more important to the total foot surface, due to its relationship to the distribution and support of weight than differences in toe height and depth.

The coefficients of correlation among toe and pad measurements, for the front feet only, are shown in Table 11. The larger coefficients were observed at day 1 and, as age approached day 223, their magnitude

TABLE 10. Means and standard deviations of objective toe and pad measurements and calculated toe differences for the combined front feet, by age, in cm

	Age, days					
	1	7	14	21	60	223
Measurement	N = 117	N = 101	N = 93	N = 85	N = 64	N = 61
Lateral						
Toe Height	1.05 ± .10	1.10 ± .10	1.25 ± .10	1.62 ± .14	1.92 ± .18	3.67 ± .29
Toe Width	.84 ± .09	.96 ± .09	1.12 ± .10	1.39 ± .07	1.67 ± .15	3.09 ± .22
Toe Depth	.55 ± .07	.59 ± .07	.69 ± .08	.78 ± .07	.95 ± .09	2.07 ± .22
pad Width	.86 ± .12	1.02 ± .10	1.14 ± .11	1.34 ± .10	1.60 ± .15	2.34 ± .18
Pad Depth	.87 ± .14	1.04 ± .12	1.16 ± .12	1.39 ± .12	1.64 ± .14	2.53 ± .19
Medial						
Toe Height	1.05 ± .09	1.08 ± .12	1.24 ± .11	1.62 ± .22	1.89 ± .16	3.55 ± .35
Toe Width	.64 ± .08	.81 ± .03	.97 ± .10	1.10 ± .11	1.32 ± .12	2.22 ± .18
Toe Depth	.56 ± .05	.60 = .05	.72 ± .31	.79 ± .07	.95 ± .08	1.99 ± .21
Pad Width	.82 ± .13	.99 ± .09	1.10 ± .10	1.29 ± .10	1.51 ± .14	2.18 ±. 26
Pad Depth	.84 ± .15	1.04 ± .14	1.17 ± .14	1.44 ± .15	1.66 ± .19	2.57 ± .32
Total Pad Width	1.78 ± .19	2.03 ± .23	2.52 ± .28	2.77 ± .20	3.21 ± .24	5.03 ± .32
Differences						
Toe Height	-.01 ± .06	.02 ± .11	.01 ± .07	.00 ± .18	.04 ± .09	.12 ± .18
Toe Width	.16 ± .23	.14 ± .23	.19 ± .25	.21 ± .25	.19 ± .24	.20 ± .22
Toe Depth	-.01 ± .05	-.01 ± .07	-.03 ± .31	-.01 ± .07	-.01 ± .08	.08 ± .18
Pad Width	.04 ± .05	.03 ± .09	.04 ± .08	.04 ± .09	.06 ± .13	.04 ± .26
Pad Depth	.06 ± .08	.03 ± .06	.04 ± .07	.06 ± .08	.08 ± .09	.17 ± .22

TABLE 11. Coefficients of correlation among objective toe and pad measurements for the front feet at selected pig ages

Objective measurements	Age day[a]	Lateral Toe Height	Lateral Toe Width	Lateral Toe Depth	Lateral Pad Width	Lateral Pad Depth	Medial Toe Height	Medial Toe Width	Medial Toe Depth	Medial Pad Width	Medial Pad Depth	Total Pad Width
Lateral												
Toe Height	1		.97	.97	.95	.94	.98	.95	.84	.94	.94	.97
	60		.63	.36*	.73	.70	.71	.57	.50	.67	.62	.74
	223		.29*	.43**	.73	.43**	.73	.32*	.44**	.16ns	.35*	.23ns
Toe Width	1			.95	.96	.93	.96	.96	.82	.95	.95	.97
	60			.51	.62	.46	.36	.50	.49	.46	.60	.67
	223			.24*	.27*	.14ns	.17ns	.25*	.02ns	.16ns	.40**	.31*
Toe Depth	1				.37	.28**	.46	.38	.47	.38	.26**	.36
	60				.41	.35**	.26*	.34**	.27*	.35**	.31*	.42
	223				.20ns	.05ns	.35**	.10ns	.51	-.13ns	.06ns	.08ns
Pad Width	1					.71	.66	.47	.29**	.82	.66	.84
	60					.51	.59	.57	.37**	.67	.60	.85
	223					-.01ns	.16ns	.22ns	.25*	.34**	.21ns	.56
Pad Depth	1						.64	.45	.18*	.72	.69	.68
	60						.56	.45	.49	.58	.64	.66
	223						.36**	.33**	.26*	.19ns	.37**	.17ns
Medial												
Toe Height	1							.44	.34	.65	.59	.59
	60							.51	.39**	.54	.49	.63
	223							.44	.41	.28*	.42	.30*
Toe Width	1								.44	.49	.39	.47
	60								.47	.59	.53	.61
	223								.45	.51	.23ns	.51

TABLE 11 (Continued)

		Lateral					Medial					Total
Objective measurements	Age day[a]	Toe Height	Toe Width	Toe Depth	Pad Width	Pad Depth	Toe Height	Toe Width	Toe Depth	Pad Width	Pad Depth	Pad Width
Toe Depth	1									.27**	.26*	.28**
	60									.35**	.51	.50
	223									.12[ns]	.13[ns]	.20[ns]
Pad Width	1										.73	.82
	60										.60	.81
	223										.48	.69
Pad Depth	1											.69
	60											.69
	223											.41*

*P<.05.

**P<.001.

[ns]nonsignificant

[a]There were 117 pigs at age 1, 64 pigs at age 60, and 61 pigs at age 223.

[b]All other coefficients were significant at P<.001.

and significance decrease. One explanation for this could be that after day 1, increased use of the toes and pads for support and changes in the environments to which the pigs feet were subjected (floor surface) resulted in changes in the measurements. It is possible, also, that the relationships observed at day 1 represented more nearly pure genetic influences and that later relationships were altered by genetic-environmental interactions.

Coefficients of correlation among the pooled means of the objective front measurements and subjective estimates of growth and composition are shown in Table 12. The largest coefficients, for all relationships, are those at day 60. The coefficients show that toe and pad measurements were correlated with growth and composition estimates in a similar fashion and at a similar level at ages 1, 60, and 223. This indicates that the differences in lateral and medial toe measurements were considered to be related in a like manner at all ages, but that there was less variation between the measurements at day 60. The coefficients of correlation between pad width, pad depth, and total pad width tend to be larger than those among other objective measurements at all days (1, 60, and 223).

Table 13 contains results of the analysis of variance for litter effect on overall soundness score. Litter differences accounted for 34% of the total variation in overall soundness score (P<.0001). However, the variation explained by litter at day 1 could be either genetic differences or differences in prenatal

TABLE 12. Coefficients of correlation among objective toe and pad measurements for the combined front feet and subjective estimates of growth and composition at selected pig ages

Objective measurements	Age, days[a]	Frame	Fat	Loin eye area	Body width	Body depth	Bone size
Lateral							
Toe Height	1	.49[b]	-.14[ns]	.26*	.16[ns]	.34**	.36**
	60	.59	-.40**	.51	.72	.71	.78
	223	.52**	-.26[ns]	-.11[ns]	.31*	.36*	.27[ns]
Toe Width	1	.40	-.07[ns]	.38*	.22*	.29*	.33**
	60	.60	-.45**	.61	.67	.76	.82
	223	.50	-.21[ns]	-.09[ns]	.35*	.38*	.39*
Toe depth	1	.28*	-.09[ns]	.09[ns]	.02[ns]	.18[ns]	.33**
	60	.50	-.30*	.44**	.50	.54	.53
	223	.11[ns]	-.20[ns]	-.14[ns]	.23[ns]	-.18[ns]	-.01[ns]
Pad Width	1	.40	-.03[ns]	.27*	.17[ns]	.39	.27*
	60	.55	-.39*	.63	.68	.75	.72
	223	.48*	-.16[ns]	.07[ns]	.37*	.36*	.48*
Pad Depth	1	.43	-.02[ns]	.29*	.19[ns]	.43	.29*
	60	.55	-.25*	.48	.62	.70	.68
	223	.32*	-.03[ns]	.02[ns]	.27[ns]	.31	.44*
Medial							
Toe Height	1	.49	-.06[ns]	.30*	.14[ns]	.34**	.32*
	60	.67	-.33*	.57	.66	.64	.71
	223	.40*	-.19[ns]	-.04[ns]	.32*	.27[ns]	.31*
Toe Width	1	.34**	.08[ns]	.14[ns]	.11[ns]	.24*	.19[ns]
	60	.68	.55	.45**	.49	.58	.58
	223	.30*	-.11[ns]	.05[ns]	.35*	.23[ns]	.33*

TABLE 12 (Continued)

Objective measurements	Age, days[a]	Frame	Fat	Loin eye area	Body width	Body depth	Bone size
Toe Depth	1	.36**	-.12[ns]	.08[ns]	.06[ns]	.18[ns]	.29*
	60	.47	-.31*	.42**	.42**	.52	.46
	223	.41*	-.47*	.00[ns]	.41*	.21[ns]	.09[ns]
Pad Width	1	.35**	-.11[ns]	.35**	.22*	.41	.31*
	60	.62	-.39*	.59	.68	.79	.60
	223	.39*	-.19[ns]	.05[ns]	.43*	.38*	.46*
Pad Depth	1	.42	-.13[ns]	.34**	.26*	.44	.35**
	60	.41**	-.33*	.53	.55	.56	.73
	223	.36*	-.46*	-.03[ns]	.40*	.26[ns]	.30[ns]
Total Pad Width	1	.44	-18[ns]	.36*	.26*	.43	.43
	60	.63	-.44**	.68	.75	.79	.81
	223	.57	-.03[ns]	-.04[ns]	.46*	.36*	.72

*$P<.05$.

**$P<.001$.

[ns]=nonsignificant.

[a]There were 117 pigs at age 1, 64 pigs at age 60, and 61 pigs at age 223.

[b]All other coefficients were significant at $P<.0001$.

TABLE 13. Analysis of variance of litter effect on overall soundness score

Source	Overall soundness score df	MS
Litter	9	44.14*
Residual	90	8.24
	R-square	.3488

*P<.0001.

environment. The means and standard deviations of subjectively evaluated traits with litter effect included and with litter effect removed were identical. Therefore, it appears that genetic development was not masked by prenatal environment; however, there could be a prenatal genotype-environmental interaction.

The effects of age on selected subjective scores and measurements are shown in Table 14. where Y is topline, shoulder side view, front pastern, foreleg side view, overall soundness score, and weight. The effect of age on topline was linear ($P<.05$). As the pigs became older, they developed more arch to their topline. Shoulder side view was linear ($P<.05$) and, therefore, as the pigs became older, the shoulder tended to be more forward, reducing the angle of the humerus. Only the cubic term was significant ($P<.05$) in this model. The models for foreleg sideview, overall soundness score, and weight were all cubic, and were significant at the $P<.05$ level or greater. This indicated that there was a rapid early increase in conditions reflected by the scores followed by a period of slower increase, and this was followed by another rapidly increasing phase. One explanation of the trends observed from the model for weight would be that, in the early phase, when the pigs were nursing, the dependency on the sow resulted in similar rapid weight increases, while the stresses of weaning resulted in the leveling-off phase. The magnitude of the mean square for the nursery phase (35 to 60 days) indicated that this environment accounts for more of the variation in weight increase than that of

TABLE 14. Analysis of variance of the effect of day of age on subjective scores and measurements

		Measurement or score mean squares					
Source	df	Topline	Shoulder side view	Front pastern	Foreleg side view	Overall soundness score	Weight
Age	1	13.25*	19.62*	13.59	38.60*	141.84***	493.69*
Age^2	1	7.07	17.98	17.80	35.55*	108.24**	12730.89***
Age^3	1	4.71	16.94	19.81*	32.54*	89.92	6216.48***
Residual	486	3.65	5.03	4.89	6.66	8.38	147.19
R-square		.0140	.0093	.0914	.0118	.0380	.9726

*P<.05.

**P<.01.

***P<.001.

the final increasing phase after the pigs have adjusted to weaning. This is further illustrated in Figure 3. The R-square for the models show that weight was the only variable that contributes any appreciable amount of variation.

Stepwise regression analyses were performed to evaluate the effect of subjective component scores on overall soundness score. Variables that entered the equations early (at all ages) are shown in Table 15. The best one-variable models contained either foreleg side view (days 1, 7, 21, and 223) or front pastern (days 14 and 60). In the best two-variable models, new variables that entered the equation were rear leg side view, shoulder side view, and toe uniformity (front) scores. Increases in R-squares were .07, .04, .06, .06, .08, and .08 for days 1, 7, 14, 21, 60, and 223, respectively. The best three-variable models showed that width, muscle design, and shoulder top view were important new variables that had not entered previously. Changes in R-squares due to adding a third variable to the model were .04, .03, .05, .02, .04, and .02 for days 1, 7, 14, 21, 60, and 223, respectively. The only additional variable to enter the models, including the best four-variable model, was weight. Although small, the increase in R-square due to adding the fourth variable to the model were .02, .02, .02, .01, .04, and .04 for days 1, 7, 14, 21, 60, and 223, respectively. The contributions of other variables were inconsistent, and changes in R-square were small when these variables entered the system. The previously identified trend, for the lower amount

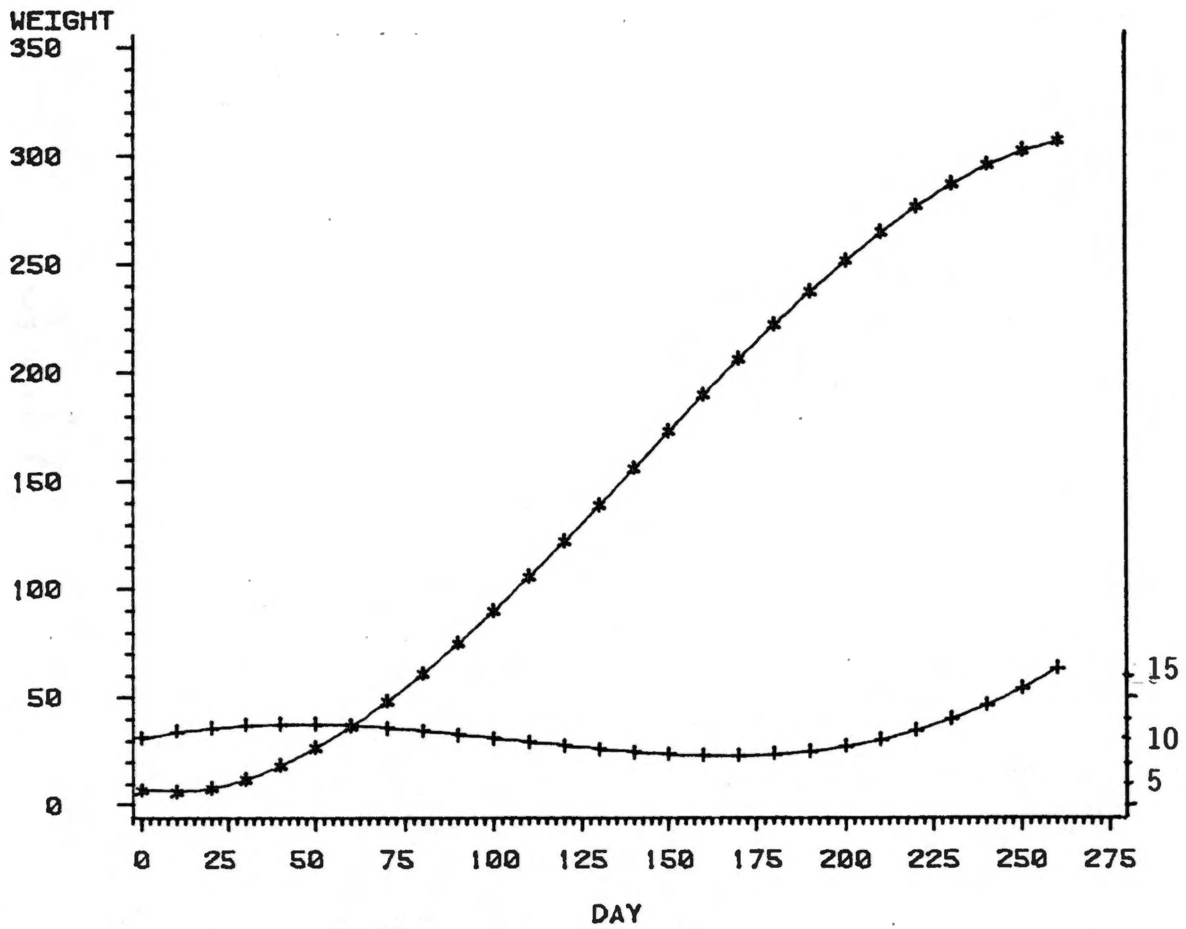

FIGURE 3. Changes in mean body weight and subjective overall soundness score of pigs from birth to slaughter.

TABLE 15. Changes in R-square due to sequentially adding variables to the regression model for estimating overall soundness score

	Fore leg side view	Front pasterns	Topline	Rear pasterns	Rear leg, side view	Shoulder side view	Front toe uniformity	Width	Muscle design	Shoulder top view	Weight	Age, days					
												1	7	14	21	60	223
One variable models	X											.75	.71		.52	.58	.72
		X												.52			
Two variable models	X	X										.07					
	X		X										.04		.06		
		X					X							.06			
		X				X										.08	
	X				X												.06
Three variable models	X	X	X									.04					
	X		X					X					.03				
		X	X				X							.05			
	X		X		X										.02		
		X				X			X							.04	
	X				X					X							.02
Four variable models	X	X	X	X								.02					
	X		X	X				X					.02				
		X	X	X			X							.02			
	X		X		X					X					.01		
		X		X		X			X							.04	
	X				X					X	X						.04

of variation explained in the intermediate or nursery ages, was again observed upon examination of the R-squares from the stepwise regression, and an explanation for these lower values is probably similar to that discussed previously.

The analysis of variance for the effect of the subjective estimates of unsoundness components that were found to be consistent and pertinent in the stepwise regression analyses on overall soundness scores are shown in Table 16. The model accounted for 76% of the variation in overall soundness score. The variables foreleg side view, front pastern, and topline all accounted for significant amounts ($P<.0001$) of the variation. This was considered logical, since they all affected skeletal shape and the differences were easily observed and utilized by the evaluator during scoring. Age, although significant ($P<.0001$) explained the least variation in overall soundness score of any variable included in the model.

Overall soundness score at day 1, 7, 14, 21, and 60 was used, in separate models, to predict overall soundness score at day 223 with R-square values of .0039, .0174, .0197, .0001, and .0116 for days 1, 7, 14, 21, and 60, respectively (Table 17). This could be explained by the fact that previous results have shown that the component scores evaluated different effects at the different ages.

Analyses of variance of overall soundness score with models containing toe and pad measurements are shown in Table 18. Models containing toe height, width, and depth variables explained very

TABLE 16. Analysis of variance of the effect of unsoundness of various body components and age on the overall soundness score[a]

Source[b]	Overall soundness score df	MS
Foreleg side view	1	2760.23*
Front pastern	1	193.94*
Topline	1	116.83*
Age	6	24.39*
Residual	480	2.12
	R-square	.7598

*P<.0001.

[a]Immediately after viewing the animal, an overall unsoundness score was recorded. Then various body components were studied in detail and scored individually.

[b]The independent variables were subjective scores evaluating structure of the foreleg when viewed from the side, the front pastern, and the topline of each animal at ages 1, 7, 14, 21, 60, and 223 days.

TABLE 17. Analysis of variance of the effect of overall soundness scores at early ages on overall soundness score at day 223

	Overall soundness score, at day				
	1	7	14	31	60
df	1	1	1	1	1
Mean square	1.57	8.80	9.92	.07	5.56
Residual	11.29	11.51	11.48	11.99	14.29
Residual df	35	43	43	42	33
R-square	.0039	.0174	.0197	.0001	.0116

TABLE 18. Analyses of variance of overall soundness score with models containing toe and pad dimensions

Source	Toe Height		Toe Width		Toe Depth		Pad Width		Pad Depth		Total Pad Width		
	df	MS	df	MS	df	MS	df	MS	df	MS	Source	df	MS
Lateral 1[a]	1	7.08	1	17.42	1	5.88	1	16.05	1	5.37	Total pad width 1	1	5.36
Medial 1	1	15.82	1	.85	1	9.52	1	218.75***	1	55.11**	Total pad width 2	1	45.50*
Lateral 2	1	36.08*	1	.03	1	36.04*	1	.90	1	.01	Total pad width 3	1	8.28
Medial 2	1	4.32	1	64.11**	1	.11	1	8.21	1	4.14	Total pad width 4	1	2.80
Lateral 3	1	9.94	1	5.11	1	3.98	1	105.43**	1	.04			
Medial 3	1	.89	1	47.76**	1	9.04	1	6.03	1	9.94			
Lateral 4	1	.31	1	37.85*	1	3.48	1	4.49	1	29.04*			
Medial 4	1	17.58	1	8.57	1	10.47	1	5.80	1	93.36***			
Residual	467	8.62	466	8.33	466	8.55	464	8.01	464	8.37		468	8.59
R-square	.02		.04		.02		.09		.05			.02	
R-square[b]	.07		.13		.03		.21		.09			.16	
R-square[c]	.09		.09		.06		.10		.04			.08	
R-square[d]	.20		.18		.12		.17		.12			.11	
R-square[e]	.07		.11		.16		.11		.06			.07	
R-square[f]	.16		.16		.25		.25		.10			.03	
R-square[g]	.35		.15		.09		.26		.37			.07	

*P<.05.

**P<.01.

***P<.001.

[a]Foot 1 = left front foot, foot 2 = left rear foot, foot 3 = right rear foot, foot 4 = right front foot.

[b]R-square for model at day 1

[c]R-square for model at day 7.

[d]R-square for model at day 14.

[e]R-square for model at day 21.

[f]R-square at day 60.

[g]R-square at day 223.

small amounts of the variation in overall soundness score with R-square values of .02, .04, and .02, respectively. Models containing pad width and depth variables had higher R-square values of .09 and .05, respectively. This agrees with the previous analyses where pad width and depth were more highly associated with overall soundness score. All models had higher R-square values at day 223 than at day 1, however, the R-square values at days 7, 14, 21, and 60 were inconsistent, and no trend was observed.

Models containing toe and pad difference variables (Table 19) show similar trends. The models containing pad with differences and toe depth differences tend to have the higher R-square values at all ages. One explanation of this is that as the angulation of the foreleg was moved forward, the depth and pad width decreased. As the foreleg was cushioned back, more weight was distributed to the heel of the foot, thereby resulting in widening of the pad and lengthening of the toe.

II. DISCUSSION

Pigs can be evaluated or described for structural soundness; however, this evaluation appears to change from birth to market age as does the general appearance of the pig. Differences in structural soundness among pigs are apparent at birth, but the pigs tend to appear more sound at intermediate ages with less variation in the population. This trend continues to weaning age and through the weaning adjustment period. Differences among pigs

TABLE 19. Analyses of variance of overall soundness score with models containing the variables for difference between lateral and medial toes and pads

Source	Toe Height Difference df	Toe Height Difference MS	Toe Width Difference df	Toe Width Difference MS	Toe Depth Difference df	Toe Depth Difference MS	Pad Width Difference df	Pad Width Difference MS	Pad Depth Difference df	Pad Depth Difference MS
Foot 1[a]	1	12.82	1	3.63	1	13.51	1	143.73***	1	46.77*
Foot 2	1	.82	1	22.70*	1	13.33	1	2.36	1	.16
Foot 3	1	1.70	1	.20	1	1.30	1	30.70**	1	1.29
Foot 4	1	4.23	1	.84	1	15.00	1	.77	1	21.48*
Residual	471	8.70	470	8.59	470	8.55	468	8.33	468	8.57
R-square	.005		.01		.01		.05		.02	
R-square[b]	.02		.02		.25		.17		.01	
R-square[c]	.07		.02		.02		.03		.02	
R-square[d]	.005		.05		.09		.08		.09	
R-square[e]	.06		.04		.08		.06		.007	
R-square[f]	.05		.12		.007		.22		.08	
R-square[g]	.03		.04		.05		.17		.07	

*P<.10.

**P<.05.

***P<.001.

[a]Foot 1 = left front foot, foot 2 - left rear foot, foot 3 = right rear foot, foot 4 = right front foot.

[b]R-square at day 1.

[c]R-square at day 7.

[d]R-square at day 14.

[e]R-square at day 21.

[f]R-square at day 60.

[g]R-square at day 223.

begin to increase during the growing phase and continue increasing to market age. This structural soundness pattern tends to follow the growth production pattern of the pig. At birth, the pig is dependent upon the sow for energy to grow and must compete with other pigs to get his requirements for growth. The competition to obtain these requirements provides the pig exercise which stretches and extends his musculoskeletal system, making him appear more sound. this phenomenon appears to continue to weaning, at which time the pig is stressed and usually placed in a new environment with a new diet. The pig requires time to become acclimated to his new surroundings, and during this time, the pig tends to exhibit a similar appearance. This is supported by the generally recognized ability of feeder pig graders to accurately describe and sort pigs into uniform outcome groups. The pigs, after adjustment to their new environment, start to grow rapidly, and this rapid growth continues to market weight with considerably variation in the time required to reach that point.

These structural soundness and growth patterns raise the question of whether differences in structural soundness are more largely due to genetic differences or to environmental differences. The fact that pigs are born structurally unsound and the litter effect observed in this study makes it appear that differences in structural soundness are more largely the result of genetic differences. The question of the influence of prenatal development on structural unsoundness has been relatively untouched by researchers and could provide valuable information concerning structural soundness. The environmental activities of the pig at early ages appear to result in the pig being more structurally sound; however, there is undoubtably a genetic x environmental interaction involved.

An evaluator tends to use those skeletal shape components (foreleg side view, front pastern, and topline) which are easily and readily recognized to aid in estimation of overall soundness score. Although other factors may be used to arrive at the overall score, these component scores are more closely associated with the foreleg, which is the area in which structural soundness is given more attention by producers.

Foot size and toe uniformity are of great concern to the swine producer when evaluating soundness. However, it appears that toe depth, pad width, and pad depth should be of more concern. These measures tend to be affected by the angulation of the foreleg and the front pastern. The pig that is unsound and "over" at the knee or pastern would have its weight distributed more to the front of its foot. This would cause wear and shorten the toe, and the lack of weight carried on the pads would decrease the dimensions of this softer tissue (pad). However, if the knee and pastern were more curved and "set-back," the weight load would be shifted to the rear of the foot causing less wear to the toe and a spreading of the softer pad tissue.

Growth and composition of the pig tends to be used to influence structural soundness at an early age, but less association was observed from weaning to market. It could be suggested that a genetic x environmental interaction is affecting the association of growth and composition with structural soundness.

Conclusions drawn from this study are: (1) skeletal shape components do affect estimates of overall soundness; (2) pad width and depth are more highly associated with the subjective estimate of overall soundness than other foot measurements; (3) differences in size between lateral and medial toes increases with age, but accounts for little variation in overall soundness score; (4) the most variation in overall soundness score is explained by scores made between birth and weaning and at market age, with the least variation explained by scores made during the weaning to the grower phase; (5) structural soundness in pigs follows the pattern of growth but is influenced by environment; and (6) variation in overall soundness score appears to be due to both genetic and environmental differences.

CHAPTER V

SUMMARY

One hundred eighteen pigs, representing 12 litters, were used to study structural soundness and toe size uniformity. The pigs were sired by either a Hampshire or Duroc boar and the sows were Duroc x Yorkshire, Yorkshire x Duroc, or Landrace x Yorkshire x Duroc crosses. Pigs were cared for by normal and standard management and feeding practices. While in the farrowing house, the floor surface was partly concrete and partly one-half inch steel rods spaced three-eights of an inch apart. The grower-finishing unit had a total concrete floor. Pigs were visually appraised by an experienced evaluator at 1, 7, 14, 21, 60, and 223 days of age. Pigs were first scored for overall soundness and then scored for components of growth and composition, and components of skeletal shape. All scoring was on a 1-15 basis. At the same days of age, each pig was measured, in centimeters, for toe and pad size and the differences between lateral and medial toe measurements were calculated.

The evaluator's scores accounted for more variation among younger pigs and pigs at 223 days of age, while there was less variation in scores at the intermediate time of 60 days of age. The skeletal shape components of foreleg side view, front pastern, and topline and the variable age accounted for 76% of the total variation in overall soundness score.

Pad width and pad depth were more highly associated to overall soundness score than any other foot measures. Calculated differences between lateral and medial toes and pads provided little explanation in the variation of overall soundness score, however, scores for pad width and pad depth did tend to explain the most variation in overall soundness score at all ages, especially at day 223 with R-squares of .26 and .37 respectively.

Growth of the pigs tended to follow the chronological schedule of management and environmental changes. This chronological schedule affected the total variation that the evaluator observed in the population. Litter effect explained 34% of the variation in overall soundness score at birth, however, when litter effect was removed the means of the subjective components remained the same. This would indicate that soundness score is the result of genetics, however, more likely it is influenced by both genetic and environmental components.

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