# THE INFLUENCE OF MONTH OF BIRTH ON GROWTH AND DEVELOPMENT OF THOROUGHBRED FOALS AND YEARLINGS

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# INTRODUCTION

Most breed associations have adopted the universal horse birth date of January 1. Therefore, many horse owners now emphasize early breeding in order to produce futurity prospects or young horses for the show circuit. Producers of yearlings are concerned primarily with the short-term goal of obtaining the highest prices for their horses. Buyers traditionally, have paid more for a large-framed, well-muscled yearling, assuming that the larger the horse, the sooner it can begin training and competition.

It has seemed logical to horse breeders that foals born earlier in the calendar year are larger-framed and heavier at a later fixed date than foals born later. Thus, owners of race horses are most concerned with the production of early foals. However, breeding to produce foals early in the calendar year is costly in terms of reproductive efficiency; neither the stallion nor the mare are physiologically or behaviorally adapted for such an early breeding season.

Therefore, this study was developed with the following objectives:

1. To obtain definitive information on growth patterns of Thoroughbred foals from birth to the summer of their yearling year.

2. To evaluate the influence of month of birth on growth and development.

3. To develop equations that predict and describe the patterns of growth in various parts of the body.

If it could be established that foals born later in the spring were not at a disadvantage in terms of size, maturity or racing ability compared to foals born in January and February, the emphasis placed on an early-breeding schedule could be adjusted. In order to convince horse owners, buyers of prospective race horses and futurity prospects, stud farm managers and breed associations to make any change regarding current management practices, the relationships between birth month and size or ability need to be studied. Previous researchers have alluded to the idea that there are no differences in size between early- and later-born foals, once a particular age is reached. However, many of those studies were conducted with small numbers of animals and many factors that could influence growth and size were ignored. A recent study, conducted with 1100 Thoroughbred foals, was designed much like the proposed project. However, it was conducted in Canada, where enviromental and seasonal conditions differ from those in Virginia.

None of the established growth studies of horses have been conducted in Virginia, nor have the effects of month of birth or sex on growth been determined at constant ages and at constant dates. Thus, the proposed research would increase our knowledge and understanding of the growth patterns of Thoroughbred foals. Additionally, conclusions drawn from the proposed study could be useful to individuals raising other breeds of horses as well.

## REVIEW OF LITERATURE

### Growth and development

Growth can be defined as a biological synthesis. Development can be defined as specialization of that matter which is synthesized. Thus, the two phenomena can occur either simultaneously or independently. Upon reaching mature size, an animal has ceased visible growth yet homeostasis, the balance of catabolism and anabolism of physical constituents, maintains a constant mature size (Brody, 1945).

The growth of individuals and populations has been well studied and characterized. Brody (1945) reported that growth curves were asymptotic. THus, they became curvilinear with time. The inflection point in the growth curve, between the linear and quadratic protions of the curve, was equated with puberty. In general, puberty in the horse occurred at 18 mo-of-age and at a body weight equal to 68% of mature size (Willoughby, 1975). In comparison, cattle and sheep had 30% of their mature body weight at puberty (Brody, 1927).

Optimum growth or maximum growth and superior growth are not synonymous. Brody (1945) stated that superiority implied efficiency and vitality while the most rapid growth was associated with the highest early mortality. Russell (1969) and Joubert (1963) noted that in domesticated species of cattle compared with unselected species, there was a greatly accelerated rate of growth. Furthermore, puberty occurred at a time ahead of the inflection point in the growth curve such that there was no constant relationship between the inflection point and the onset of puberty. They suggested that optimum growth dissrupted the relationship between normal growth and normal reproductive function.

In 1978, the NRC stated that their estimated growth curves for horses of various mature weights were

> "examples rather than models of growth curves because the question of how fast a horse should grow for maximum performance and soundness remains unresolved".

Actual growth curves of individual body parts could serve as an index to proper feeding and management by pointing out critical periods of growth and development (Heird, 1973).

Many investigators have attempted to characterize the size and scale of various breeds of horses, including the Thoroughbred horse (table 1). However, these measurements are reference points only and offer no insight into the growth and development of the horse.

TABLE 1. AVERAGE MEASUREMENTS OF CONFORMATIONAL COMPONENTS IN THOROUGHBRED HORSES AT BIRTH[1,2] OR AT MATURITY[3].

| Horses | Number | Body measurement | | | |
|---|---|---|---|---|---|
| | | Weight (kg) | Wither height (cm) | Heart girth (cm) | Cannon bone circumference (cm) |
| Foals[1] | 55 | 42.7 | 92.8 | 78.6 | 11.8 |
| Stallions[2] | 8 | – | 166.1 | – | – |
| Stallions[2] | 6 | – | 162.0 | – | – |
| Stallions[3] | – | 545.0 | 162.0 | – | – |
| Mares[3] | – | 500.0 | 160.0 | – | – |

[1]McNellis, 1945
[2]Dinsmore, 1959
[3]Willoughby, 1975

The growth rates of different breeds are similar, yet their mature sizes differ. Thus, stages of growth are commonly expressed as percentages of the mature size. Percentages are most meaningful when comparing different breeds or sexes within a breed.

Degree of mature size at birth and the age of maturity

At birth, horses possess a larger proportion of their mature limb length compared to the proportion of their mature body mass at birth (table 2). The percentage of mature weight at birth was lower than the percentage maturity of all other measurements at birth. Likewise, the percentage increase in weight from birth to maturity was greater than the percentage increase in all other conformational components during the same period. On the other hand, the proportion of the mature length from knee to ground, an indirect measure of cannon bone length, was largest at birth and the least percentage increase in length from knee to ground from birth to maturity was observed. Trowbridge and Chittendon (1932) reported that at birth, 32 and 67% of wither height were due to chest depth and length from chest floor to ground, respectively. At five yr-of-age, chest depth made up 48% of wither height. Wojciechowski (1965) reported that the postnatal increase in limb length was minimal when compared to growth in other

TABLE 2. THE PERCENTAGE OF MATURE SIZE IN VARIOUS CONFORMATIONAL COMPONENTS ATTAINED AT BIRTH AND THE PERCENTAGE INCREASE IN THOSE COMPONENTS MEASURED FROM BIRTH TO MATURITY

| | Studies reporting percentage | | | |
|---|---|---|---|---|
| | of mature size at birth | | | increase from birth to maturity |
| Measurement | A[1] | B[2] | C[3] | D[4] |
| Wither height | 62 | 79 | 62 | 58 |
| Hip height | - | - | - | 54 |
| Body weight | 8 | - | 10 | 932 |
| Knee to ground | 82 | 94 | - | 26 |
| Elbow to ground | 71 | - | - | - |
| Cannon bone circumference | 59 | 75 | - | 65 |
| Body length | 45 | 65 | - | - |
| Chest width | 39 | 64 | - | - |
| Heart girth | 42 | - | - | 124 |

[1]Cunningham and Fowler, 1961
[2]Heird, 1973
[3]Hintz et al., 1978
[4]Trowbridge and Chittendon, 1932

parts of the body. This further illustrates that quantitative postnatal growth of body mass is proportionally greater than growth of skeletal frame.

Because foals possess varying degrees of maturity in specific body measurements at birth, it is not surprising that they attain maturity in particular measurements at diverse ages. Reed and Dunn (1977) and Cunningham and Fowler (1961) reported that females reached mature proportions earlier than did males (table 3). In comparison, Heird (1973) suggested that the age at maturity was equivalent for both sexes. In all of these studies, measurements were not obtained between 48 and 60 mo-of-age. Thus, the accuracy of obtaining age at maturity was limited to 12 mo. Furthermore, there were considerable discrepancies between reported ages at maturity, particularly for the length from knee to ground. The discrepancies were due to a very small increase in the length from knee to ground from 6 to 60 mo-of-age. Reed and Dunn (1977) reported the age at maturity as 60 mo-of-age while Cunningham and Fowler (1961) were less precise. They assumed the sizes at 6 and 18 mo-of-age of males and females, respectively, to be mature.

In general, horses reached mature skeletal dimensions before they attained mature body mass. This is not

TABLE 3. AGE ( MONTHS) AT WHICH HORSES ACHEIVED MATURE SIZE IN VARIOUS CONFORMATIONAL COMPONENTS

| | Individual studies | | | | | |
|---|---|---|---|---|---|---|
| | A[1] | | B[2] | | C[3] | |
| Measurement | Males | Females | Males | Females | Males | Females |
| Wither height | 60 | 48 | 60 | 48 | 36 | 36 |
| Hip height | 60 | 36 | 60 | 48 | - | - |
| Knee to ground | 60 | 60 | 6 | 18 | 60 | 18 |
| Body weight | 60 | 60 | 60 | 60 | - | - |
| Body length | 36 | 36 | 36 | 48 | 48 | 60 |

[1]Reed and Dunn, 1977 : Arabian horses

[2]Cunninghan and Fowler, 1961 : Quarter horses

[3]Heird, 1973 : Quarter horses

surprising as foals are born with a larger proportion of their mature limb length relative to body mass. The maturation in length from knee to ground occurred earlist in foals followed by the maturation of body length, hip height and wither height, respectively. Mature body weight was acheived after all skeletal components had reached mature size (table 3).

The daily quantitative requirements for protein, calcium and phosphorus and the percentage of dietary energy is greater for horses from birth to 24 mo-of-age than for horses older than 2 yr-of-age (NRC, 1978). In addition, protein quality, particularly lysine availability, is more critical for young growing animals than for mature horses (Ott et al., 1979). Colts fed diets containing either milk protein or linseed meal plus lysine gained more weight, had greater nitrogen retention and exhibited a higher feed efficiency than colts fed a diet containing linseed meal as the only protein source (Hintz et al., 1971). Thus, the importance of proper nutrition for the young animal can be emphasized. Dietary requirements are greater for younger vs older animals, and most of the linear or skeletal growth must be acheived by 12 to 24 mo-of-age (Heird, 1973).

Differences in size between males and females

Heird (1973) and Hintz et al., (1979) reported that colts were heavier and taller than fillies at birth. During growth, colts were generally larger than fillies (Dawson et al., 1945; Heird, 1973; Hintz et al., 1979). Furthermore, differences in size between mature males and females have been observed for Arabians, Thoroughbreds and Quarter horses (table 4). Mature males were heavier, taller at the withers, hip, knees and hocks, possessed more forearm muscle, chest width and a greater cannon bone circumference than did females. However, females were longer than males (Cunningham and Fowler, 1961; Heird, 1973; Willoughby, 1975; Reed and Dunn, 1977). Similar comparisons for weight and height between mature males and females of Belgian, grade draft, Morgan and grade light breeding were made (Dawson et al., 1945).

Growth rates in various portions of the body

To characterize growth patterns, it is necessary to obtain measurements at intervals throughout the growing phases. The rate of growth changes from birth to maturity (Brody, 1945). Additionally, growth rates differ between various parts of the body and between sexes.

TABLE 4. DIFFERENCES IN CONFORMATION OF STALLIONS AND MARES AT MATURITY

| | Breeds investigated | | | |
|---|---|---|---|---|
| Measurement | Arabians[2] | Quarter horses[3] | Quarter horses[4] | Thoroughbreds[5] |
| Body weight (kg) | 19.5[1] | 13.2 | - | 45.0 |
| Wither height (cm) | 3.2 | 3.3 | - | 2.0 |
| Hip height (cm) | 3.2 | - | - | - |
| Hock to ground (cm) | .76 | 2.3 | - | - |
| Knee to ground (cm) | 1.12 | .88 | - | - |
| Chest width (cm) | 5.3 | 6.35 | - | - |
| Cannon bone circumference (cm) | .51 | .51 | - | - |
| Circumference of forearm muscle (cm) | - | 7.6 | 6.05 | - |
| Body length (cm) | -3.3 | -4.57 | -9.42 | - |

[1]Each measurement represents mean measurement of stallion - mean measurement of mare.

[2]Reed and Dunn, 1977

[3]Cunningham and Fowler, 1961

[4]Heird, 1973

[5]Willoughby, 1975

Growth of Thoroughbred and pony foals was more rapid from birth to 3 mo-of-age when compared to growth between 4 and 12 mo-of-age (Wojciechowski, 1965; Goyal et al., 1981). Green (1976) observed that Thoroughbred colts born from February to June exhibited a period of rapid growth from 13 to 18 mo-of-age in conjunction with spring and early summer pastures or pre-sale conditioning in the late summer. Growth was less intense from 18 to 36 mo-of-age and was more variable due to various training and nutritional regimens.

The increase in body weight of ponies or Quarter horses was fairly constant from birth to 3 mo-of-age but the rate or gain decreased with increasing age. (Jordan, 1977; McKeever et al., 1981). The curvilinear nature of growth in various measurements is exemplified by the amount of gain exhibited by horses during various age intervals (table 5) and by the percentage of mature size acheived by horses at various ages (table 6). Males of the Arabian breed, exhibited greater increases in wither height, hip height, body length and body weight from birth to 12 mo-of-age than did females (Reed and Dunn,1977). Quarter horse colts had a greater increase in wither height and cannon bone circumference from birth to 6 mo-of-age than did fillies (McKeever et al., 1981). In contrast, Heird (1973) stated that from birth to 6 mo-of-age, Quarter horse fillies grew

TABLE 5. THE INCREASE IN SIZE OF CONFORMATIONAL COMPONENTS OF FOALS WITHIN AGE INTERVALS.

| Measurement | Age interval (months) | Breeds investigated: Arabians[1] males | Arabians[1] females | Thoroughbreds[2] foals |
|---|---|---|---|---|
| Wither height (cm) | 0-12 | 44.9 | 44.5 | - |
| Hip height (cm) | 0-12 | 48.3 | 46.3 | - |
| Body length (cm) | 0-12 | 70.1 | 67.9 | - |
| Body weight (kg) | 0- 3 | - | - | 110 |
| | 3- 6 | 170.5 | 166.8 | 75 |
| | 6- 9 | - | - | 60 |
| | 9-12 | 94.2 | 92.4 | 45 |

[1]Reed and Dunn, 1977
[2]Hintz et al., 1978

TABLE 6. THE PERCENTAGE OF MATURE SIZE ATTAINED BY HORSES AT VARIOUS AGES.

| | | Breeds investigated | | | | |
|---|---|---|---|---|---|---|
| | | Thoroughbreds[1] | Quarter horses[2] | | Arabians[3] | |
| Measurement | Age (months) | foals | males | females | males | females |
| Body weight | 6 | 46 | 43.8 | 43.7 | - | - |
| | 12 | 67 | 57.8 | 62.5 | - | - |
| | 18 | 80 | 81.3 | 77.2 | - | - |
| Wither height | 6 | 83 | 82.1 | 84.5 | - | - |
| | 12 | 90 | 89.4 | 91.9 | 90.78 | 92.03 |
| | 18 | 95 | 95.3 | 95.4 | - | - |
| Body length | 6 | - | 78.6 | 76.2 | - | - |
| | 12 | - | 89.0 | 86.2 | 90.69 | 88.4 |
| | 18 | - | 95.2 | 91.1 | - | - |
| | 24 | - | - | - | 97.92 | 97.74 |
| Chest width | 6 | - | 67.0 | 74.6 | - | - |
| | 12 | - | 77.0 | 86.7 | - | - |
| | 18 | - | 87.4 | 94.6 | - | - |
| Cannon bone circumference | 6 | - | 82.2 | 83.4 | - | - |
| | 12 | - | 90.9 | 93.8 | - | - |
| | 18 | - | 98.8 | 96.9 | - | - |
| Knee to ground | 6 | - | 100.0 | 99.4 | - | - |
| | 12 | - | 100.0 | 99.9 | 96.11 | 97.49 |
| | 18 | - | 100.0 | 100.0 | - | - |
| Hip height | 12 | - | - | - | 92.55 | 94.28 |

[1] Hintz et al., 1978

[2] Cunningham and Fowler, 1961

[3] Reed and Dunn, 1977

faster than males. Others reported equal gains by males and females up to 12 mo-of-age (Cunningham and Fowler, 1961; Wojciechowski, 1965; Green, 1969).

Females generally attained mature proportions before males (table 3). Moreover, fillies were generally more mature than colts at various ages during growth (table 6). The relationship of greater maturity in body weight, wither height, chest width and cannon circumference at 6, 12 and 18 mo-of-age for females vs males can be related to smaller mature proportions exhibited by females vs males (table 4). Body length of females was at a lesser stage of maturity than body length of males at 12 or 24 mo-of-age (Reed and Dunn, 1977). In addition, mature length of females was greater than that of males (table 4).

Brody's (1945) growth curve equation is written

$$Wt = A(1-B^{-kt})$$

where Wt is weight at time t, A is the mature weight, B is a constant of integration and k is the maturing rate. Brown et al., (1972) reported a strong negative correlation between A, the mature weight, and k, the maturing rate for Hereford and Angus cattle. They concluded that an animal that matures earliest will possess the smallest body weight. Fitzhugh and Taylor (1971) further concluded that individuals that were more mature at any age were lighter at maturity. Researchers, previously mentioned, who have studied equine growth, have not utilized standard growth curve equations to characterize growth. However, similar conclusions about maturing rate and its relation to mature size can be drawn.

In general, fillies were smaller at birth and thereafter to maturity, were more mature than colts throughout the growth phase. Additionally, fillies attained mature size at a younger age than did colts.

Variability in measurements

The standard deviations of most body measurements increased from birth to maturity. (Cunningham and Fowler, 1961). For example, the standard deviations of birth weight were 5.0 kg for males and 6.4 kg for females. At 5 yr-of-age, they were 36.3 and 54.4 kg for males and females, respectively. However, the coefficients of variation of birth weight and weight at 5 yr-of-age were 10.8 and 6.7%, respectively, for males, and were 14.4 and 10.2%, respectively, for females. As horses matured, they became more uniform in size. The least variability among measures was in those influenced by skeletal development such as wither height and length of head. Heart girth and body weight were most variable as they depend, to a great extent, on general physical condition, training, etc. (Cunningham and Fowler, 1961; Green 1961; Reed and Dunn, 1977).

Correlations between various body measurements

The relationship between growth in various parts of the body can be determined by correlation coefficients. For instance, 92% of the variation in heart girth was associated with variation in body weight (Cunningham and Fowler, 1961). However, only 19% of the change in body weight was related to an increase in the length from knee to ground (Heird, 1973). The increase in limb length is less than the increase in size of body mass from birth to maturity.

Correlation coefficients can also be used to determine if mature size can be estimated from measurements obtained at birth. Hintz et al., (1978) observed that the relationship or the correlation between birth weight and body weight at 4, 6 or 12 mo-of-age decreased over time (table 7). A similar trend was observed for wither height at birth and at the various ages. In contrast, Reed and Dunn (1977) established a growth curve for wither height that enabled them to estimate mature height from the height at birth.

Heird (1973) suggested that bone size was indicative of overall muscling and mature size. High correlations between cannon bone circumference or muscling and skeletal size have been reported (table 8). Muscling was determined from

TABLE 7. CORRELATIONS BETWEEN MEASUREMENTS AT VARIOUS MONTHS OF AGE FOR 62 THOROUGHBRED FOALS[1]

| | | Body measurement | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Body weight | | | | Wither height | | | | Cannon bone circumference | | | |
| Body measurement | Age (months) | 0 | 4 | 6 | 12 | 0 | 4 | 6 | 12 | 0 | 4 | 6 | 12 |
| Body weight | 0 | 1.0 | .70 | .63 | .61 | .52 | .63 | .59 | .47 | .49 | .23 | .28 | .46 |
| | 4 | | 1.0 | .89 | .69 | .23 | .71 | .65 | .45 | .33 | .39 | .36 | .55 |
| | 6 | | | 1.0 | .67 | .24 | .61 | .61 | .37 | .38 | .35 | .37 | .53 |
| | 12 | | | | 1.0 | .24 | .51 | .57 | .55 | .29 | .24 | .24 | .64 |
| Wither height | 0 | | | | | 1.0 | .37 | .37 | .20 | .38 | .09 | .12 | .19 |
| | 4 | | | | | | 1.0 | .86 | .70 | .44 | .47 | .41 | .48 |
| | 6 | | | | | | | 1.0 | .77 | .34 | .32 | .41 | .54 |
| | 12 | | | | | | | | 1.0 | .23 | .32 | .27 | .53 |
| Cannon bone circumference | 0 | | | | | | | | | 1.0 | .30 | .19 | .33 |
| | 4 | | | | | | | | | | 1.0 | .42 | .32 |
| | 6 | | | | | | | | | | | 1.0 | .37 |
| | 12 | | | | | | | | | | | | 1.0 |

[1]From Hintz et al., 1978

TABLE 8. CORRELATIONS BETWEEN CANNON BONE CIRCUMFERENCE AND VARIOUS MEASUREMENTS OF QUARTER HORSES

| Measurement | Individual studies: Heird[1] | Cunningham and Fowler[2] |
|---|---|---|
| Wither height | .89 | .95 |
| Heart girth | .89 | .93 |
| Forearm muscle (circumference) | .84 | .87 |
| Width of quarters | .86 | .91 |
| Body length | .86 | .90 |
| Chest width | .77 | .88 |
| Body weight | .81 | .90 |

[1]Heird, 1973

[2]Cunningham and Fowler, 1961

circumferential measurements of the forearm and gaskin muscles. Hintz et al., (1978) reported that the correlations between weight or height and cannon bone circumference increased with age. The highest correlation between wither height and cannon bone circumference was obtained at 12 mo-of-age (r=.64; table 7). Perhaps the differences in these data can be attributed to breed conformation. Quarter horses (Cunningham and Fowler, 1961; Heird, 1973) 1978) are generally more compact animals, with heavier, more massive muscling and bone than Thoroughbreds (Hintz et al., 1978).

The correlation between age and circumference of the forearm muscle was .51. Thus, muscling was dependant to a large extent on factors other than age. Forearm muscle circumference was highly correlated (r=.92) with chest width. As the amount of muscling increased, the animal became broader (Cunningham and Fowler, 1961). Heird (1973) reported a correlation of .75 (r) between chest width and forearm muscle circumference..

Age was not highly correlated with the distances from knee or hock to ground; r= .22 and .37, respectively (Cunningham and Fowler, 1961). These are reasonable figures; foals possess a high degree of mature size in these proportions at birth and they reach mature size at a young age.

Bone growth in horses

Various portions of the equine physique are at various stages of maturity at birth and throughout growth. Likewise, skeletal growth in various locations is asynchronous and nonlinear. In general, long bone growth was rapid prior to 80 d-of-age. Thereafter, there was a gradual decrease in growth rates; no obvious lags or spurts were noted (Campbell and Lee, 1981). Meakim et al., (1981) indicated that progressive mineralization (bone mineral content as determined by ash) of the third metacarpal of weanling foals was curvilinear between 120 and 470 d-of-age. Fifty-three, 87 and 100% of the total growth at the proximal radial cartilage was present at 3, 12 and 18 mo-of-age, respectively. However, growth at the distal radial cartilage was more linear.

At birth, 6 to 7 epiphyseal plates were not ossified in Quarter horse and Thoroughbred foals (Campbell, 1977). Between birth and 12 mo-of-age, the phalangeal plates ossified (table 9). From birth to maturity, less than 5% of the increase in height was attributed to growth in carpal and metacarpal areas (Heinze and Lewis, 1969). Likewise, the length of the metacarpals, metatarsals and phalanges increased only 5 to 10% of their original length compared to a 50% increase in length of other bones (Campbell and Lee, 1981).

TABLE 9. RATES OF GROWTH FOR VARIOUS LONG BONES BETWEEN 52 AND 104 DAYS-OF-AGE AND THE APPROXIMATE AGE AT WHICH THE EPIPHYSEAL PLATES OSSIFY.

| Long Bone | Age (mo) at epiphyseal ossification[1,2,3,4,5] | Growth rate[6] (ug $d^{-1}$) |
|---|---|---|
| Distal third metacarpal | 10-18 | 73 |
| Proximal first phalanx | 12-15 | 63 |
| Distal first phalanx | 0- 1 | -- |
| Proximal second phalanx | 9-12 | 32 |
| Proximal radius | 15-20 | 123 |
| Distal radius | 30-36 | 165 |
| Proximal ulna | 24-36 | -- |
| Distal ulna | 6- 9 | -- |
| Proximal humerus | 18-30 | 168 |
| Distal humerus | 14-20 | 88 |
| Proximal tibia | 24-30 | 198 |
| Distal tibia | 18-24 | 178 |
| Proximal femur | --- | 207 |
| Distal femur | 24-30 | 192 |

[1]Myers et al., 1966
[2]Heinze and Lewis, 1968
[3]Morgan, 1974
[4]Campbell, 1977
[5]Campbell and Lee, 1981
[6]Goyal et al., 1981

When comparing the rate of growth of two opposing epiphyseal plates, growth was most rapid at the extremity where the epiphysis was last to unite (table 9; Goyal et al., 1981). The ratio of proximal to distal radial growth from birth to maturity was 36:64% (Heinze and Lewis, 1968). A similar ratio of 37:63% was reported (Campbell and Lee, 1981). Growth at the proximal humeral extremity accounted for 75% of the total increase in the humerus. In both the femur and tibia, growth at the proximal extremity predominated; the ratios were 55:45%.

Growth was more rapid in the hind limb than in the forelimb (Goyal et al., 1981). Closure of the distal metatarsals was later than closure of the distal metacarpals (Kruger, 1939; Heinze and Lewis, 1968; Morgan, 1974; Campbell and Lee, 1981). The total increase in length of the tibia was greater than the increase in length of any other bone. The ratio of tibial to radial growth in the foal was 1.3:1 (Campbell and Lee, 1981).

Between 52 and 104 d-of-age, growth rates at all of the extremities were slower in females than in males (Goyal et al., 1981). Additionally, Myer et al., (1966) reported that ossification of most epiphyseal plates occurred earlier in fillies than in colts.

Heritability of body measures

The total phenotypic variation in a population is due to environmental influences, heredity and their interaction. Heritability estimates are based on the resemblance between relatives, for instance, the degree of resemblance between parents and their offspring. Thus, an estimate of the correlation between the phenotype and the genotype can be obtained. (Lasley, 1972).

The mature weights of sires and dams of 409 American bred draft colts were 930.1 and 798.5 kg, respectively. (Crampton, 1923a). The offspring's mature weight was between its parents weights. Furthermore, the mature weight of colts was closest to the weight of their sires while the mature weight of fillies was closest to the weight of their dams. Thus, the weight of offspring was influenced by both of its parents heights and by sex.

The heritability estimates of various body measures varied widely among researchers (table 10). Hintz et al., (1979) and Kownacki et al., (1971) noted that heritability estimates increased with age. Heritability estimates for various body measures, based on intraclass correlations of paternal half-sibs among 5996 mares, were highest at 5 yr-of-age (Varo, 1965). The heritability estimates of conformational traits in male offspring were higher than

TABLE 10. HERITABILITY ($h^2$) ESTIMATES OF BODY MEASUREMENTS OF PONIES AND HORSES.

| Measure | Individual studies | | | | | | |
|---|---|---|---|---|---|---|---|
| | A[1] | B[2] | C[3] | D[4] | E[5] | F[6] | |
| | | | | | | males | females |
| Wither height | .996 | .628 | .42 | .391-.68 | .33-.88 | .572-.778 | .265-.520 |
| Body length | .385 | ---- | --- | .225-.645 | -- | -- | -- |
| Heart girth | .26 | .118 | --- | .319-.642 | -- | .358-.555 | .125-.359 |
| Cannon bone circumference | .13 | .284 | .25 | .276-.558 | .17-.77 | .438-.779 | .225-.534 |
| Body weight | -- | .274 | --- | -- | .21-.90 | -- | -- |

[1]Barauskas, 1975 : 60 ponies, dam-daughter pairs

[2]Dusek, 1965 : 130 halfbred Thoroughbreds, dam-daughter pairs

[3]Khotov, 1971 : dam-daughter pairs, warm-bloods

[4]Kalmykov, 1973, 1974 : 1855 Standardbreds, offspring-midparent correlations

[5]Hintz et al., 1979 : 1992 Thoroughbreds, $h^2$ calculated at 0 to 44 and 450 to 714 days-of-age

[6]Kownacki et al., 1971 : 2582 horses, unknown breeding

those calculated for female offspring (Kownacki et al., 1971).

Influence of age of the parent on size of the foal at birth and on its development

Maternal age may influence the size and development of its offspring. Dams less than 7 and greater than 11 yr-of-age had lighter foals at birth than did mares 7 to 11 yr-of-age (Hintz et al., 1979). Differences among foals, from mothers of different ages, persisted until foals reached 510 d-of-age. The same trends were observed for wither height and cannon bone circumference. In contrast, mare age did not affect the size of Quarter horse foals from birth to 6 mo-of-age (McKeever et al., 1981). However, the sample size in the study of Quarter horse foals was considerably smaller (27 foals), thus differences may have been undetected. Jordao and DeCamargo (1950) reported that neither mare nor stallion age influenced the wither height of foals at birth.

Nutritional influences on equine growth

Crampton (1923b) stated that proper nutrition of the growing horse, particularly during stressful periods allows an animal to reach its maximum potential. Draft colts that were fed a limited grain diet during their first 3 yr of life, had skeletal measurements similar to those of colts that received a more liberal diet (80.22% more grain and 22.7% less hay) (Trowbridge and Chittendon, 1932). At 3 yr-of-age, limit-fed colts were 48.1 kg lighter than liberally-fed colts. The liberally-fed colts commanded a higher sale price but had less endurance for work. Dawson et al., (1945) noted that inadequate nutrition (range wintering) affected weight more than height in 6-mo to 5-yr-old horses. The horses not subjected to adverse environmental conditions weighed 45.3 kg more and were 3.81 cm taller at the withers at maturity than range-wintered horses.

Weanlings that were restricted nutritionally for 4 mo, then fed ad libitum for 4 mo, developed contracted tendons (Hintz et al., 1976). However, weanlings that were full fed for 8 mo did not exhibit similar problems. Weight gains of both groups, while receiving feed ad libitum, were similar. After 8 to 9 mo of receiving full feed, and in spite of continuous weight gains, the angle of the fetlocks returned to normal. Thus, increasing body weight was not detrimental to the recovery process. Goyal et al., (1981) reported no significant correlations between weight gain and growth rate at the extremities of limb bones of foals from 52 to 104 d-of-age. Contracted tendons were observed in yearlings (Hintz et al., 1976). The horses were unhealthy, heavily parasitized and small for their age. Within 2 mo of consuming a 65% TDN diet ad libitum, 4 of 6 animals developed contracted tendons and 2 of the 4 exhibited anterior deviation of the metacarpo-phalangeal joints. Liberally-fed colts were more succeptible to problems of feet and leg soundness in comparison to limit-fed colts (Trowbridge and Chittendon, 1932).

Stromberg (1979) attributed the development of osteochondrosis dissecans in young horses to a genetic predisposition for rapid growth combined with excess dietary energy intake. Transition of cartilage to bone was disturbed and contours of the ossified articular cartilage were altered such that subchondral bone cysts developed. Basal layers of thickened retained cartilage became necrotic. Resulting fissures were replaced by fibrocartilage rather than normal, hyaline cartilage. Thus, a general skeletal weakening diminished the usefulness of the horse. Stromberg (1979) did not relate excesses of dietary protein, vitamins or minerals to the development of the condition. He did note that the incidence of osteochondrosis dissecans was twice as great in males as in females.

Epiphysitis, a disruption of normal growth at the diaphysis, is similar to osteochondrosis dissecans.

Possible causative agents of epiphysitis are lack of unrestricted exercise (Owen,1975), mineral imbalances, excessive dietary protein and energy, or any combination of factors (Coffman, 1973; Hintz and Schruyver, 1976).

Proper nutrition throughout growth is critical to proper development; neither under-nor over-feeding is beneficial. However, until the optimum growth rate of the horse is elucidated, the nutritional requirements needed to acheive optimum growth will remain an egnima as well.

The influence of month of birth on size at birth, growth and performance

Thoroughbred foals born in April, May or June were significantly heavier, taller at the withers and had greater cannon bone circumference than foals born in January, February or March (Hintz et al., 1978). Differences persisted until 18 mo-of-age. Further examination of the data revealed that at a common date of Sept 15 (weanling year), foals born January 15 were 76 kg heavier and 8 cm taller than foals born April 15. However, 11 mo later, in August of their yearling year, differences had decreased to 30 kg of body weight and 2.7 cm of height at the withers. McKeever et al., (1981) studied the changes in body weight, wither height, cannon bone circumference, and the distance from knee and hock to ground of 27 Quarter horse foals from birth to 6 mo-of-age. Only the rate of cannon bone growth and the increase in distance from hock to ground varied due to month of birth. Foals born in April and May gained more length from the hock to the ground than foals born in February, March and June. The rate of increase in cannon bone circumference was greatest for foals born in June. As previously mentioned, the sample size and subclass numbers in this study were small, particularly in February and June (1 and 2, respectively), thus, the reliability of results is questionable. Neither Green (1969) nor Wojciechowski (1965) observed differences in growth rates between foals born in January or February vs foals born in March, April or May.

When comparing foals of indigenous breeding, those born in the spring were taller and heavier at birth than those born in the fall (Lohman and Marimac, 1952). The difference was reversed at 1 yr-of-age. Foals born in the fall showed a more rapid post-weaning gain, because they were weaned in the late spring, compared to foals born in the spring and weaned in the fall. Conversely, Jordao and DeCamargo (1950) reported that foals born from May to September were smaller-framed foals at birth than those born from October to December. Also, shorter gestation periods were associated with the smaller foals. Hintz et al., (1979) noted that mares with late spring foals not only had gestation periods of 3 d less than early foaling mares, but their foals were larger at birth. Mares exposed to 16 h light:8 h dark prepartum, had shorter gestations (337 d) than mares exposed to natural lighting (348 d) (Hodge et al., 1981). However, the measurements at birth of weight, cannon bone length, cannon bone circumference, wither height and heart girth of foals were not different between groups. Thus, there is a possibility that photoperiod influences the onset of parturition, prenatal growth and fetal development.

There has been much speculation on the magical formula for producing a winner. Limited scientific data are involved in the speculation. However, an investigation of the lifetime race performance of 1822 Thoroughbreds was conducted at Claiborne farm in Kentucky. Foals born in January and June had lower lifetime earnings and an average earning index (AEI) one third less than the AEI of horses born from late February to May. The percentages of stakes winners, winners and non-starters, calculated from records of all foals born in each month, did not vary among birth months. An interesting note was that racing age, or the date of the first start, was no sooner in the early than in the late born foals. Thus, there was no apparent advantage for the older horses at the race track (Hollingsworth, 1975).

The influence of season on reproduction in the mare

The primary cause of reproductive inefficiency in the horse is due to the incompatibility of the operational and the physiological breeding seasons (Kenney et al., 1975). The operational season, based on the univeral birthdate of January 1 (Jockey Club, 1982), begins in February and extends to July 1. However, the mare is most receptive, both physiologically and behaviorally, from May to September.

Normally, estrus lasts for a period of 4 to 10 d (Loy, 1967). The normal cycle length is 20 to 21 d, estrus lasts an average of 5.5 d, ovulation occurs 24 to 48 h prior to the end of estrus and the corpus luteum (CL) is active for 2 to 13 d (Hughes et al., 1972). Regression of the CL occurs 3 d prior to the onset of estrus. Trum (1950) characterized 1543 estrous cycles and reported that the occurance of abnormally long estrous periods was most prevalent in the early spring. Of estrous periods in March, April, May and June to July, 18, 7, 2 and 0%, respectively, were longer than 9 d. Concurrently, Loy (1967) and Hughes et al., (1972) reported that while 80% of mares responded to a teaser in May, only 20 to 25% of mares exhibited behavioral estrus in January and February. Based on examination of 5000 slaughter specimens, Osborne (1966) concluded that 91%

of mares ovulated during the winter. In contrast, Van Niekerk (1967) reported that during the winter and spring, 85% of mares had little to no follicular growth, long estrous periods or follicular development without ovulation. In the summer, 96 to 100% of mares in heat ovulated.

As the summer solstice (June 21) approaches, there is an increase in pregnancy rate and a decrease in required services per conception (Kenney et al., 1975). First service pregnancy rates of 1777 Quarter horse and Thoroughbred mares were 44, 40 and 54% for maiden, barren and foaling mares, respectively (Sullivan et al., 1975). The cumulative pregnancy rates following 5 services were 84, 74 and 84% for the three groups of mares, respectively. Hutton and Meacham (1968) calculated several ratios in an effort to characterize the reproductive efficiency of horses at 14 farms. There were an average of 1.58 estrous periods per mare, 1.64 services per period and 2.59 total services per mare during the breeding season until mares were pronounced in foal. Caslick (1937) reported that the average Thoroughbred mare required three periods of service for conception.

Conception rates of mares bred in January and February were 28.6 and 27.8%, respectively (Hutton and Meacham, 1968). Jennings (1981) reported a 22.9% conception rate for mares bred in February. Conception rates in May, June and July, increased to 57.2, 51.9 and 59.3%, respectively (Hutton and Meacham, 1968). Similarly, Jennings (1981) reported higher rates of 53.2, 57.1 and 37.5% during the respective months. There were a number of mares with breeding unsoundnesses included with the data for July (Jennings, 1981), thus, the conception rate in July was lower than that observed by Hutton and Meacham (1968).

The influence of season on reproduction in the stallion

Season also influences the stallion's reproductive efficiency. The effect of month and stallion on 180 paired ejaculates (two ejaculates collected within 4 hr), obtained from 5 stallions at weekly intervals, was studied (Pickett et al., 1970). The mean volume of semen was 36.6 and 33.1 ml in first and second ejaculates, respectively. Month significantly influenced the volume of both ejaculates. The mean volume in December was 25 ml compared to 50 ml in March. Sperm concentration, total sperm per ejaculate, motility, mounts/ejaculate and reaction time were influenced by season. In April, first ejaculates contained an average of $450 \times 10^6$ sperm $ml^{-1}$; in Oct, they contained $300 \times 10^6$ sperm $ml^{-1}$. Total sperm numbers per ejaculate, collected in May or November, were 12.7 and $6.6 \times 10^9$, respectively. There was a consistent 50% reduction in sperm numbers of second ejaculates. Motility of raw semen was highest (60%) in the winter or spring and lowest (45%) in late summer or fall. Mounts per first ejaculate increased from 1.2 to 2.4 in April and October, respectively., The reaction time increased from 206 s in August to 819 s in January. The degree of sperm agglutination was highest in the fall months and lowest in December and January. Clumping was probably related to gel-volume. There were no seasonal effects on pH. The pH of first and second ejaculates were 7.43 and 7.6, respectively. An increase in the contribution from the accessory sex glands accounted for the higher pH in the second ejaculate.

In a subsequent experiment of a similar design (Pickett and Voss, 1972), most results were comparable to those obtained by Pickett et al., (1970). However, they found that pH of raw semen increased from 7.36 in May of the first year to 7.57 during the following April. The pH of accessory gland fluid is approximately 8.0, thus it was concluded that increasing pH represented an increased output of accessory sex glands and(or) a decrease in epididymal contributions. A skim milk extender prevented sperm agglutination such that motility did not change with season. Reaction time or the time between sight of the mare and full erection was 47 s in May and 10.8 min in Dec. In addition, the increased tendency for stallions to savage mares during the non-breeding season was observed.

Alternatives to early breeding schedules

The operational breeding season begins in February (Kenney et al., 1975) and does not coincide with the natural breeding season of the horse. Therefore it seems impractical to breed mares before April. There is a general consensus among breeders that more abortions and general reproductive problems occur in mares bred in February rather than in late spring. Thus, early breeding must be justified by another means.

Sullivan et al., (1975) stated that the pregnancy rate in mares could be as high as that observed in cattle. Utilization of artificial insemination (A.I.) combined with sound management could increase equine reproductive efficiency. The advantages of A.I. in terms of safety, health and precision have been established (Jennings, 1981). Another advantage is that a large number of mares may be bred within a short period of time. Many breed associations allow the use of A.I., however the Jockey Club (1982) states that

> "A foal is not eligible for registration unless it is begotten by a stallion's natural service of a mare and unless a natural gestation takes place in

and delivery is from the body of the mare in which the foal is conceived. Natural service includes, for the purpose of this paragraph, the immediate reinforcement of the stallion's service by a portion of the ejaculate produced by the stallion during such cover".

Thus, the Thoroughbred producers, in order to facilitate the servicing of 60 to 80 mares per stallion per year, must breed mares throughout a period of 5 mo. However, if it can be shown that foals born in late spring have an advantage in terms of growth rate and performance, it would be most efficient and economical to adjust the breeding season to an April and May foaling schedule and to explore new techniques and management schemes to allow such a practice.

# EXPERIMENTAL PROCEDURE

## Data collection

Thirteen Thoroughbred farms in Virginia were utilized for this study. Records were compiled on 121 foals born in 1981. The contemporary group consisted of foals born in January (7), February (10), March (33), April (44), May (24) and June (3). Of the 121 horses, 67 were fillies and 54 were colts. Foals were sired by 85 different stallions. Records were also obtained on 139 foals born in 1982 at the same farms. The contemporary group included foals born in January (6), February (18), March (29), April (48), May (33) and June (5). Of the 139 horses, 71 were fillies and 68 were colts. For the 260 foals born in 1981 and 1982, there were 145 sires and 196 dams represented.

Body measurements were recorded on the foals born in 1981 beginning in February of their yearling year. Measurements were taken four times at 6-wk intervals from February through the third week in July. Concurrently, records were initiated on the foals born in 1982, beginning within 7 d of birth (when possible) and were updated at 2-mo intervals through the third week in July of their yearling year. Several mares were sent to breeding farms prepartum for foaling and rebreeding, thus, initial measurements on their foals were obtained at approximately 3 mo-of-age.

Each animal was held to stand quietly and squarely during the measuring procedure. Seven different measurements were taken on each animal.

Height at the withers: the vertical distance from the highest protruding thoracic vertebra to the ground.

Body length: the length from the point of the shoulder to the furthest protruding point of the buttocks.

Height at the hip: the vertical distance from the highest point of the croup to the ground.

The length from the knee to the ground: the vertical distance from the distal point of the carpus to the ground.

Cannon bone circumference: the distance around the midshaft portion of the third metacarpus.

Chest width: the horizontal distance between the points of the shoulders.

Heart girth: the circumference around the body at the point where the wither height measurement was obtained.

Height at the withers, body length and height at the hip were obtained with a standard horse measuring stick, calibrated to a metric scale and fitted with levels on both the vertical shaft and horizontal arm. The distance from knee to ground, cannon bone circumference, chest width and heart girth measurements were obtained with a flexible fiberglass tape. All measurements were recorded in cm, once on each side of the animal in order to account for uneven stances, unlevel ground and discrepancies between points of measure. They were recorded to the nearest .1 cm.

Body weight was calculated from the mean heart girth measurement using the following equations (Willoughby, 1975).

a. Colts with a heart girth < 167.6 cm:

$[(.0546 \times \text{heart girth}) + .4]^3/2.204 = \text{body weight}$

b. Fillies with a heart girth < 167.6 cm:

$[(.0544 \times \text{heart girth}) + .344]^3/2.204 = \text{body weight}$

c. Colts with a heart girth > 167.6 cm:

$(.0570 \times \text{heart girth})^3/2.204 = \text{body weight}$

d. Fillies with a heart girth > 167.6 cm:

$(.0565 \times \text{heart girth})^3/2.204 = \text{body weight}$

Other items in each horse record included birth date, farm, sex, age and height of the sire and dam. Notes were maintained on feeding regimens at each farm.

Statistical methods

The average of each paired measurement obtained for each horse was calculated and used for all further analyses. Data from each birth year were analyzed separately. Horses were classified by farm, sex and month of birth. Because of the small number of foals born in January and June, foals born in January and February were classified together, and foals born in May and June were grouped. Farm effects were not of primary interst, thus, multiple comparisons between farms were not conducted. Sex and month of birth were fixed variables and when either was significant ($P\leq.1$), comparisons between levels were made. The general linear models procedure of the Statistical Analysis System (SAS, 1979) was used for the analyses.

Growth curves

The model employed to identify differences in birth measurements or initial measurements included the effects of farm, sex, birth month and the interactions of farm x sex, farm x birth month and sex x birth month as sources of variation. The appropriate error term for these effects was the horse within farm x sex x month mean square. Linear and quadratic regressions of serial body measurements on age and the interactions of linear and quadratic age effects with birth month, sex and farm were included in the analysis. In order to estimate regression coefficients, the individual horse effects were absorbed. The horse effect and the regression coefficients were tested by the residual error term (Appendix tables 1 and 5). Growth curves for each measurement, adjusted for farm and sex were derived from the estimates of the intercept and the linear and quadratic coefficients. Regression equations for the growth curves were calculated for foals in each birth month. Growth curves were plotted by date rather than by age.

<u>Least squares analysis of variance of body measurements adjusted to constant ages</u>

In order to facilitate comparisons of body measurements of foals at a given age, based on month of birth or sex, all measurements for 1981 foals were interpolated linearly to 350 or 400 d-of-age. These two constant ages were chosen because measurements of each of the foals were available throughout the range of these constant ages. Measurements of 1982 foals were interpolated linearly to 30, 90, 150, 210, 270, 340 or 400 d-of-age. Actual measurements were also available throughout this range. In most of the tables, comparisons at 340 d-of-age were not included because they did not aid in interpretation of the data. The model used to analyze data adjusted to a constant age included the effects of farm, sex, birth month, the sex x birth month interaction and residual error as sources of variation. All main effects and the interaction were tested by the residual error term (Appendix table 2). Least squares means and their standard errors were calculated for measurements of foals born in each birth month and for measurements of colts and fillies at each constant age.

If the effect of month of birth was significant ($P \leq .1$), least squares means of body measurements were compared. Tukey's pairwise comparisons were conducted when appropriate. Tukey's procedure assumes that each pair of means being compared are ranked at extreme ends of the array of means. Furthermore, the experimentwise error rate or the proportion "alpha" of all subsequently repeated experiments that would contain one or more erroneous decisions is controlled by the chosen "alpha" level. Tukey's critical differences are more conservative than those calculated by other multiple comparison procedures, thus the power of each test is less than that of tests made by other comparison procedures. Differences between measurements at constant ages were not identified by Tukey's critical values, although the F-tests were significant ($P \leq .1$). Therefore, Duncan's multiple range test was utilized. This procedure sacrifices the experimentwise error rate or increases the probability of making an incorrect declaration of treatment differences. However, the power of the test is greater, thus, the chance of locating the cause of the significant F is greater (Lentner and Bishop, 1978). To characterize growth of the foals and to explain where differences existed, Duncan's multiple range test was utilized. Due to unequal subclass numbers, a harmonic mean of the standard errors was calculated and used to determine critical values. There were no significant sex x birth month interactions, therefore, differences between sexes, averaged across months of birth, were examined when the probability associated with the F-test for sex effects was $\leq .1$.

<u>The effect of mare age on measurements of foals at constant ages</u>

In each data set, mares were grouped in ages from 4 to 7, 8 to 11 and older than 11 yr. Thirty, 40 and 30 % of the mares were in the respective age classifications in both data sets. The effect of mare age on all parameters at the constant ages was tested by least squares analysis of variance using a model (Appendix table 3) that included the effects of farm, sex, birth month, mare age, the interaction of mare age x birth month and residual error as sources of variation. Least squares means of measurements at specific ages were determined when mare age was significant ($P \leq .1$).

<u>Least squares analysis of variance of body measurements, obtained at common dates</u>

The measurements of 1981 foals in July of their yearling year and of 1982 foals in January and July of their yearling year were classified by month of birth and by sex across birth month. The model used to test the sources of variation was the same model used to analyze values adjusted to constant ages (Appendix table 4). Comparisons were done on the same basis except that differences between least squares means, due to month of birth, were tested using Tukey's pairwise comparisons ($P<.05$). Tukey's critical values were utilized to identify differences between measurements due to month of birth rather than Duncan's multiple range test for several reasons. Tukey's is a more conservative test, yet we were able to locate differences due to birth month. Furthermore, in July of their yearling year, foals are sold to prospective race horse owners. The size of the horse is a factor that affects the selling price of the animal. Thus, the economic decisions made at this time, influenced in part by the size of the animal, made it necessary that we be confident in stating that differences did exist (i.e.: that the experimentwise error rate was controlled). The harmonic mean of standard errors was used to determine critical values.

## The resemblance between the wither height of parents and offspring

The resemblance between the wither height of parents and their offspring was investigated. Mare height, stallion height and average height of the two were analyzed; the effects of farm, birth month and residual error were sources of variation in the analysis. The variation due to month of birth was consistently non-significant, thus the three parameters were analyzed using a model without the effect of birth month included as a source of variation. The relationship between wither heights of parents and measurements of their 1981 offspring at 350 or 400 d-of-age and in July of the yearling year were determined. It was determined for 1982 foals using measurements obtained at 30, 90, 210 and 400 d-of-age and in July of their yearling year. Three models were used to generate estimates of resemblance. Farm, sex and month of birth were discrete effects while all others were continuous variables. The offspring-sire and offspring-dam regression coefficients were derived from a model that included effects of farm, sex, birth month, sire height, dam height and residual error as sources of variation. The offpring-midparent regression coefficients were determined using a model that included effects of farm, sex, birth month, the average height of the parents and residual error as sources of variation. The regression coefficients describing the resemblance between the wither height of offspring in July of the yearling year and the height of their their parents, came from a model that included effects of farm, sex, average height of the parents, the age of the offspring in July and residual error as sources of variation.

## RESULTS AND DISCUSSION

### Foals born in 1982

#### Growth curves of body measurements of 1982 foals

Initial body measurements and growth patterns of the 1982 foals were studied using the model shown in Appendix table 1. Probabilities associated with the F-tests of the sources of variation are listed in table 11. All the initial body measurements, except cannon bone circumference, varied due to farm effects ($P < .03$). Sex of the foal contributed a significant amount of variation to initial wither and hip height. The measurements of heart girth, calculated body weight and body length were influenced by month of birth ($P < .09$). The interactions of farm x sex and month x sex did not influence any of the initial measures, however, the effect of farm x month contributed a significant amount of variation to initial heart girth, wither and hip height, knee to ground and body weight measurements. In general, the most prevalent factors that affected initial measurements were farm, month of birth and individual horse differences. Least squares means were not calculated with this data set as they would have needed adjusting for differences in age of all foals at any point in time. However, the calculated intercepts were used to

TABLE 11. THE PROBABILITIES ASSOCIATED WITH THE F-TESTS OF SOURCES OF VARIATION IN THE ANALYSIS OF VARIANCE OF EACH SET OF SERIAL BODY MEASUREMENTS OF 1982 FOALS[1]

| Source of Variation | Body measurement | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Heart girth | Wither height | Hip height | Chest width | Knee to ground | Body weight | Body length | Cannon bone circumference |
| Farm | .01 | .01 | .01 | .03 | .01 | .01 | .01 | .18 |
| Sex | .19 | .07 | .10 | .99 | .19 | .50 | .22 | .70 |
| Month (of birth) | .01 | .38 | .27 | .23 | .23 | .09 | .08 | .34 |
| Farm x Sex | .29 | .26 | .14 | .33 | .11 | .30 | .27 | .48 |
| Farm x Month | .05 | .02 | .05 | .58 | .08 | .04 | .55 | .42 |
| Sex x Month | .64 | .85 | .60 | .24 | .95 | .69 | .25 | .77 |
| Horse | .01 | .01 | .01 | .01 | .01 | .01 | .01 | .01 |
| Age | .01 | .01 | .01 | .01 | .01 | .01 | .01 | .01 |
| Age x Age | .01 | .01 | .01 | .01 | .01 | .01 | .01 | .01 |
| Age x Sex | .06 | .01 | .01 | .40 | .39 | .01 | .08 | .01 |
| Age x Age x Sex | .18 | .03 | .04 | .67 | .92 | .12 | .59 | .07 |
| Age x Month | .01 | .76 | .41 | .05 | .19 | .03 | .30 | .01 |
| Age x Age x Month | .03 | .09 | .11 | .12 | .67 | .51 | .51 | .13 |
| r-square | .97 | .98 | .97 | .95 | .83 | .98 | .97 | .97 |
| Coefficient of variation (%) | 3.0 | 1.9 | 2.1 | 4.1 | 2.6 | 5.9 | 3.4 | 2.3 |
| Repeatability between paired measurements (%) | 99.86 | 99.09 | 99.09 | 97.01 | 91.84 | - | 99.28 | 99.18 |

[1]The analysis follows the model depicted in Appendix table 1

identify differences in size of the foals at birth (table 12). Foals born in May-June had the largest initial body measurements and the foals born in January-February were the smallest overall. In most cases, the range of intercepts from smallest to largest paralleled the range of birth months from January-February to May-June. The model explained a large percentage of the variation in the data (table 11), thus the intercepts were reasonably close to the true initial mean values. However, the intercepts were estimated by the best fit of the data. Several uncontrollable factors in the data collection process may have influenced the value of the estimated intercepts. Several mares did not foal at the farms visited, and measurements of their foals were not obtained until a time later than birth. Thus, the predicted values of initial measures on those foals were outside the range of actual data. Half of the foals born in February were at one farm. Furthermore, those foals were not measured until they were at least 1 wk old, therefore, the predictions of their initial body measures were outside the data set. Predicted values, outside the range of actual data, increase variation in the measurements. However, the coefficient of variation in the initial measures was fairly low and ranged from 3.2 to 7.6%.

TABLE 12. REGRESSION EQUATIONS WITH LINEAR AND QUADRATIC COMPONENTS OF SERIAL BODY MEASUREMENTS ON AGE THAT WERE USED TO PLOT GROWTH CURVES OF 1982 FOALS BORN DURING DIFFERENT MONTHS.

| Body measurement | Month of birth | Components of the regression equations | | |
|---|---|---|---|---|
| | | Intercept | Linear ( x age) | Quadratic ( x age x age) |
| Heart girth | Jan-Feb | 87.456239 | + .34646943 | - .00035117 |
| | March | 88.684879 | + .36258681 | - .00040326 |
| | April | 93.930193 | + .33087487 | - .00036757 |
| | May-June | 97.417101 | + .32190113 | - .00036662 |
| Wither height | Jan-Feb | 102.1474 | + .19746075 | - .00019806 |
| | March | 104.29063 | + .20114325 | - .00021743 |
| | April | 104.17517 | + .19845895 | - .00022203 |
| | May-June | 106.15574 | + .19463606 | - .00022040 |
| Hip height | Jan-Feb | 105.10629 | + .20973465 | - .00022248 |
| | March | 107.72268 | + .20872831 | - .00024804 |
| | April | 107.68864 | + .20872831 | - .00024569 |
| | May-June | 109.96612 | + .20351067 | - .00024513 |
| Chest width | Jan-Feb | 22.372913 | + .07273869 | - .0000728 |
| | March | 23.071838 | + .0738098 | - .00008035 |
| | April | 23.739398 | + .06620406 | - .00006667 |
| | May-June | 24.150619 | + .07050843 | - .00007674 |
| Knee to ground | Jan-Feb | 34.052833 | + .02913688 | - .00003162 |
| | March | 35.170142 | + .02710665 | - .0000331 |
| | April | 34.702729 | + .02829563 | - .00003628 |
| | May-June | 35.490141 | + .02428223 | - .0000316 |
| Body weight | Jan-Feb | 52.224226 | +1.175236 | - .00080427 |
| | March | 56.521293 | +1.2080831 | - .00091974 |
| | April | 74.204402 | +1.0946582 | - .00079719 |
| | May-June | 86.696971 | +1.0577537 | - .0007516 |
| Body length | Jan-Feb | 76.459021 | + .3050946 | - .00032215 |
| | March | 77.838808 | + .3090186 | - .00034619 |
| | April | 80.032741 | + .29602903 | - .00033559 |
| | May-June | 83.36888 | + .29289452 | - .00034594 |
| Cannon bone circumference | Jan-Feb | 12.740104 | + .02923972 | - .0000303483 |
| | March | 12.907801 | + .0284182 | - .00002724 |
| | April | 13.015638 | + .02699102 | - .00002885 |
| | May-June | 13.44347 | + .02691103 | - .0000284403 |

The trend for foals born in late spring to be larger than early-born foals at birth was noted by Hintz et al., (1979). Many environmental factors influence prenatal development, yet they have not been quantified. Nutritional status of the dam probably influences fetal development more than any other environmental factor. The possibility of under-nutrition of the mares cannot be considered in this study. Management practices, nutrition, health and exercise programs varied widely among farms, but in general, were well above average. Sixty percent of equine fetal growth occurs during the last 90 d of gestation (Bergin et al., 1967). This 3-mo period occurred during winter in early-foaling mares and in early spring in late-foaling mares. The fact that horses are seasonal breeders (Kenney et al., 1975) leads to the suggestion that season, also, may influence prenatal development. Furthermore, season and stage of pregnancy may interact. In spite of a greater energy intake by the mare during the winter, the energy available for production or growth of the fetus may be less during winter than in the spring.

The growth curves for all body measurements were curvilinear. The linear and quadratic regressions of serial body measurements on age were consistantly significant ($P < .01$; table 11). Several investigators have reported that equine growth is linear initially and, subsequently, is quadratic (Wojciechowski, 1965; Green, 1976; Jordan, 1977; Goyal et al., 1981; McKeever et al., 1981). During the linear portion of growth of foals, month of birth influenced the rate of increase in heart girth, chest width, body weight and cannon bone circumference (P <.05). Sex differences accounted for differing rates of increase in all measurements (P <.03) except chest width and the length from knee to ground (P <.40). During the non-linear portion of growth in foals, heart girth and wither height were affected by month of birth (P <.03 and .09, respectively). The amount of variation in the shape of the growth curves for hip height, chest width and cannon bone circumference that was attributed to month of birth approached significance (P <.13). The growth patterns of cannon circumference, wither and hip height differed because of to sex (P<.07, .03 and .04, respectively).

Growth curves of each of the foals measurements were plotted by date and were separated by the effects of birth month (figures 1 to 8). Variation in the curves can be noted and related to the significant sources in the analysis of variance. For instance, the slope of the four curves for cannon bone circumference (figure 7) differed due to month of birth as there were intersecting lines on the plot. In

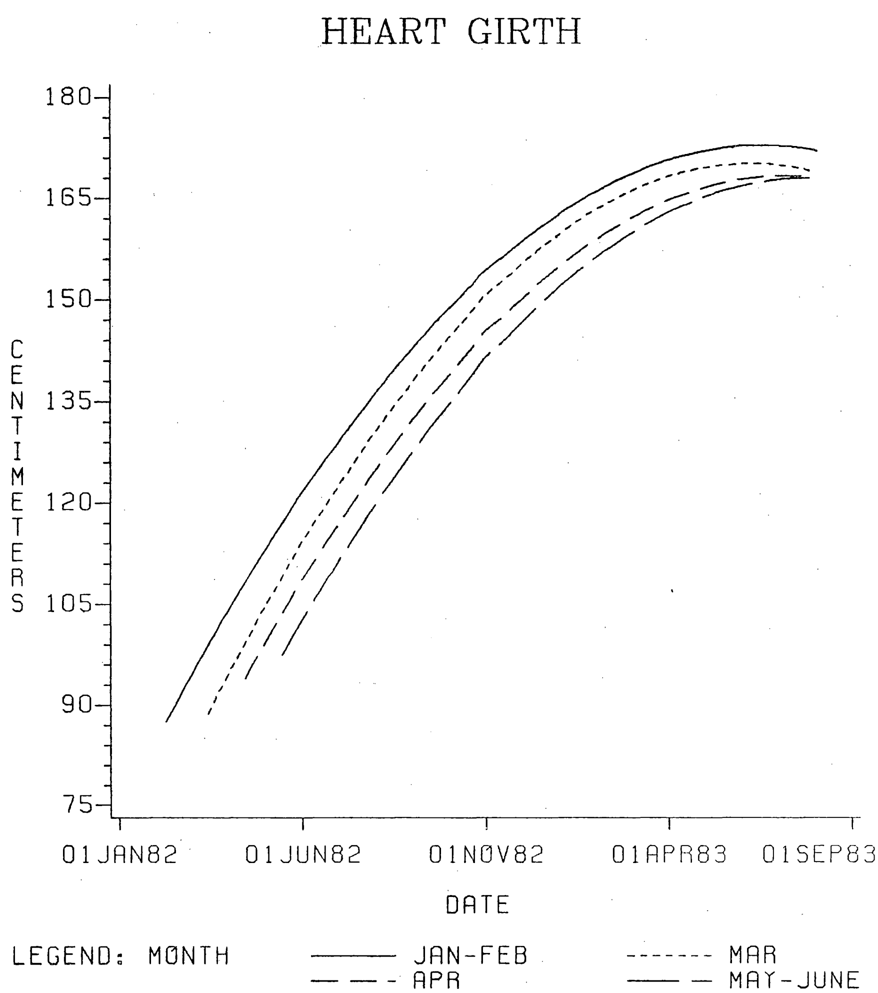


FIGURE 1. GROWTH CURVES DEPICTING THE PATTERNS OF HEART GIRTH GROWTH OF 1982 FOALS BORN IN THE VARIOUS MONTHS.

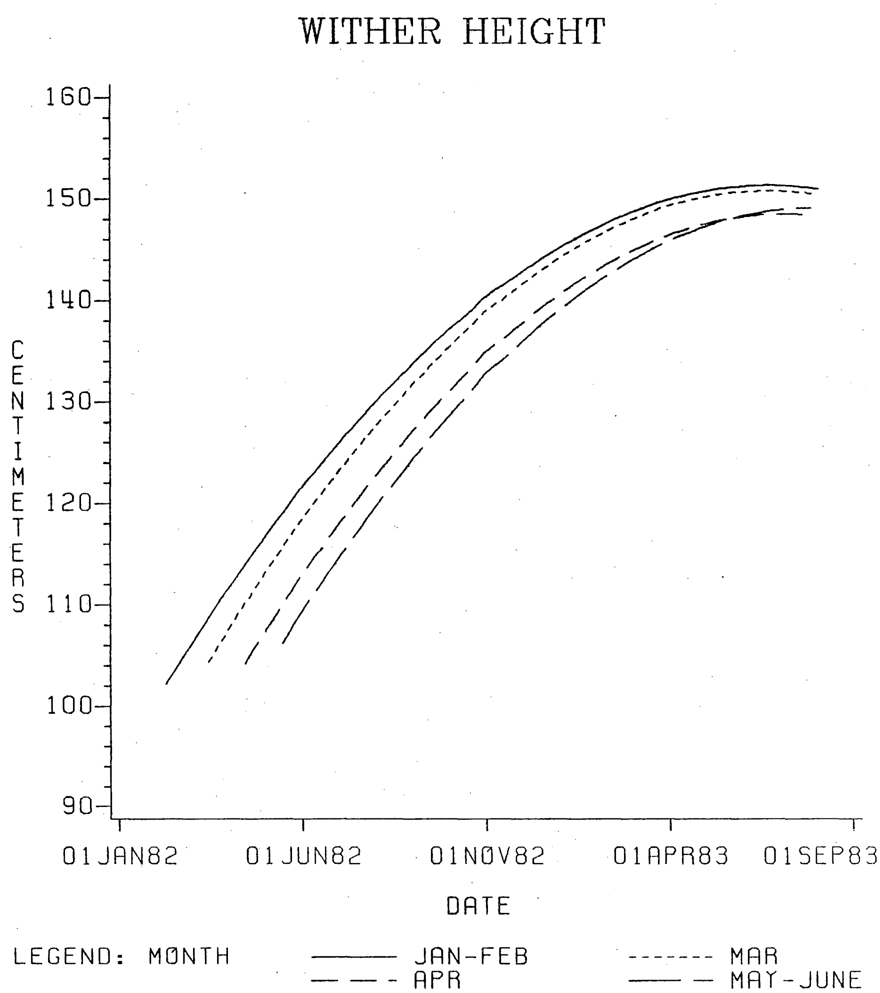


FIGURE 2. GROWTH CURVES DEPICTING THE PATTERNS OF WITHER HEIGHT GROWTH OF 1982 FOALS BORN IN THE VARIOUS MONTHS.

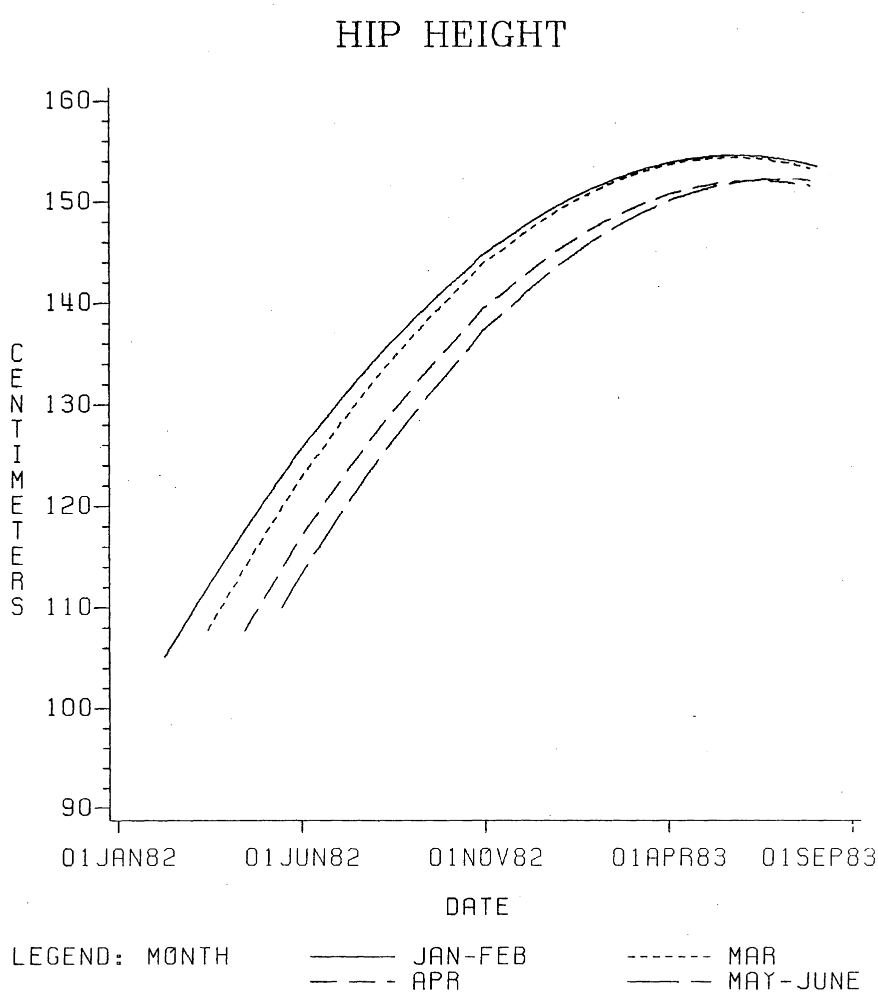


FIGURE 3. GROWTH CURVES DEPICTING THE PATTERNS OF HIP HEIGHT GROWTH OF 1982 FOALS BORN IN THE VARIOUS MONTHS.

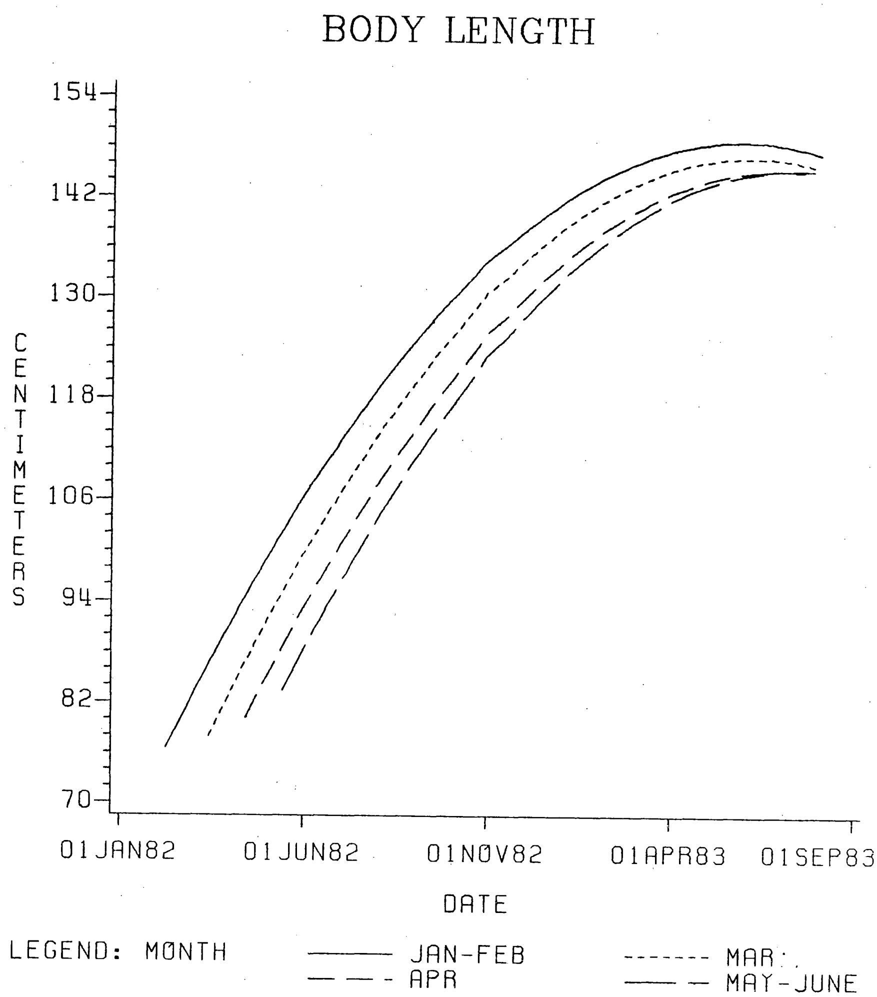


FIGURE 4. GROWTH CURVES DEPICTING THE PATTERNS OF BODY LENGTH GROWTH OF 1982 FOALS BORN IN THE VARIOUS MONTHS.

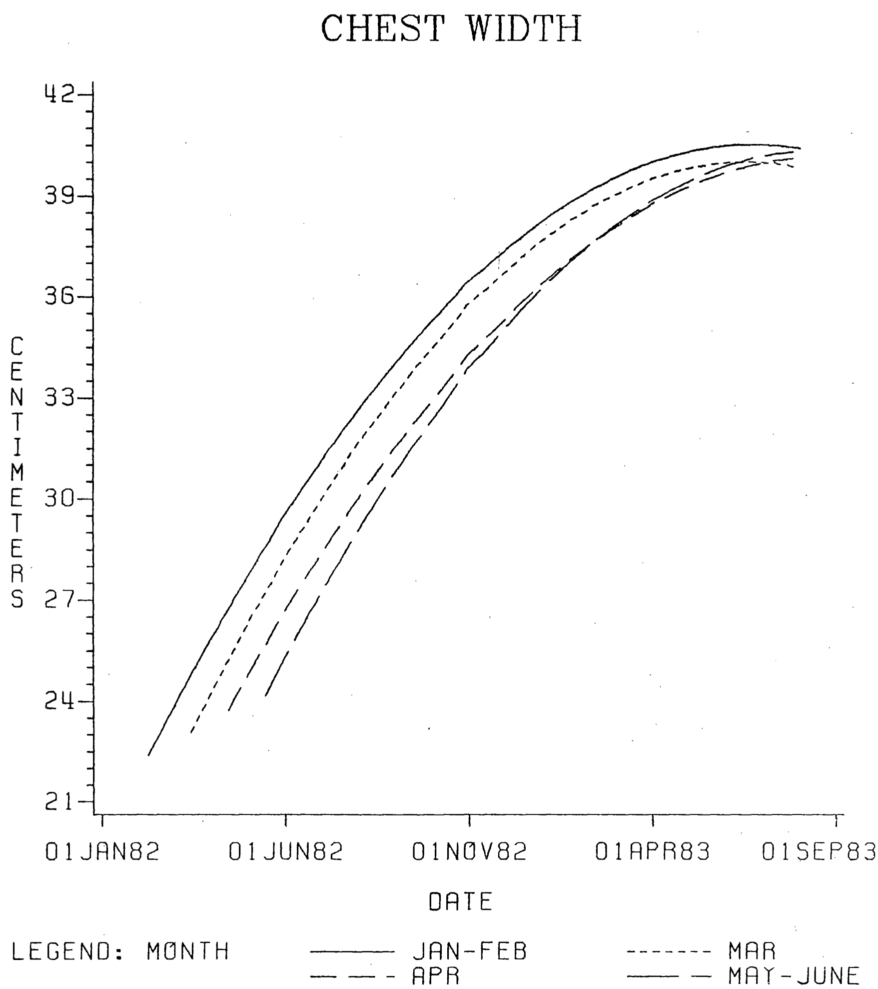


FIGURE 5. GROWTH CURVES DEPICTING THE PATTERNS OF CHEST WIDTH GROWTH OF 1982 FOALS BORN IN THE VARIOUS MONTHS.

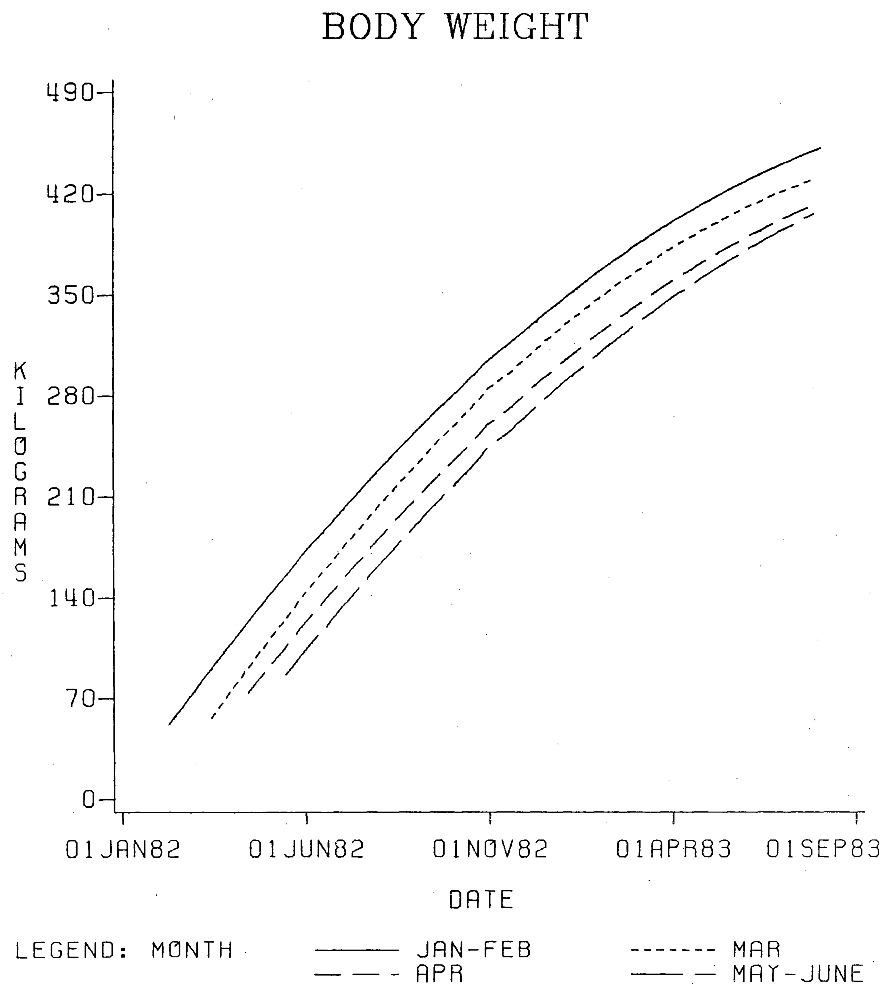


FIGURE 6. GROWTH CURVES DEPICTING THE PATTERNS OF BODY WEIGHT GROWTH OF 1982 FOALS BORN IN THE VARIOUS MONTHS.

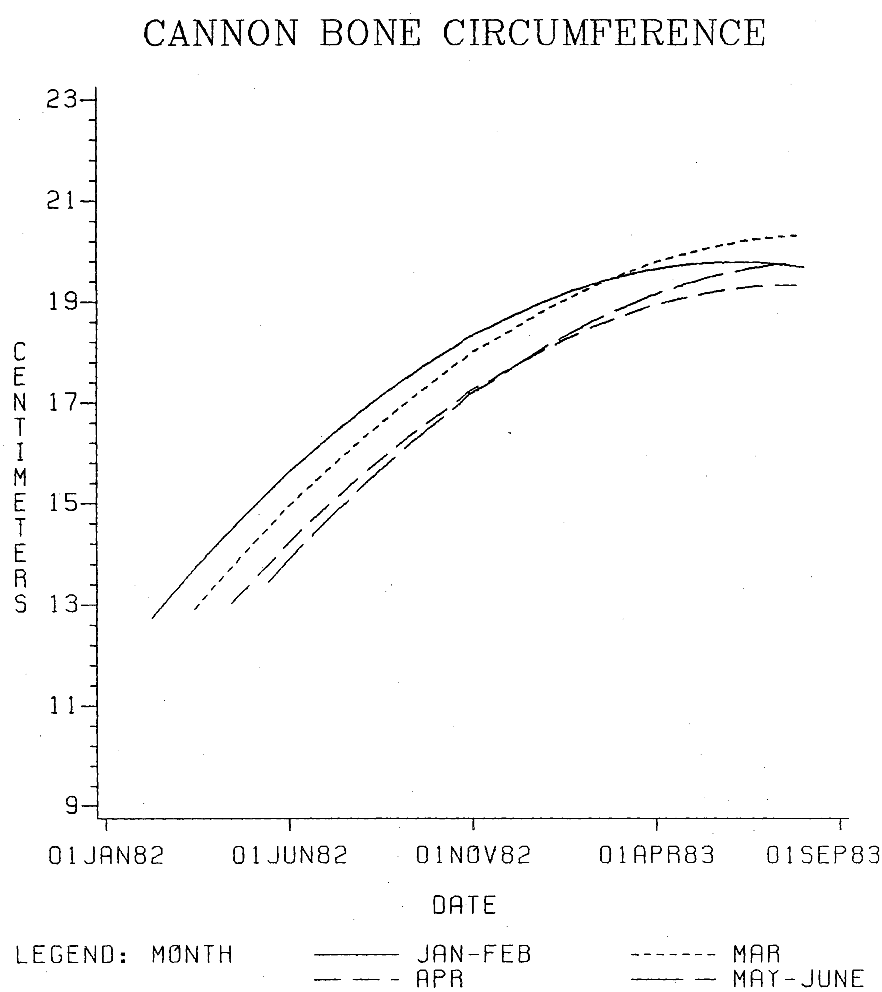


FIGURE 7. GROWTH CURVES DEPICTING THE PATTERNS OF CANNON BONE CIRCUMFERENCE GROWTH OF 1982 FOALS BORN IN THE VARIOUS MONTHS.

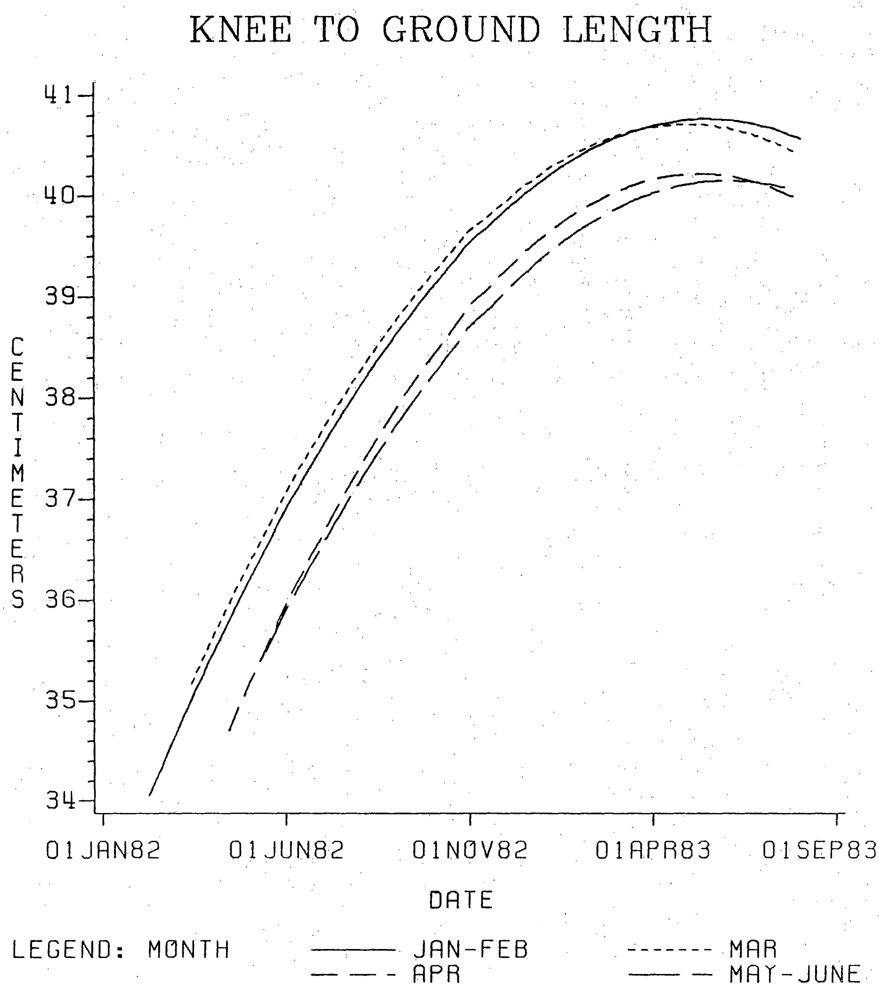


FIGURE 8. GROWTH CURVES DEPICTING THE PATTERNS OF KNEE TO GROUND GROWTH OF 1982 FOALS BORN IN THE VARIOUS MONTHS.

general, later-born foals were larger initially than early-born foals and differences in size between older and younger foals decreased over time. The differences among the heart girths (figure 1) of foals born in January-February- and May-June on November 1, 1982, was larger than the difference observed in July of 1983.

The length from knee to ground appeared to decrease (figure 8) toward the end of the data collection period. This was due to several factors. The measurement was obtained from the distal point of the knee to the ground. As horses matured, the knee became larger, thus the reference point probably varied from one measurement period to the next. The accuracy of this measurement would have been greater if the reference point had been the center rather than the distal point of the knee.

Another possible explanation for the alleged decrease in the length from knee to ground, is that as horses matured, the angle of the pastern probably decreased due to an increase in weight, thus caused a decrease in the measured length. Plots represented the best fit of the data. True quadratic curves have a maximum value followed by a curve of negative slope. Therefore, the observed decrease in the plot of the length from knee to ground may have been partially due to the use of the quadratic regression equation. The actual measurements obtained at the end of the experimental period were less than measurements obtained at previous dates, thus the decrease of the pastern angle was probably most responsible for the observed decrease.

Points plotted at specific dates were not as accurate as the least squares means which were calculated from values interpolated to constant ages. Thus, discussion of the results was based primarily on the data adjusted to constant ages. Furthermore, when differences between measurements due to birth month were not significant, the plotting procedure was not sensitive enough to accurately depict or parallel the values obtained by interpolation. Separate plots for colts and fillies were drawn, however, they were not presented. There were inconsistencies between the plotted points and the least squares means when differences between sexes were not significant. Additionally, the figures were extremely cluttered and did not add to interpretation of the growth patterns.

<u>Comparisons of body measures made at specific ages in 1982 foals born during different months</u>

The numbers of foals for which data were available at each constant age are listed (table 13). Means, standard deviations and coefficients of variation of foal

TABLE 13. THE NUMBER OF 1982 FOALS THAT WERE USED AT EACH CONSTANT AGE TO CALCULATE LEAST SQUARES MEANS OF THE VARIOUS CONFORMATIONAL COMPONENTS.

| | Month of birth | | | |
|---|---|---|---|---|
| Age (days) | January February | March | April | May June |
| 30 | 22 | 25 | 32 | 22 |
| 90 | 22 | 26 | 44 | 30 |
| 150 | 24 | 27 | 45 | 37 |
| 210 | 24 | 28 | 47 | 37 |
| 270 | 24 | 28 | 46 | 36 |
| 400 | 23 | 27 | 43 | 32 |

measurements were calculated for each birth month class (table 14). The standard deviations of all measurements except predicted body weight did not change with age. The standard deviations of body weight increased with age for several reasons. The percentage increase in a foals' body weight from birth to maturity is greater than the percentage increase in size of the equine skeletal features (Trowbridge and Chittendon, 1931; Cunningham and Fowler, 1961; Heird, 1973; Hintz et al., 1978). Additionally, Trowbridge and Chittendon (1932) and Dawson et al., (1945) determined that nutritional regimens influenced weight more than skeletal development. Thus, the increase in magnitude of body weight combined with the variation contributed by dietary regimens leads to the suggestion that the growth curve for body weight was variable due to farm, month of birth, individual horse differences and residual effects. The coefficients of variation of all measurements decreased with age, thus horses became more uniform in size than they were at birth. The same phenomenon was noted by Cunningham and Fowler (1961). Furthermore, as horses grow, genetic and environmental sources of variation that influence growth, decrease over time. This is because the rate of growth decreases with age. Thus, the decrease in coefficients of variation over time was understandable. Another point to

TABLE 14. LEAST SQUARES MEANS, STANDARD DEVIATIONS (S.D.) AND COEFFICIENTS OF VARIATION (C.V.) OF THE BODY MEASUREMENTS OF 1982 FOALS THAT WERE CALCULATED AT CONSTANT AGES.

| | | Body measurement | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Age (days) | calculated values | Heart girth (cm) | Chest width (cm) | Wither height (cm) | Hip height (cm) | Body length (cm) | Knee to ground (cm) | Cannon bone circumference (cm) | weight (kg) |
| 30 | mean | 99.5 | 24.7 | 108.8 | 112.3 | 86.1 | 35.3 | 13.7 | 95.9 |
| | S.D. | 4.4 | 1.4 | 3.5 | 3.9 | 3.8 | 1.2 | .5 | 12.7 |
| | C.V. (%) | 4.4 | 5.6 | 3.2 | 3.4 | 4.4 | 3.3 | 3.7 | 13.2 |
| 90 | mean | 122.0 | 29.6 | 121.8 | 126.5 | 106.4 | 37.8 | 15.4 | 163.7 |
| | S.D. | 4.7 | 1.5 | 3.6 | 4.2 | 4.2 | 1.1 | .6 | 16.0 |
| | C.V. (%) | 3.8 | 5.2 | 2.9 | 3.3 | 4.0 | 3.0 | 3.6 | 9.8 |
| 150 | mean | 136.2 | 32.7 | 130.8 | 135.5 | 119.4 | 38.9 | 16.6 | 218.2 |
| | S.D. | 4.1 | 1.4 | 3.5 | 4.0 | 4.2 | 1.2 | .5 | 16.9 |
| | C.V. (%) | 3.0 | 4.2 | 2.7 | 2.9 | 3.5 | 3.1 | 3.1 | 7.7 |
| 210 | mean | 147.1 | 35.0 | 136.7 | 141.4 | 127.8 | 39.2 | 17.7 | 269.8 |
| | S.D. | 3.7 | 1.2 | 3.5 | 3.6 | 3.6 | 1.2 | .5 | 19.2 |
| | C.V. (%) | 2.5 | 3.5 | 2.6 | 2.6 | 2.8 | 3.1 | 3.0 | 7.1 |
| 270 | mean | 154.7 | 36.6 | 141.0 | 145.4 | 134.1 | 39.3 | 18.3 | 310.7 |
| | S.D. | 4.1 | 1.3 | 3.5 | 3.5 | 3.6 | 1.2 | .6 | 23.6 |
| | C.V. (%) | 2.6 | 3.5 | 2.5 | 2.4 | 2.7 | 3.1 | 3.0 | 7.6 |
| 400 | mean | 166.3 | 38.9 | 148.4 | 152.0 | 144.2 | 40.4 | 19.4 | 382.3 |
| | S.D. | 4.1 | 1.2 | 3.6 | 3.6 | 3.8 | 1.3 | .6 | 27.2 |
| | C.V. (%) | 2.4 | 3.1 | 2.4 | 2.4 | 2.6 | 3.1 | 3.0 | 7.1 |

mention here is that foals, in the first few days of life, although they were fully capable of standing, running etc, did not necessarily exhibit full extension of their limbs. In many cases, the flexor tendons are not completely developed at birth, thus, the angle of the metacarpo-phalangeal joints is less than normal. Likewise, the foals were held as quietly as possible during the measuring procedure and an effort was made to relax the foals. However, when the measuring stick or tape was placed on them, they became tense, thus, some of the skeletal measurements may have been less than accurate. This phenomenon primarily affected the measurements adjusted to 30 d-of-age and caused an increase in the variability in measurements at 30 d-of-age.

Proportions with the least variability were the skeletal measures of wither and hip height, body length, the distance from knee to ground and cannon bone circumference. The body weight measurements became more uniform over time, yet variation among predicted values was greater than among the other measurements. Reed and Dunn (1977) attributed the greater variability in body weight as opposed to skeletal measures to differences in general physical condition among animals. Moreover, at 400 d-of-age, horses possess 56 to 81% of their mature body weight whereas they have 86 to 100% of their mature skeletal size (table 6).

If measurements had been obtained later than July of the yearling year, the foals probably would have become even more uniform in size. Likewise, the small decrease in the variability in the distance from knee to ground throughout the experimental period was attributed to the young age when foals reach mature proportion in that parameter (table 6).

The least squares means of body measurements, interpolated to constant ages were calculated (tables 15 to 22). At 30 and 90 d-of-age, foals born in January-February were the smallest foals. Furthermore, the differences between body measurements of foals due to month of birth generally dissappeared by 270 d-of-age. Foals born in May-June had a larger heart girth measure (7 cm) at 30 d-of-age than those born in January-February ($P < .01$ for the effect of birth month). At 210 d-of-age, the difference was less (2.1 cm; $P < .09$ for the effect of birth month). At 400 d-of-age, foals born in January-February were .3 cm larger at the girth than foals born in May-June ($P < .62$ for the effect of birth month). From 150 to 400 d-of-age, foals born in March had the largest heart girth (table 15). The analysis of variance utilized to generate growth curves of heart girth (table 11) identified variation in heart girth due to the interaction of birth month with age ($P < .01$) and with age x age ($P < .03$). Thus, the month of birth influenced the

TABLE 15. LEAST SQUARES MEANS OF THE HEART GIRTH MEASUREMENT (CM) OF 1982 FOALS, CALCULATED FROM DATA ADJUSTED TO VARIOUS CONSTANT AGES.

| | | Month of birth | | | | | Duncan's critical values[3] | | |
|---|---|---|---|---|---|---|---|---|---|
| Age (days) | Probability[1] (P <) | January February | March | April | May June | SE[2] | p=2 | p=3 | p=4 |
| 30 | .01 | 96.4[a] | 99.0[ab] | 100.2[bc] | 103.4[c] | 1.25 | 3.34 | 3.52 | 3.63 |
| 90 | .01 | 118.2[a] | 122.8[b] | 123.0[b] | 123.7[b] | 1.08 | 2.88 | 3.03 | 3.13 |
| 150 | .01 | 134.0[a] | 137.2[b] | 136.2[b] | 137.0[b] | .80 | 2.22 | 2.34 | 2.41 |
| 210 | .09 | 145.7[a] | 148.0[b] | 147.5[ab] | 147.8[b] | .70 | 1.96 | 2.06 | 2.12 |
| 270 | .19 | 155.5 | 156.3 | 154.7 | 154.1 | .78 | | | |
| 400 | .62 | 166.8 | 167.3 | 166.0 | 166.5 | .83 | | | |

[1]Probability associated with the F-test from the analysis of variance for the main effect of birth month

[2]Standard error of the means averaged across birth months.

[3]Duncan's multiple range conducted when probability $\leq .10$. Means in the same row with different superscripts were significantly different ($\alpha$=.05). To conduct test, rank means in order from smallest to largest. "p" is the number of least squares means included within the range of the comparison. To compare 2 least squares means that are adjacent within the array of means, use p=2. To compare 2 least squares means ranked 1 and 3 or 2 and 4, use p=3. To compare the smallest and largest least squares means, use p=4.

TABLE 16. LEAST SQUARES MEANS OF THE CHEST WIDTH MEASUREMENT (CM) OF 1982 FOALS, CALCULATED FROM DATA ADJSUTED TO VARIOUS CONSTANT AGES.

| Age (days) | Probability[1] (P < ) | Month of birth: January February | March | April | May June | SE[2] | Duncan's critical values[3]: p=2 | p=3 | p=4 |
|---|---|---|---|---|---|---|---|---|---|
| 30 | .01 | $24.1^{a}$ | $25.2^{b}$ | $25.1^{ab}$ | $25.3^{b}$ | .35 | .97 | 1.02 | 1.05 |
| 90 | .01 | $28.8^{a}$ | $30.1^{b}$ | $29.8^{b}$ | $29.9^{b}$ | .33 | .90 | .95 | .98 |
| 150 | .11 | 32.2 | 33.0 | 32.8 | 32.9 | .25 | | | |
| 210 | .21 | 34.7 | 35.2 | 34.9 | 35.2 | .23 | | | |
| 270 | .12 | 36.4 | 36.9 | 36.6 | 36.9 | .25 | | | |
| 400 | .01 | $38.4^{a}$ | $38.7^{a}$ | $38.7^{a}$ | $39.7^{b}$ | .25 | .67 | .71 | .73 |

[1]Probability associated with the F-test from the analysis of variance for the main effect of birth month

[2]Standard error of the means averaged across birth months.

[3]Duncan's multiple range conducted when probability $\leq$ .10. Means in the same row with different superscripts were significantly different ($\alpha$=.05). To conduct test, rank means in order from smallest to largest. "p" is the number of least squares means included within the range of the comparison. To compare 2 least squares means that are adjacent within the array of means, use p=2. To compare 2 least squares means ranked 1 and 3 or 2 and 4, use p=3. To compare the smallest and largest least squares means, use p=4.

TABLE 17. LEAST SQUARES MEANS OF THE WITHER HEIGHT MEASUREMENT (CM) OF 1982 FOALS, CALCULATED FROM DATA ADJUSTED TO VARIOUS CONSTANT AGES.

| | | Month of birth | | | | | Duncan's critical values[3] | | |
|---|---|---|---|---|---|---|---|---|---|
| Age (days) | Probability[1] (P <) | January February | March | April | May June | SE[2] | p=2 | p=3 | p=4 |
| 30 | .17 | 107.6 | 109.8 | 108.4 | 109.3 | .90 | | | |
| 90 | .04 | 120.9[a] | 122.6[b] | 122.4[b] | 122.5[b] | .75 | 2.07 | 2.18 | 2.24 |
| 150 | .32 | 130.0 | 131.7 | 130.8 | 130.8 | .68 | | | |
| 210 | .22 | 136.9 | 137.7 | 136.0 | 136.2 | .68 | | | |
| 270 | .63 | 141.7 | 141.7 | 140.2 | 140.3 | .68 | | | |
| 400 | .27 | 148.7 | 148.7 | 147.8 | 148.0 | .73 | | | |

[1]Probability associated with the F-test from the analysis of variance for the main effect of birth month

[2]Standard error of the means averaged across birth months.

[3]Duncan's multiple range conducted when probability $\leq .10$. Means in the same row with different superscripts were significantly different ($\alpha = .05$). To conduct test, rank means in order from smallest to largest. "p" is the number of least squares means included within the range of the comparison. To compare 2 least squares means that are adjacent within the array of means, use p=2. To compare 2 least squares means ranked 1 and 3 or 2 and 4, use p=3. To compare the smallest and largest least squares means, use p=4.

TABLE 18. LEAST SQUARES MEANS OF THE HIP HEIGHT MEASUREMENT (CM) OF 1982 FOALS, CALCULATED FROM DATA ADJUSTED TO CONSTANT AGES.

| | | Month of birth | | | | | Duncan's critical values[3] | | |
|---|---|---|---|---|---|---|---|---|---|
| Age (days) | Probability[1] (P <) | January February | March | April | May June | SE[2] | p=2 | p=3 | p=4 |
| 30 | .06 | 110.9[a] | 113.5[b] | 111.0[ab] | 113.1[b] | .80 | 1.97 | 2.08 | 2.14 |
| 90 | .05 | 124.6[a] | 127.6[b] | 126.7[ab] | 127.2[b] | .88 | 2.42 | 2.55 | 2.63 |
| 150 | .15 | 134.8 | 136.9 | 135.0 | 135.5 | .78 | | | |
| 210 | .03 | 141.7[ab] | 142.9[b] | 140.7[a] | 140.6[a] | .70 | 1.96 | 2.06 | 2.12 |
| 270 | .06 | 146.4[a] | 146.7[a] | 144.5[a] | 144.6[a] | .68 | 1.88 | 1.98 | 2.04 |
| 400 | .40 | 152.4 | 152.6 | 151.3 | 151.5 | .78 | | | |

[1]Probability associated with the F-test from the analysis of variance for the main effect of birth month

[2]Standard error of the means averaged across birth months.

[3]Duncan's multiple range conducted when probability $\leq$ .10. Means in the same row with different superscripts were significantly different ($\alpha$=.05). To conduct test, rank means in order from smallest to largest. "p" is the number of least squares means included within the range of the comparison. To compare 2 least squares means that are adjacent within the array of means, use p=2. To compare 2 least squares means ranked 1 and 3 or 2 and 4, use p=3. To compare the smallest and largest least squares means, use p=4.

TABLE 19. LEAST SQUARES MEANS OF THE BODY LENGTH MEASUREMENT (CM) OF 1982 FOALS, CALCULATED FROM DATA ADJUSTED TO CONSTANT AGES.

| | | Month of birth | | | | | Duncan's critical values[3] | | |
|---|---|---|---|---|---|---|---|---|---|
| Age (days) | Probability[1] (P <) | January February | March | April | May June | SE[2] | p=2 | p=3 | p=4 |
| 30 | .01 | 84.1[a] | 87.3[b] | 85.5[ab] | 87.9[b] | .95 | 2.67 | 2.81 | 2.90 |
| 90 | .01 | 103.6[a] | 107.4[b] | 106.5[b] | 108.5[b] | .90 | 2.53 | 2.66 | 2.74 |
| 150 | .01 | 117.6[a] | 120.7[b] | 119.3[ab] | 120.5[b] | .85 | 2.35 | 2.48 | 2.56 |
| 210 | .49 | 128.2 | 128.8 | 127.5 | 127.9 | .68 | | | |
| 270 | .61 | 134.9 | 134.7 | 133.8 | 133.8 | .70 | | | |
| 400 | .66 | 143.9 | 144.8 | 143.9 | 144.4 | .80 | | | |

[1]Probability associated with the F-test from the analysis of variance for the main effect of birth month

[2]Standard error of the means averaged across birth months.

[3]Duncan's multiple range conducted when probability $\leq .10$. Means in the same row with different superscripts were significantly different ($\alpha=.05$). To conduct test, rank means in order from smallest to largest. "p" is the number of least squares means included within the range of the comparisons. To compare 2 least squares means that are adjacent within the array of means, use p=2. To compare 2 least squares means ranked 1 and 3 or 2 and 4, use p=3. To compare the smallest and largest least squares means, use p=4.

TABLE 20. LEAST SQUARES MEANS OF THE KNEE TO GROUND MEASUREMENT (CM) OF 1982 FOALS, CALCULATED FROM DATA ADJUSTED TO CONSTANT AGES.

| | | Month of birth | | | | | Duncan's critical values[3] | | |
|---|---|---|---|---|---|---|---|---|---|
| Age (days) | Probability[1] (P <) | January February | March | April | May June | SE[2] | p=2 | p=3 | p=4 |
| 30 | .03 | 34.7[a] | 35.5[ab] | 35.3[ab] | 35.8[b] | .30 | .85 | .89 | .92 |
| 90 | .01 | 37.0[a] | 38.1[b] | 37.9[b] | 38.0[b] | .23 | .62 | .65 | .67 |
| 150 | .68 | 38.7 | 39.1 | 38.9 | 38.9 | .25 | | | |
| 210 | .20 | 39.3 | 39.6 | 39.2 | 38.9 | .23 | | | |
| 270 | .22 | 39.7 | 39.6 | 39.2 | 39.2 | .20 | | | |
| 400 | .42 | 40.6 | 40.4 | 40.1 | 40.1 | .28 | | | |

[1]Probability associated with the F-test from the analysis of variance for the main effect of birth month.

[2]Standard error of the means averaged across birth months.

[3]Duncan's multiple range conducted when probability $\leq .10$. Means in the same row with different superscripts were significantly different ($\alpha$=.05). To conduct test, rank means in order from smallest to largest. "p" is the number of least squares means included within the range of the comparisons. To compare 2 least squares means that are adjacent within the array of means, use p=2. To compare 2 least squares means ranked 1 and 3 or 2 and 4, use p=3. To compare the smallest and largest least squares means, use p=4.

TABLE 21. LEAST SQUARES MEANS OF THE CANNON BONE CIRCUMFERENCE MEASUREMENTS (CM) OF 1982 FOALS, CALCULATED FROM DATA ADJUSTED TO CONSTANT AGES.

| Age (days) | Probability[1] (P <) | Month of birth | | | | SE[2] | Duncan's critical values[3] | | |
|---|---|---|---|---|---|---|---|---|---|
| | | January February | March | April | May June | | p=2 | p=3 | p=4 |
| 30 | .03 | 13.5[a] | 13.8[ab] | 13.6[a] | 13.9[b] | .1 | .28 | .30 | .31 |
| 90 | .10 | 15.2[a] | 15.4[ab] | 15.4[ab] | 15.6[b] | .1 | .28 | .30 | .31 |
| 150 | .42 | 16.6 | 16.6 | 16.5 | 16.7 | .1 | | | |
| 210 | .87 | 17.8 | 17.7 | 17.6 | 17.7 | .1 | | | |
| 270 | .02 | 18.6[a] | 18.5[ab] | 18.2[c] | 18.2[bc] | .1 | .28 | .30 | .31 |
| 400 | .30 | 19.3 | 19.4 | 19.5 | 19.6 | .1 | | | |

[1] Probability associated with the F-test from the analysis of variance for the main effect of birth month.

[2] Standard error of the means averaged across birth months.

[3] Duncan's multiple range conducted when probability $\leq$ .10. Means in the same row with different superscripts were significantly different ($\alpha$=.05). To conduct test, rank means in order from smallest to largest. "p" is the number of least squares means included within the range of comparisons. To compare 2 least squares means that are adjacent within the array of means, use p=2. To compare 2 least squares means ranked 1 and 3 or 2 and 4, use p=3. To compare the smallest and largest least squares means, use p=4.

TABLE 22. LEAST SQUARES MEANS OF THE BODY WEIGHT MEASUREMENTS (KG) OF 1982 FOALS, CALCULATED FROM DATA ADJUSTED TO CONSTANT AGES

| Age (days) | Proba-bility[1] (P <) | Month of birth | | | | SE[2] | Duncan's critical values[3] | | |
|---|---|---|---|---|---|---|---|---|---|
| | | January February | March | April | May June | | p=2 | p=3 | p=4 |
| 30 | .01 | 88.1[a] | 95.7[ab] | 98.9[b] | 109.9[c] | 3.2 | 8.92 | 9.39 | 9.68 |
| 90 | .01 | 152.7[a] | 168.4[b] | 166.0[b] | 166.0[b] | 3.4 | 9.48 | 9.98 | 10.29 |
| 150 | .06 | 211.5[a] | 223.1[b] | 216.8[ab] | 219.3[ab] | 3.4 | 9.42 | 9.92 | 10.22 |
| 210 | .09 | 262.7[a] | 174.4[b] | 271.0[ab] | 273.0[ab] | 3.8 | 10.52 | 11.08 | 11.41 |
| 270 | .18 | 315.9 | 319.8 | 310.1 | 307.1 | 4.7 | | | |
| 400 | .43 | 386.7 | 391.5 | 380.4 | 384.7 | 5.7 | | | |

[1]Probability associated with the F-test from the analysis of variance for the main effect of birth month.

[2]Standard error of the means averaged across birth months.

[3]Duncan's multiple range conducted wehn probability $\leq$ .10. Means in the same row with different superscritps were significantly different ($\alpha$=.05). To conduct test, rank means in order from smallest to largest. "p" is the number of least squares means included within the range of comparisons. To compare 2 least squares means that are adjacent within the array of means, use p=2. To compare 2 least squares means ranked 1 and 3 or 2 and 4, use p=3. To compare the smallest and largest least squares means, use p=4.

rate of increase of heart girth and the shape of the growth curve for heart girth. The age at which the differences occurred were elucidated by the use of least squares analysis of variance.

The differences among the chest widths of foals born in January-February and those born from March to June ranged from 1 to 1.3 cm through 90 d-of-age ($P < .01$ for the effect of birth month). Differences due to birth month were not observed at 150, 210 or 270 d-of age. However, at 400 d-of-age, the chest of foals born in May-June was 1 to 1.3 cm wider than that of all other foals ($P < .01$ for the effect of birth month; table 16).

Differences in wither height due to month of birth were observed at 90 d-of-age only. Foals born from March to June were an average 1.4 cm taller than foals born in January-February ($P < .04$). Foals born in March were the tallest foals at each of the constant ages (table 17).

At 30 and 90 d-of-age, foals born in May-June were 2.2 and 2.6 cm taller at the hip, respectively, than foals born in January-February ($P < .06$; $P < .05$). However, the hip height of foals born in March through June did not differ at these ages. Differences among hip heights of foals born during different months were negligible by 400 d-of-age ($P < .40$). Foals born in March were consistantly tallest at the hip (table 18).

Foals born in May-June were 3.8 cm and 2.9 cm longer at 30 and 150 d-of-age, respectively, than foals born in January-February (P< .01). Differences in body length due to month of birth were not observed after 150 d-of-age (table 18). Foals born in May-June possessed 1.1 cm more length from knee to ground at 30 and 90 d-of-age, than did foals born in January-February (P< .03; P< .01 for the effect of birth month; table 20). Differences in cannon bone circumference due to month of birth were observed at 30, 90 and 270 d-of-age (P< .03, .10 and .02, respectively). The largest difference detected was .4 cm; at 30 and 90 d-of-age, foals born in May-June foals had a larger cannon bone circumference than foals born in January-February. However, the difference was reversed at 270 d-of-age (table 21).

Differences in body weight due to month of birth were evident from 30 to 210 d-of-age. Foals born in May-June were 21.8 kg heavier than foals born in January-February at 30 d-of-age and weighed 10.3 kg more at 210 d-of-age. From 90 to 400 d-of-age, foals born in March were the heaviest foals (table 22). Body weight was calculated from the heart girth measurement, thus it was not unusual that the differences in heart girth and body weight due to month of birth were similar.

Beyond the consistently smaller size of early-born foals at 30 and 90 d-of-age, there were no trends noted when comparing measurements of foals by month of birth or by age. Foals born in March tended to be the largest foals more often than foals born at any other time. The differences due to birth month, that were observed at earlier ages and that dissappeared from 210 to 400 d-of-age, leads to the suggestion that foals born in May-June exhibited more rapid growth in all conformational components, from birth to 210 d-of-age, than did early-born foals. It has already been proposed that foals born in May-June were larger at birth than early-born foals (in reference to the intercepts obtained from the regression equations). Foals born in late spring and early summer may have been exposed to more optimal environmental conditions from birth to 90 d-of-age than were early-born foals. Influences that were potentially more optimal for growth included higher temperature, higher pasture quality and quality and(or) greater quantity Gibbs et al., (1979) reported that mares foaling in May had a higher average daily milk yeild than mares that foaled in March or April ($P < .05$).

The effect of stress caused by weaning was not quantified in this study. Weaning age ranged from 95 to 185 d-of-age and was not consistant within a birth month or within a farm. However, weaning date was fairly consistant within a farm. Possibly, the growth of foals that were weaned at earlier ages, was facilitated as the foals were removed from mares' milk during the second 3 mo of lactation. Ullrey et al., (1966) and Gibbs et al., (1979) reported that the nutritional quality and quantity of milk declined after 2 to 3 mo postpartum. Thus, the foals born later in the spring and weaned when they were younger than their contempories, did not depend on the lower quality source of nutrition for as long a period of time as did the early-born foals.

The percentage of maximum size at specific ages in 1982 foals born during different months.

Another way to interpret the data is in terms of percentage maturity attained at various ages. Differences in body size due to month of birth were not significant at 400 d-of-age except for chest width. Thus, all measures at 400 d-of-age were designated as 100% of maximum size in order to establish a reference point (table 23). Trends similar to those observed with the least squares means of measurements at specific ages were noted. At 30 and 90 d-of-age, foals born in May-June possessed 1 to 6% more of their maximum size than did foals born in January-February. By 210 d-of-age, there were essentially no differences in

TABLE 23. THE PERCENTAGE OF MAXIMUM SIZE (SIZE AT 400 DAYS-OF-AGE = MAXIMUM SIZE) OF CONFORMATIONAL COMPONENTS OF 1982 FOALS, CALCULATED AT VARIOUS CONSTANT AGES.

| Body measure | Age (days) | Month of birth | | | |
|---|---|---|---|---|---|
| | | January February | March | April | May June |
| Heart girth | 30 | 58 | 59 | 60 | 62 |
| | 90 | 71 | 73 | 74 | 74 |
| | 150 | 80 | 82 | 82 | 82 |
| | 210 | 87 | 88 | 89 | 89 |
| | 270 | 93 | 93 | 93 | 93 |
| | 340 | 97 | 97 | 97 | 97 |
| Chest width | 30 | 63 | 65 | 65 | 65 |
| | 90 | 75 | 78 | 77 | 77 |
| | 150 | 84 | 85 | 85 | 85 |
| | 210 | 90 | 91 | 90 | 91 |
| | 270 | 95 | 95 | 95 | 95 |
| | 340 | 99 | 99 | 97 | 98 |
| Wither height | 30 | 72 | 74 | 73 | 74 |
| | 90 | 81 | 82 | 83 | 83 |
| | 150 | 87 | 89 | 88 | 88 |
| | 210 | 92 | 93 | 92 | 92 |
| | 270 | 95 | 95 | 95 | 95 |
| | 340 | 98 | 98 | 98 | 98 |
| Hip height | 30 | 73 | 74 | 74 | 74 |
| | 90 | 82 | 84 | 84 | 84 |
| | 150 | 88 | 90 | 89 | 89 |
| | 210 | 93 | 94 | 93 | 93 |
| | 270 | 96 | 96 | 96 | 95 |
| | 340 | 98 | 98 | 98 | 98 |
| Body length | 30 | 58 | 60 | 59 | 61 |
| | 90 | 72 | 74 | 74 | 75 |
| | 150 | 82 | 83 | 83 | 84 |
| | 210 | 89 | 89 | 89 | 89 |
| | 270 | 96 | 96 | 96 | 95 |
| | 340 | 97 | 97 | 96 | 97 |
| Knee to ground | 30 | 85 | 88 | 88 | 89 |
| | 90 | 91 | 94 | 95 | 95 |
| | 150 | 95 | 97 | 97 | 97 |
| | 210 | 97 | 98 | 98 | 97 |
| | 270 | 98 | 98 | 98 | 98 |
| | 340 | 99 | 99 | 100 | 99 |
| Cannon bone circumference | 30 | 70 | 72 | 70 | 71 |
| | 90 | 79 | 79 | 79 | 80 |
| | 150 | 86 | 86 | 85 | 85 |
| | 210 | 92 | 91 | 90 | 90 |
| | 270 | 96 | 95 | 93 | 93 |
| | 340 | 98 | 97 | 96 | 97 |
| Body weight | 30 | 23 | 24 | 26 | 29 |
| | 90 | 39 | 43 | 44 | 43 |
| | 150 | 55 | 57 | 57 | 57 |
| | 210 | 68 | 70 | 71 | 71 |
| | 270 | 82 | 82 | 82 | 80 |
| | 340 | 93 | 92 | 91 | 90 |

percentage of maximum size across all measurements due to month of birth. Thus, the foals born later in the spring were larger initially and exhibited a period of growth that was more rapid than growth displayed by foals born in January-February.

The values calculated for percentage of maximum body size (table 23) were inflated compared to percentages reported in table 6. Horses reach their mature proportions after 400 d-of-age (table 6), thus, size at 400 d-of-age was not equivalent to 100% of mature size. However, the relative differences between percentages at specific ages reflected relative growth rates at the various points of measure. Foals possessed a greater proportion of the maximum length from knee to ground (average of 88%) and less body weight (average of 24%) at 30 d-of-age than the proportion of any other measure. Wither and hip height were 73 to 74% of maximum size at 30 d-of-age and cannon bone circumference was approximately 71% of maximum size. Although the percentages obtained in this study were inflated in comparison to the values in table 6, the ranking of percentage maturity of body measures paralleled the results obtained by Trowbridge and Chittendon (1932), Cunningham and Fowler (1961), Heird (1973) and Hintz et al., (1978).

Skeletal growth, expressed in terms of the relative increase from birth to 400 d-of-age, was less than the increase in body mass. Lawrence (1980) stated that the mass of the body increases as the cube of its length. In other words, if the skeleton increased in size in proportion to the body without altering its shape, the cross-section of the bones would only be squared. Eventually, the bones would be crushed by the mass they needed to support. In light of the fact that linear skeletal growth was less than the increase in body mass, it can be suggested that most of the skeletal growth from birth to maturity involved an increase in the calcification of bone, the strength and diameter of bone, rather than an increase in length.

Previous researchers stated that the percentage of mature chest width from 6 to 8 mo-of-age was less than the percentage of mature skeletal measures during this period (table 6). In the current study, the percentages of maximum chest width were greater than the percentages of body length. However, there were differences in chest width measurements at 400 d-of-age due to month of birth. Actual maturing rates of horses and age at which proportions were mature were not available in this study due to the limitations of the data.

Correlations at various ages between body measures in 1982 foals

The relationships between growth in specific measurements were determined (table 24). Heart girth was highly correlated with body weight (r= .76 to .99). This was not unexpected because body weight was calculated from the heart girth measurement. From 30 to 400 d-of-age, 31 to 62% of the variation in heart girth was associated with variation in chest width, wither and hip height and body length. The relationships decreased with age. Thus, growth rates were asynchronous at the various points of measure. Chest width was most consistantly related to body weight over time (r = .62 to .74). Both measures are a function of skeletal as well as muscular development, whereas, muscular development does not extensively influence wither and hip height or body length. Furthermore, the rate at which horses reached mature body weight and chest width was slower than the maturing rates in skeletal measures (Cunningham and Fowler, 1961; table 6). Thus, although the correlations between chest width and wither height, hip height and body length were relatively high at birth, the fact that they decreased over time was not unexpected.

Wither height and hip height were highly and consistantly related from 30 to 400 d-of-age (r=.94 to .90).

TABLE 24. CORRELATIONS BETWEEN MEASUREMENTS AT VARIOUS CONSTANT DAYS-OF-AGE FOR 1982 FOALS.[1]

| | | Body measurement | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Body measurement | Age (days) | Chest width | Wither height | Hip height | Body length | Knee to ground | Cannon bone circumference | Body weight |
| Heart girth | 30 | .79 | .73 | .73 | .77 | .45 | .67 | .76 |
| | 90 | .77 | .73 | .76 | .74 | .53 | .68 | .97 |
| | 150 | .74 | .66 | .68 | .70 | .51 | .66 | .97 |
| | 210 | .64 | .65 | .60 | .63 | .40 | .70 | .99 |
| | 270 | .65 | .59 | .62 | .56 | .38 | .69 | .99 |
| | 400 | .66 | .57 | .56 | .58 | .45 | .63 | .99 |
| Chest width | 30 | | .71 | .71 | .72 | .36 | .67 | .68 |
| | 90 | | .70 | .71 | .67 | .57 | .69 | .74 |
| | 150 | | .63 | .63 | .65 | .49 | .67 | .72 |
| | 210 | | .48 | .49 | .59 | .37 | .50 | .62 |
| | 270 | | .52 | .52 | .55 | .44 | .52 | .65 |
| | 400 | | .53 | .54 | .50 | .56 | .62 | .67 |
| Wither height | 30 | | | .94 | .73 | .62 | .67 | .55 |
| | 90 | | | .93 | .73 | .78 | .65 | .70 |
| | 150 | | | .92 | .63 | .81 | .62 | .62 |
| | 210 | | | .92 | .68 | .78 | .61 | .64 |
| | 270 | | | .92 | .68 | .80 | .56 | .59 |
| | 400 | | | .90 | .65 | .79 | .67 | .57 |
| Hip height | 30 | | | | .71 | .65 | .65 | .56 |
| | 90 | | | | .75 | .77 | .64 | .72 |
| | 150 | | | | .70 | .79 | .59 | .64 |
| | 210 | | | | .70 | .80 | .55 | .58 |
| | 270 | | | | .71 | .77 | .53 | .61 |
| | 400 | | | | .66 | .76 | .51 | .57 |
| Body length | 30 | | | | | .40 | .63 | .57 |
| | 90 | | | | | .55 | .71 | .71 |
| | 150 | | | | | .55 | .61 | .68 |
| | 210 | | | | | .51 | .58 | .61 |
| | 270 | | | | | .55 | .56 | .56 |
| | 400 | | | | | .54 | .55 | .58 |
| Knee to ground | 30 | | | | | | .42 | .27 |
| | 90 | | | | | | .48 | .50 |
| | 150 | | | | | | .47 | .46 |
| | 210 | | | | | | .47 | .39 |
| | 270 | | | | | | .42 | .38 |
| | 400 | | | | | | .59 | .47 |
| Cannon bone circumference | 30 | | | | | | | .64 |
| | 90 | | | | | | | .69 |
| | 150 | | | | | | | .66 |
| | 210 | | | | | | | .69 |
| | 270 | | | | | | | .69 |
| | 400 | | | | | | | .63 |

[1]All correlations were significant, p $\leq$.0001.

The slight decrease over time can be explained by the fact that during growth, hip height was generally greater than wither height. However, during the yearling year, the difference between the two measurements decreased as horses became more level over the topline. The relationship between wither height and body length growth was fairly high, ranging from 40 to 53% ($r^2$).

The correlation between wither height and the distance from knee to ground increased from .62 at 30 d-of-age to .79 at 400 d-of-age. Because foals possess a high degree of maturity in the length from knee to ground at birth, and as the length from knee to ground contributes to wither height, the increasing relation between the two measures was understandable.

The correlations between hip height and body length or between hip height and the distance from knee to ground were similar to those for wither height and the two measurements. The relationship between cannon bone circumference and most of the measurements remained fairly stable over time. Apparently, bone growth inherently paralleled the growth of the rest of the body; the column of bone increased in diameter and presumably in strength in order to support a larger frame and weight. The correlations between bone size and skeletal measures were not as high as those reported by

Cunningham and Fowler (1961) or Heird (1973)(table 8). However, the relationships in this study were greater than the values reported by Hintz et al., (1978).

Differences in size of 1982 colts and fillies at various ages.

The values of all body measures interpolated to each constant age were grouped by sex within a birth month. Numbers of colts and fillies within each birth month are listed in table 25. Table 26 includes the means for colts and fillies when the main effect of sex at a specific age was significant ($P \leq .1$). There were no significant birth month x sex interactions, therefore, differences between sexes across birth months were examined. Colts were uniformly larger than fillies when sex differences existed ($P \leq .1$). Colts had an average .62 cm greater width through the chest, 1.72 cm greater body length and 14.82 kg greater body weight than fillies from 210 to 400 d-of-age. The cannon bone circumference of colts measured from 150 to 400 d-of-age, was an average .36 cm greater than that of fillies.

The first significant differences between body measurements of colts and fillies occurred at 150 d-of-age. Cunningham and Fowler (1961), Wojciechowski (1965) and Green (1969) reported that males and females grew uniformly from

TABLE 25. THE NUMBER OF 1982 COLTS AND FILLIES THAT WERE BORN IN THE VARIOUS MONTHS AND THAT WERE INCLUDED IN THE LEAST SQUARES MEANS OF CONFORMATIONAL COMPONENTS, DETERMINED AT VARIOUS CONSTANT AGES.

| Age (days) | Month of birth | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | January February | | March | | April | | May June | |
| | Fillies | Colts | Fillies | Colts | Fillies | Colts | Fillies | Colts |
| 30 | 14 | 8 | 13 | 12 | 13 | 19 | 14 | 8 |
| 90 | 14 | 8 | 14 | 12 | 18 | 26 | 16 | 14 |
| 150 | 15 | 9 | 15 | 12 | 19 | 26 | 20 | 17 |
| 210 | 9 | 15 | 14 | 14 | 27 | 20 | 18 | 19 |
| 270 | 9 | 15 | 13 | 15 | 27 | 19 | 17 | 19 |
| 400 | 9 | 14 | 12 | 15 | 25 | 18 | 14 | 18 |

TABLE 26. LEAST SQUARES MEANS OF THE CONFORMATIONAL COMPONENTS OF 1982 COLTS AND FILLIES, CALCULATED FROM DATA ADJUSTED TO VARIOUS CONSTANT AGES.[1]

| Body measurements | Age (days) | Probability[2] (P <) | Least squares means | | Difference between the measures of colts - fillies | SE[3] | |
|---|---|---|---|---|---|---|---|
| | | | Colts | Fillies | | Colts | Fillies |
| Chest width (cm) | 210 | .03 | 35.3 | 34.73 | .57 | .18 | .15 |
| | 270 | .01 | 37.15 | 36.3 | .85 | .19 | .15 |
| | 400 | .02 | 39.0 | 38.55 | .45 | .20 | .15 |
| Body length (cm) | 210 | .07 | 128.88 | 127.35 | 1.53 | .52 | .48 |
| | 270 | .07 | 135.18 | 133.5 | 1.68 | .52 | .48 |
| | 400 | .02 | 145.28 | 143.23 | 2.05 | .59 | .50 |
| Cannon bone circumference (cm) | 150 | .02 | 16.75 | 16.45 | .30 | .21 | .16 |
| | 210 | .01 | 17.89 | 17.58 | .31 | .25 | .16 |
| | 270 | .01 | 18.58 | 18.18 | .40 | .25 | .16 |
| | 400 | .01 | 19.68 | 19.25 | .43 | .09 | .10 |
| Body weight | 210 | .01 | 275.43 | 265.13 | 10.30 | 2.8 | 2.5 |
| | 270 | .01 | 321.55 | 304.88 | 16.67 | 3.4 | 3.1 |
| | 400 | .01 | 394.58 | 377.08 | 17.50 | 4.2 | 3.7 |

[1]Table includes differences between colts and fillies when the probability associated with the F-test for the main effect of sex $\leq .10$.

[2]Probability associated with the F-test for the main effect of sex

[3]Standard error of the means averaged across birth months.

birth to 12 mo-of-age. In contrast, Reed and Dunn (1977) reported that males gained faster and possessed a greater wither height, hip height, body length and body weight than did females up to 12 mo-of-age. Likewise, Heird (1973) and Hintz et al., (1978) stated that colts were generally larger than fillies from birth to maturity. Several researchers have observed that mature females were longer than mature males (Cunningham and Fowler, 1961; Heird, 1973; Willoughby, 1975; Reed and Dunn, 1977). The current data did not necessarily conflict with previous data as it was not obtained through the age when horses reach their mature body length.

Sex differences in size and the physiological basis for such differences have been widely researched. Joubert (1956) attributed differences in the size of ewes and rams to a greater number of muscle cells in males which is determined two-thirds of the way through prenatal development. In the current study, the observed differences in body mass were attributed to a presumably greater mass and number of muscle cells in males than in females.

Wilson et al., (1980) reported that during the initial part of gestation, the development of male and female embryos was identical. After the differentiation of the gonads, the male phenotype could occur. The two secretions of the fetal testis, Mullerian regression factor and testosterone, were required for the expression of the male phenotype. The absence of gonadal sex differentiation resulted in the phenotypic female. They made the comment that the molecular mechanisms by which hormones act during fetal development appear to be the same as those operative in the postnatal state.

The age at puberty also contributes to differences in size due to sex. At puberty, there is a "spurt" of growth which is followed by a virtual cessation of growth. The timing of the peak velocity in growth differs between males and females (Lawrence, 1980). Tanner et al., (1976) noted that in humans, boys reached their peak height velocity approximately 2 yr later than girls, thus, they had more time to grow prior to the pubertal growth phase. Boys grew an average of 28 cm in height between the beginning and the end of the pubertal growth spurt. However, girls increased their height during this period by 25 cm. Thus, 80% of the difference in height between mature males and females was attributed to the delayed onset of puberty in males, while 20% was accounted for by a greater magnitude of increase.

Tanner (1962) found no evidence of a peak growth spurt in animals, comparable with the peak height spurt of man. However, the time-frame for studying such changes in animals, is less than that in people, thus, the changes are probably less noticable.

Puberty in colts and fillies occurs between 11 and 15 mo-of-age (Evans, 1981). However, complete closure of the epiphyses of long bones in horses is not complete until 36 mo-of-age (table 9). Additionally, sex differences in height were not observed at any age in this study. It is suggested that differences would have been detected had measurements been obtained later than July in the yearling year. Moreover, the age at puberty, quoted by Evans (1981), is probably the age when puberty begins rather than the age of complete sexual maturation in horses.

Short (1980) wrote that any somatic characteristics by which males and females differ, are determined by sex hormones rather than sex-chromosomes. The sex specific chromosome or the Y chromosome codes for the presence of the male gonad. The majority of sexual dimorphisms in mammals are a result of testicular androgen secretion, and a minority, the result of ovarian estrogen secretion. Estrogens are involved in stimulating bone growth during childhood and initiating the peak height spurt in humans.

The stimulation of long bone growth by estrogen was demonstrated by Rosenfield and Fang (1974). They treated a group of Turner's syndrome girls with monthly injections of

1 to 2 mg estradiol cyclopentyl propianate in oil for 12 to 17 mo. During the treatment period, they observed significant increases in linear bone growth and maturation as well as some degree of epiphyseal fusion.

Many factors are related to the asynchronous occurance of puberty in males and females. The ovaries of girls started to secrete significantly more estrogen than the testes of boys at 9 to 10 yr-of-age. The rising estrogen secretion initially stimulated long bone growth, followed by epiphyseal fusion and a cessation of growth (Brown et al., 1978). On the other hand, the first pubertal event in boys was the enlargement of the testes and scrotum (Short, 1980). Testes enlargement preceeded any significant increase in peripheral blood testosterone levels, thus, the rapid increase in height that occurs during puberty was delayed (Winter and Faiman, 1972). Cessation of bone growth occurred when blood testosterone concentrations were equivalent to those in adult men. Short (1980) concluded that cessation of long bone growth at puberty occurred earlier in females than in males because bone is more sensitive to the stimulatory and inhibitory actions of estrogen than of testosterone. Fletcher and Short (1974) reported that 1 ug of estradiol was as effective as 1 mg of testosterone in producing changes in the antlers of red deer.

The effect of mare age on the size of 1982 foals.

The effect of mare age on foal growth was investigated primarily because of previous inconclusive reports that examined the effect (Jordao and DeCamargo, 1950; Hintz et al., 1978; McKeever et al., 1981). Body measurements, adjusted to constant ages, were analyzed in order to determine if there were specific ages when mare age had more of an influence on size than at other ages. There were no significant interactions between month of birth and mare age for any of the measurements. Differences in body length due to mare age were observed from 30 to 270 d-of-age ($P < .01$ to .07; table 27). Mare age contributed variation to the measurements of wither height ($P < .08$), heart girth ($P < .06$) and body weight ($P < .05$) at 90 d-of-age. In all cases where there were significant differences due to mare age, mares older than 11 yr had the largest foals. Their foals were 2.4 to 3.8 cm longer than foals of mares 4 to 7 yr old and were 1.4 to 2.6 cm longer than foals of mares 8 to 11 yr-of-age. The oldest mares had foals that were 2.8 $\pm$.70 cm taller, 3.6 $\pm$.90 cm larger around the heart girth and that weighed 11.8 $\pm$ 3.1 kg more than the foals of the youngest mares. Additionally, they were .3 cm taller at the withers, possessed 1.5 cm more heart girth and 6.1 kg more weight than foals from 8 to 11 yr-old mares.

TABLE 27. THE EFFECT OF MARE AGE ON THE BODY MEASUREMENTS OF 1982 FOALS AT VARIOUS CONSTANT AGES[1].

| Body measurement | Age(days) | Probability[2] (P <) | Age(years) of mares 12-25 | 8-11 | 4-7 | SE[3] |
|---|---|---|---|---|---|---|
| Body length (cm) | 30 | .05 | 87.1 | 85.1 | 84.1 | 1.00 |
| | 90 | .01 | 108.3 | 105.7 | 104.5 | .90 |
| | 150 | .01 | 121.3 | 119.2 | 117.9 | .77 |
| | 210 | .03 | 129.3 | 127.9 | 126.5 | .63 |
| | 270 | .07 | 135.3 | 133.9 | 132.9 | .67 |
| Wither height (cm) | 90 | .08 | 122.7 | 122.4 | 119.9 | .70 |
| Heart girth (cm) | 90 | .06 | 123.3 | 121.8 | 119.7 | .90 |
| Body weight (kg) | 90 | .05 | 168.3 | 162.2 | 156.5 | 3.10 |

[1] Least squares means of body measurements were included only when the probability associated with the F-test for the main effect of mare age was ≤ .10.

[2] Probability associated with the F-test for the main effect of mare age

[3] Standard error of the means averaged across mare age groups.

The current observations were not in agreement with those of Hintz et al., (1979). They reported that mares which were 7 to 11 yr-of-age had the largest foals from birth to 510 d-of-age. They had more height at the withers, cannon bone circumference and body weight when compared to other foals at constant ages.

Differences up to 150 d-of-age could have been due partially to natural milking ability of the mares or the maternal influence on the growth of foals. However, it is unlikely that the older mares consistantly produced the highest quality and(or) greatest quantity of milk. Gibbs et al., (1979) noted that mares that had nursed either 2, 5 or 6 previous foals had greater mean daily milk yeilds than mares that had 0, 1 or 7 previous lactations. A correlation between milk production and foal size was not reported. Parity was not accounted for in this study. However, it could have influenced the size of the foals. Another explanation could be that older mares may have produced foals with a genetic potential to be larger than their contemporaries. In other words, the older mares may have been a select group of mares that possessed that abiity to produce larger foals than the younger mares. However, the distribution of large and small mares was fairly even across all ages of mares. Thus, if they possessed the genetic ability, it was not expressed in their phenotype. Furthermore, significant differences in foal size were not observed often enough to rely on this explanation.

<u>Comparisons of body measurements obtained in January and July of the yearling year in 1982 foals, born during different months.</u>

Hintz et al., (1978) stated that foals born in April, May and June were taller, heavier and had greater cannon bone circumferences than foals born in January, February or March when compared at common ages from birth to 510 d-of-age. Furthermore, when foals were compared at two common dates, the greater size of early-born foals, due to age, decreased over time. Foals in the current study, born late in the spring, were larger at birth and exhibited a more rapid initial growth rate than did early-born foals. However, the differences in size between foals, due to month of birth, did not persist to 400 d-of-age. Therefore, measurements of foals born at various times were compared at two common dates. The third week in January and July of the yearling year were chosen as they were the two most divergent dates at which actual measurements (vs values adjusted to a common date) were obtained on each of the foals. July also marked the end of the data collection period. Subsequent to that date, most of the yearlings were sold.

There were significant differences in all body measurements obtained in January due to month of birth ($P < .01$; table 28). Foals born in January-February were consistantly larger than foals born in April, May and June ($P < .05$). Differences between foals born in January-February vs those born in March were significant for body length (2.8 cm), cannon bone circumference (.4 cm) and body weight (19.3 kg). Foals born in April had larger measurements of heart girth (3.0 cm), body length (2.8 cm) and body weight (17.0 kg) than did foals born in May-June. Although specific differences between measures due to month of birth were observed, there was a tendency for foals born in January, February and March to be similar in size and for foals born in April, May and June to have the same proportions.

In July of the yearling year, there were no differences in the length from knee to ground ($P < .12$) or cannon bone circumference ($P < .19$) due to month of birth. The length from knee to ground was 96 to 100% of mature size by 12 mo-of-age (Cunningham and Fowler, 1961; Reed and Dunn, 1977; table 6). Therefore, differences were not expected in this measurement in July. Likewise, foals had 91 to 94% of their mature cannon bone circumference at 12 mo-of-age (Cunningham and Fowler, 1961). Due to the maturity of the horses and

TABLE 28. LEAST SQUARES MEANS OF THE CONFORMATIONAL COMPONENTS OF 1982 FOALS, CALCULATED FROM MEASUREMENTS OBTAINED IN JANUARY AND JULY OF THEIR YEARLING YEAR.

| | | | Month of birth | | | | | |
|---|---|---|---|---|---|---|---|---|
| Body measurement | Date | Probability[1] (P <) | January February | March | April | May June | SE[2] | Tukey's critical values[3] |
| Heart girth (cm) | Jan | .01 | $163.4^{a}$ | $160.4^{b}$ | $155.4^{c}$ | $152.4^{d}$ | .80 | 2.7 |
| | July | .01 | $175.5^{a}$ | $174.4^{a}$ | $170.8^{b}$ | $168.9^{b}$ | 1.00 | 3.2 |
| Chest width (cm) | Jan | .01 | $38.6^{a}$ | $38.2^{a}$ | $36.8^{b}$ | $36.8^{b}$ | .30 | .97 |
| | July | .07 | $41.4^{a}$ | $41.5^{a}$ | $40.8^{a}$ | $40.5^{a}$ | .35 | 1.1 |
| Wither height (cm) | Jan | .01 | $145.9^{a}$ | $144.0^{a}$ | $140.7^{b}$ | $139.0^{b}$ | .75 | 2.5 |
| | July | .01 | $153.8^{a}$ | $152.7^{ab}$ | $150.1^{bc}$ | $149.3^{c}$ | .90 | 3.0 |
| Hip height (cm) | Jan | .01 | $149.9^{a}$ | $148.6^{a}$ | $145.0^{b}$ | $143.3^{b}$ | .78 | 2.5 |
| | July | .01 | $157.0^{a}$ | $156.3^{ab}$ | $153.6^{bc}$ | $152.5^{c}$ | .90 | 2.9 |
| Body length (cm) | Jan | .01 | $140.7^{a}$ | $137.9^{b}$ | $134.6^{c}$ | $131.8^{d}$ | .80 | 2.7 |
| | July | .01 | $150.9^{a}$ | $151.1^{a}$ | $147.3^{b}$ | $146.3^{b}$ | .93 | 3.1 |
| Knee to ground (cm) | Jan | .01 | $40.0^{a}$ | $39.7^{a}$ | $39.1^{b}$ | $38.8^{b}$ | .25 | .91 |
| | July | .12 | 41.3 | 41.0 | 40.6 | 40.5 | .28 | |
| Cannon bone circumference (cm) | Jan | .01 | $19.0^{a}$ | $18.6^{b}$ | $18.2^{c}$ | $18.1^{c}$ | .10 | .38 |
| | July | .19 | 19.9 | 19.9 | 19.6 | 19.6 | .15 | |
| Body weight (kg) | Jan | .01 | $363.9^{a}$ | $344.6^{b}$ | $314.3^{c}$ | $297.3^{d}$ | 4.70 | 15.7 |
| | July | .01 | $449.4^{a}$ | $440.4^{a}$ | $413.1^{b}$ | $400.9^{b}$ | 7.10 | 23.4 |
| Number of Horses | Jan | | 23 | 25 | 46 | 36 | | |
| | July | | 22 | 19 | 38 | 31 | | |

[1]Probability associated with the F-test for the main effect of month of birth.

[2]Standard error of the means averaged across birth months.

[3]Tukey's pairwise comparisons conducted when probability associated with the F-test for the main effect of month $\leq$ .10; means in the same row that differ by more than Tukey's critical value and with different superscripts are significantly different at $\alpha$ =.05

the small magnitude of cannon bone circumference combined with the variability of the measure in July (SE= .15 cm), the lack of differences was understandable.

The probability that differences in chest width of foals in July was due to the month of birth was .07. The chest width of horses is not at a mature size at 18 mo-of-age (table 6), thus differences due to age or birth month were expected for this measure. However, during the pre-sale conditioning period, the increased subcutaneous adipose tissue made it difficult to locate points of the shoulders. Thus, there may have been inavoidable discrepancies between points of measure.

The measurements of heart girth, wither height, hip height, body weight and body length of foals in July of their yearling year were different due to month of birth ($P < .01$). However, significant pairwise comparisons were identified less often than in January. Additionally, the actual differences in July were smaller in magnitude than in January. Therefore, foals born in the late spring exhibited greater gains throughout the first seven mo of their yearling year when compared to foals born in the early spring. The younger foals were growing more rapidly than were the older foals during this period. Maximum size and age at the maximum values were calculated with coefficents of the regression equations. However, they were not reported as all maximums coincided with ages and measurements obtained in July. Thus, all horses were still growing in July.

Nalbandov (1963) theorized that growth rate was dependant upon the ratio of growth hormone to unit of body weight. More recently, Trenkle and Topel (1978) determined that the level of growth hormone in steers was positively correlated to carcass muscle and negatively correlated to carcass adipose tissue. The younger, smaller cattle had more growth hormone per unit of body weight. As cattle became larger, there was relatively less hormone per unit of body tissue. They also reported that the metabolic clearance rate and secretion rate of growth hormone declined as body weight increased. Thus, the smaller or younger animals in the current study may have been more sensitive to the facilitative hormonal influence on growth during this period than were the larger, older horses. Additionally, more hormone may have been available per unit body mass to stimulate more rapid growth.

Differences in size of 1982 colts and fillies in January and July of their yearling year.

Differences in size of colts and fillies in January and July were studied when the probability for the main effect of sex approached significance ($P \leq .1$; table 29). There were no sex x month interactions, thus, differences in size of colts and fillies across birth months were compared. In all cases where differences were detected, colts were larger than fillies. In January, differences in cannon bone circumference and body weight were .35 cm and 16.42 kg, respectively. In July, colts were 3.5 cm longer than fillies, .85 cm wider through the chest, had .53 cm more cannon bone circumference and weighed 18.78 kg more than fillies. The lack of many differences in January can be related to results reported in table 26; differences in cannon bone circumference, due to sex, were first noted at 150 d-of-age ($P < .02$). Differences in body weight, chest width and body length, due to sex, were first seen at 210 d-of-age.

The resemblance in wither heights of parents and their 1982 offspring.

Regression coefficients relating the wither heights of parents to the height of their 1982 offspring were determined (table 30). The figures for offspring-dam and offspring-sire resemblances estimate 1/2 heritability while the offspring-midparent regression represents an estimation of heritability. True heritability is obtained only when the traits of the parents and progeny are measured at common

TABLE 29. LEAST SQUARES MEANS OF THE CONFORMATIONAL COMPONENTS OF 1982 COLTS AND FILLIES, CALCULATED FROM MEASUREMENTS OBTAINED IN JANUARY AND JULY OF THEIR YEARLING YEAR.[1]

| Body measurement | | Date | Probability[2] (P <) | Least squares means | | Differences between the measures of colts - fillies | SE[3] | |
|---|---|---|---|---|---|---|---|---|
| | | | | Colts | Fillies | | Colts | Fillies |
| Cannon bone circumference | (cm) | Jan | .04 | 18.65 | 18.30 | .35 | .08 | .08 |
| Body weight | (kg) | Jan | .07 | 338.15 | 321.73 | 16.42 | 3.46 | 3.13 |
| Body length | (cm) | July | .01 | 150.63 | 147.13 | 3.5 | .71 | .59 |
| Chest width | (cm) | July | .01 | 41.5 | 40.65 | .85 | .24 | .20 |
| Cannon bone circumference | (cm) | July | .01 | 20.03 | 19.5 | .53 | .11 | .10 |
| Body weight | (kg) | July | .04 | 435.33 | 416.55 | 18.78 | 5.39 | 4.48 |

[1]Table includes differences between colts and fillies when the probability associated with the F-test for the main effect of sex $\leq .10$.

[2]Probability associated with the F-test for the main effect of sex

[3]Standard error of the means averaged across birth months.

TABLE 30. THE REGRESSION COEFFICIENTS DESCRIBING THE RESEMBLANCE BETWEEN THE WITHER HEIGHTS OF PARENTS AND THEIR OFFSPRING; CALCULATED FROM SINGLE MEASUREMENTS OF THE PARENTS HEIGHT AND FROM LEAST SQUARES MEANS OF THE OFFSPRINGS HEIGHT AT VARIOUS CONSTANT AGES AND IN JULY OF THEIR YEARLING YEAR.

| Year of birth | Age (day) or date | Regression coefficients of: offspring-dam | offspring-sire | offspring-midparent |
|---|---|---|---|---|
| 1982 | 30 | $.30 \pm .11^*$ | $.19 \pm .12$ | $.50 \pm .18^*$ |
| | 90 | $.16 \pm .10^*$ | $.29 \pm .11^*$ | $.44 \pm .15^*$ |
| | 210 | $.28 \pm .08^*$ | $.34 \pm .10^*$ | $.62 \pm .13^*$ |
| | 400 | $.37 \pm .09^*$ | $.42 \pm .10^*$ | $.78 \pm .14^*$ |
| | July | --- | --- | $.84 \pm .15^*$ |
| 1981 | 350 | $.21 \pm .10^*$ | $.43 \pm .11^*$ | $.61 \pm .15^*$ |
| | 400 | $.22 \pm .09^*$ | $.33 \pm .10^*$ | $.53 \pm .13^*$ |
| | July | --- | --- | $.46 \pm .15^*$ |
| Significance of farm effects on parent height in 1982 | | .20 | .01 | .01 |
| Significance of farm effects on parent height in 1981 | | .49 | .01 | .01 |

$^*p \leq .10$

ages. Otherwise, as in this case, the regression coefficients equal h(1)h(2)r(1,2) where r(1,2) is the genetic correlation between height at maturity and height at the age of the progeny when measured and h(1) and h(2) are the square root of heritability at each age. Most of the current estimates agree with previously reported values (table 10). However, the wide range of heritability estimates for wither height precludes comparisons to the current estimates. The resemblance between parents and offspring increased with age as noted previously (Varo, 1965; Kownacki et al., 1971; Hintz et al., 1979). As age of the foals increased, the proportion of the offspring-dam resemblance which contributed to the offspring-midparent correlation coefficient decreased. Maternal influence or the environment provided by the dam pre-weaning was reduced over time. The highest coefficient of regression between offspring and parents was observed in July of the yearling year (r=.84). The model used to obtain this coefficient included the effect of age of the offspring in July. The mean age of yearlings in July was 480 d. Phenotype is the combination of genetic and environmental influences. Although environment was not quantified, it was mentioned previously that management practices on the farms, used for the current study, were well above average. Perhaps the environment was favorable enough that the phenotypic expression of wither height approached the maximum genetic potential for wither height.

Foals born in 1981

As stated in the experimental procedure, measurements were obtained on the 1981 foals during their yearling year only. Horses were measured between 244 to 557 d-of-age. Due to the limitations of the data, interpretations were less complete than those of the data on 1982 foals. However, similar analyses were conducted, thus, subjective comparisons between the two data sets were made when possible.

Growth curves of body measurements of 1981 foals

The initial measurements, obtained in February, of heart girth, hip height, body length, body weight and chest width, were significantly different among farms (table 31). The farm effect for the initial wither height measure approached significance ($P < .13$). Sex, month and all two way interactions of farm, sex and birth month did not influence initial body measures. The linear portion (age effect) of the growth curve was significant for all measures ($P < .05$) except the distance from knee to ground. The linear growth of chest width and cannon circumference were

TABLE 31. THE PROBABILITIES ASSOCIATED WITH THE F-TESTS OF THE SOURCES OF VARIATION IN THE ANALYSIS OF VARIANCE OF EACH SET OF SERIAL BODY MEASUREMENTS OF 1981 FOALS[1]

| Source of variation | Body measurement | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Heart girth | Wither height | Hip height | Body length | Body weight | Knee to ground | Cannon bone circumference | Chest width |
| Farm | .01 | .13 | .05 | .01 | .01 | .53 | .31 | .01 |
| Sex | .57 | .45 | .75 | .97 | .76 | .33 | .86 | .55 |
| Month (of birth) | .86 | .96 | .90 | .50 | .81 | .94 | .97 | .92 |
| Farm x Sex | .50 | .77 | .86 | .57 | .26 | .97 | .17 | .70 |
| Farm x Month | .65 | .93 | .90 | .66 | .99 | .94 | .26 | .92 |
| Sex x Month | .53 | .54 | .77 | .94 | .27 | .70 | .99 | .79 |
| Horse | .01 | .01 | .01 | .01 | .01 | .01 | .01 | .01 |
| Age | .01 | .01 | .01 | .01 | .05 | .21 | .01 | .01 |
| Age x Sex | .48 | .52 | .19 | .49 | .61 | .84 | .01 | .04 |
| Age x Month | .04 | .39 | .05 | .01 | .45 | .61 | .84 | .91 |
| Age x Age | .01 | .01 | .01 | .78 | .01 | .27 | .01 | .01 |
| Age x Age x Sex | .58 | .60 | .13 | .49 | .36 | .71 | .01 | .05 |
| Age x Age x Month | .07 | .29 | .03 | .01 | .54 | .44 | .46 | .56 |
| r-square | .96 | .95 | .96 | .95 | .85 | .78 | .92 | .79 |
| coefficient of variation (%) | 1.2 | .9 | .7 | 1.3 | 7.5 | 2.0 | 1.4 | 3.0 |
| Repeatability between paired measurements (%) | 98.78 | 92.47 | 92.71 | 93.52 | - | 78.57 | 94.65 | 81.80 |

[1]The analysis follows the model depicted in Appendix table 5

different between sexes (P< .04 and P< .01, respectively). There were also interactions of month and age for heart girth (P< .04), hip height (P< .05) and body length (P <.01). Most of the growth curves were curvilinear. However, the probability associated with the F-test for a quadratic body length curve was .78 and for the distance from knee to ground was .27. Intermittent interactions of sex or month with age x age were observed.

Coefficients of the regression equations were calculated (table 32) and used to depict the growth curves of body measures of foals by month of birth (figures 9 to 16). The figures and equations represent a small portion of the equine growth curve. Asymtotic growth curves are characterized by an initial rapid period of growth that is followed by an increasingly slower rate of growth. The curves, although they were curvilinear, did not reflect the nature of the growth in body parts of 1982 foals. The intercepts corresponded to the initial measurements, obtained in February of the yearling year, thus the ages of the horses at the intercepts varied. Therefore, comparisons and conclusions at the intercept, about horses born during different months, were not obvious.

TABLE 32. REGRESSION EQUATIONS WITH LINEAR AND QUADRATIC COMPONENTS OF SERIAL BODY MEASUREMENTS ON AGE THAT WERE USED TO PLOT GROWTH CURVES OF 1981 FOALS BORN IN THE DIFFERENT MONTHS.

| | | Components of the regression equations | | |
|---|---|---|---|---|
| Body measurement' | Month of birth | Intercept | Linear ( x age) | Quadratic ( x age x age) |
| Heart girth | Jan-Feb | 150.39316 | + .07443467 | + .00004944 |
| | March | 153.24263 | + .02194593 | + .00023962 |
| | April | 148.35093 | + .09535981 | + .00005995 |
| | May-June | 148.35215 | + .0775629 | + .00017538 |
| Wither height | Jan-Feb | 133.71946 | + .11532993 | - .00017408 |
| | March | 137.06284 | + .08717627 | - .00010682 |
| | April | 138.30326 | + .07981925 | - .00008726 |
| | May-June | 138.23795 | + .09192673 | - .00016354 |
| Hip height | Jan-Feb | 136.76006 | + .11948321 | - .00019164 |
| | March | 142.9409 | + .06452835 | - .00005369 |
| | April | 141.13628 | + .089572 | - .00011903 |
| | May-June | 142.21412 | + .08900801 | - .00016369 |
| Body length | Jan-Feb | 128.71731 | + .08754477 | - .00003795 |
| | March | 132.40651 | + .05845915 | + .00005646 |
| | April | 126.78675 | + .12451582 | - .00013787 |
| | May-June | 131.15006 | + .05354138 | + .00015232 |
| Body weight | Jan-Feb | 323.53925 | + .20070599 | + .00070586 |
| | March | 302.61971 | + .03754329 | + .00197021 |
| | April | 271.22803 | + .56434726 | + .00060397 |
| | May-June | 276.19847 | + .36300464 | + .00162092 |
| Knee to ground | Jan-Feb | 37.408433 | + .00345766 | + .00001255 |
| | March | 37.2752971 | + .01336111 | - .0000147 |
| | April | 38.136944 | + .00035561 | + .00003353 |
| | May-June | 38.374944 | + .00376877 | + .00002258 |
| Cannon bone circumference | Jan-Feb | 17.166137 | + .0190976 | - .00003242 |
| | March | 17.469577 | + .01902218 | - .00003958 |
| | April | 17.505339 | + .0218028 | - .00004885 |
| | May-June | 17.76509 | + .0204213 | - .00005012 |
| Chest width | Jan-Feb | 32.388238 | + .05033588 | - .0000813 |
| | March | 32.903879 | + .05254909 | - .00010486 |
| | April | 33.246123 | + .06057556 | - .00014049 |
| | May-June | 33.936632 | + .0561891 | - .00014568 |

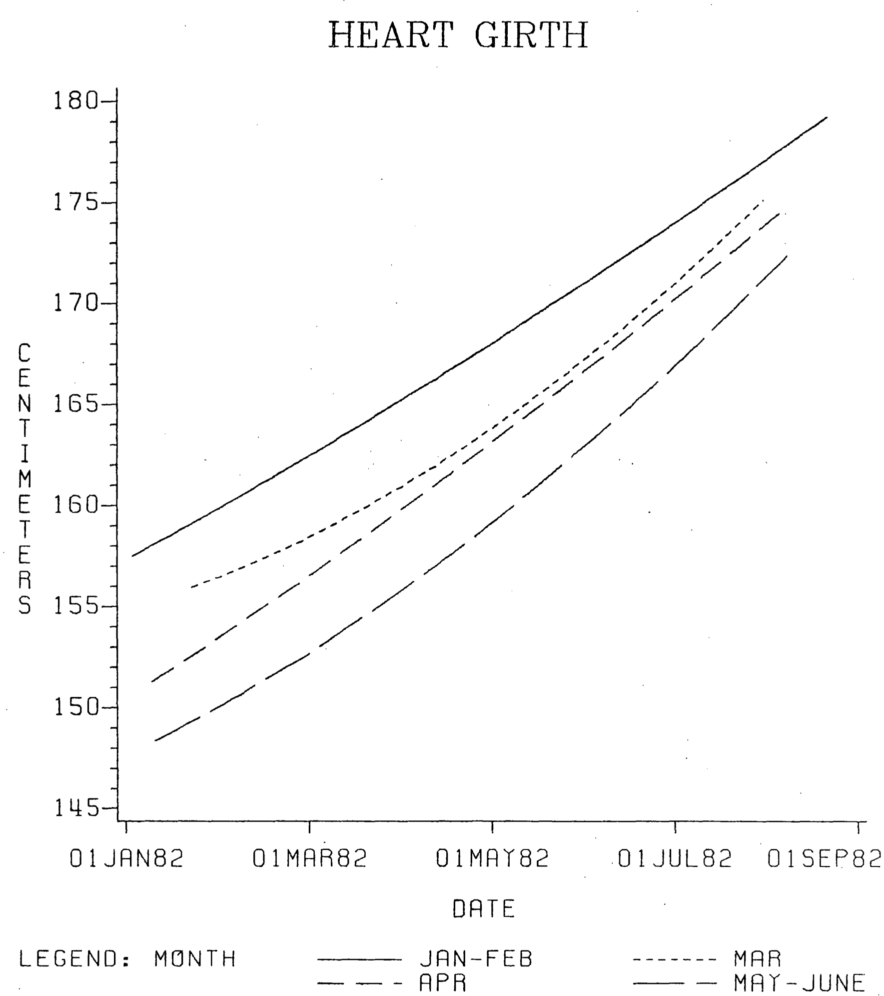


FIGURE 9. GROWTH CURVES DEPICTING THE PATTERNS OF HEART GIRTH GROWTH OF 1981 FOALS BORN IN THE VARIOUS MONTHS.

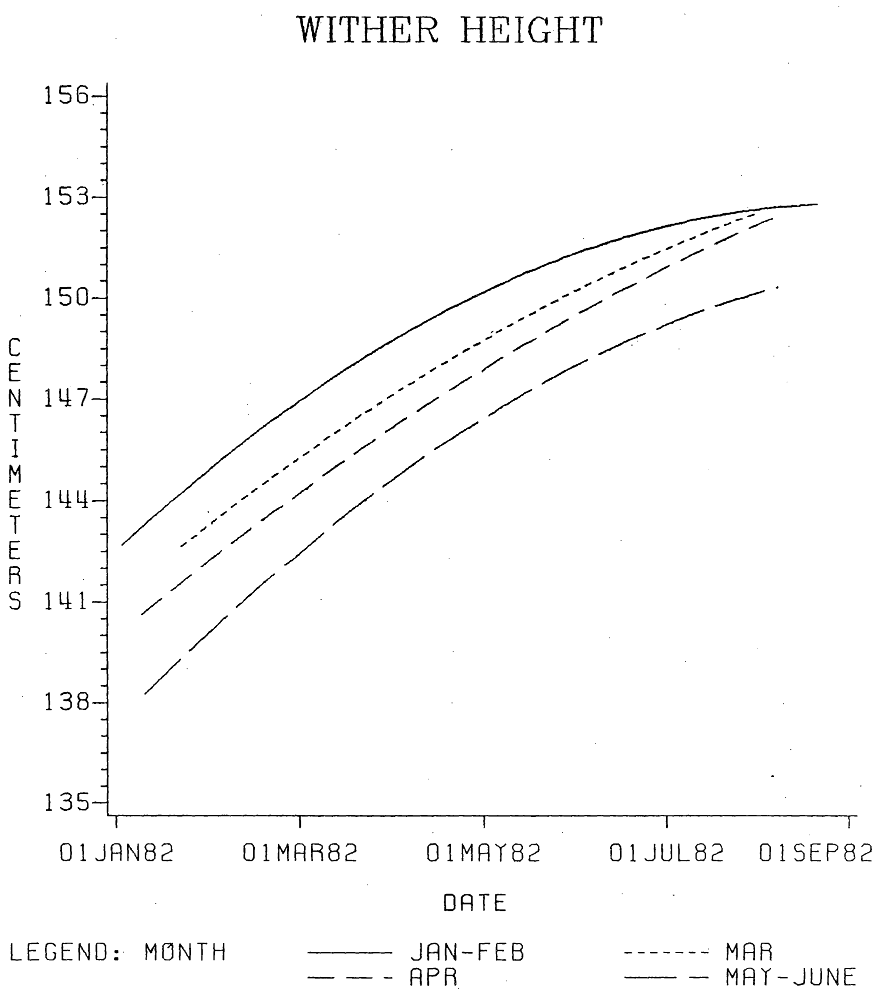


FIGURE 10. GROWTH CURVES DEPICTING THE PATTERNS OF WITHER HEIGHT CROWTH OF 1981 FOALS BORN IN THE VARIOUS MONTHS.

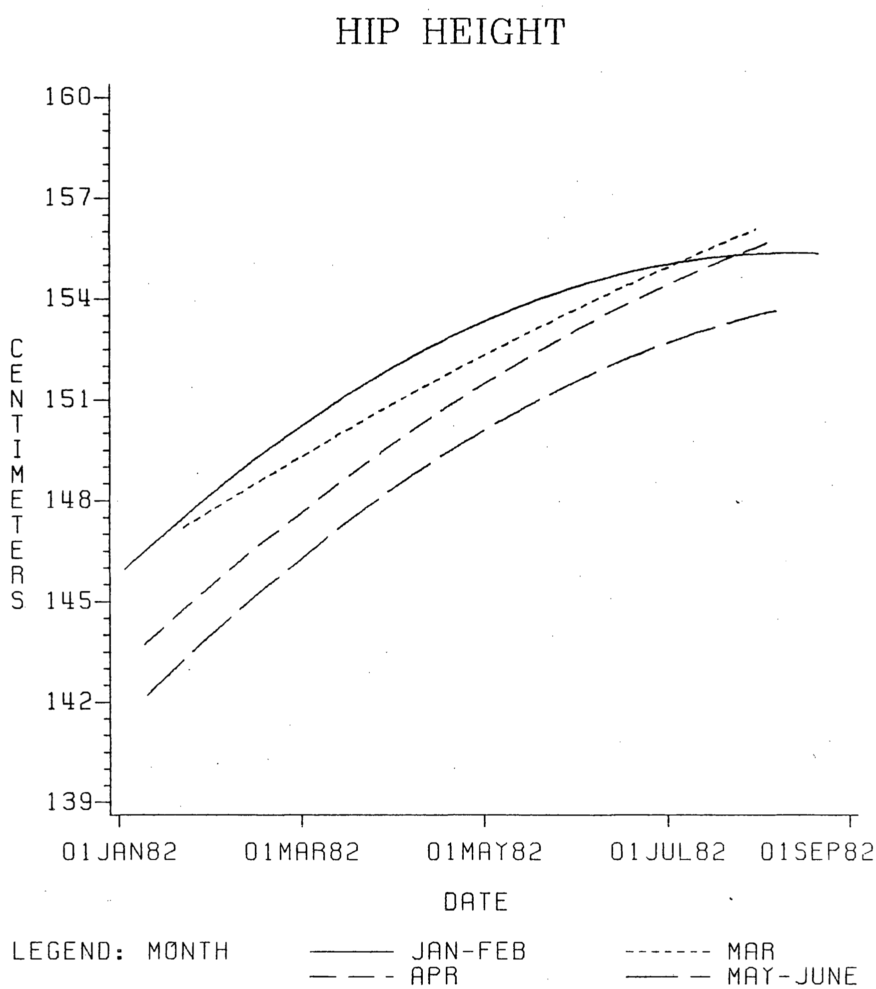


FIGURE 11. GROWTH CURVES DEPICTING THE PATTERNS OF HIP HEIGHT GROWTH OF 1981 FOALS BORN IN THE VARIOUS MONTHS.

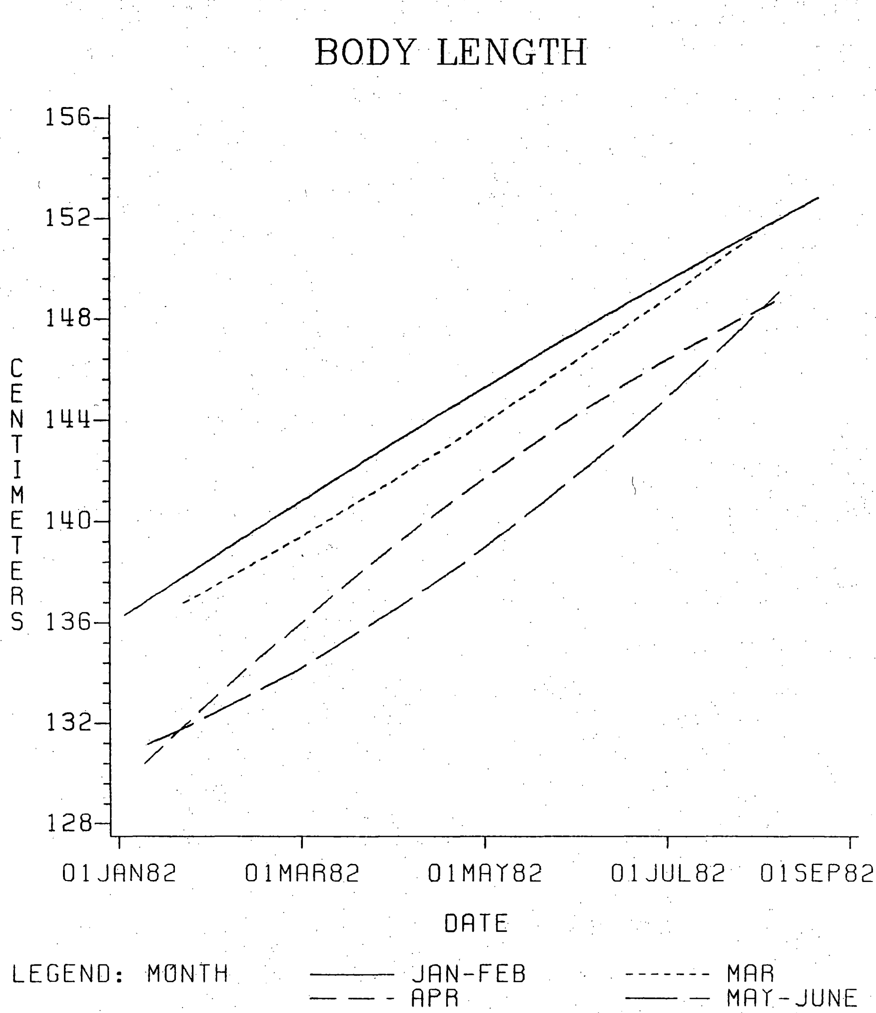


FIGURE 12. GROWTH CURVES DEPICTING THE PATTERNS OF BODY LENGTH GROWTH OF 1981 FOALS BORN IN THE VARIOUS MONTHS.

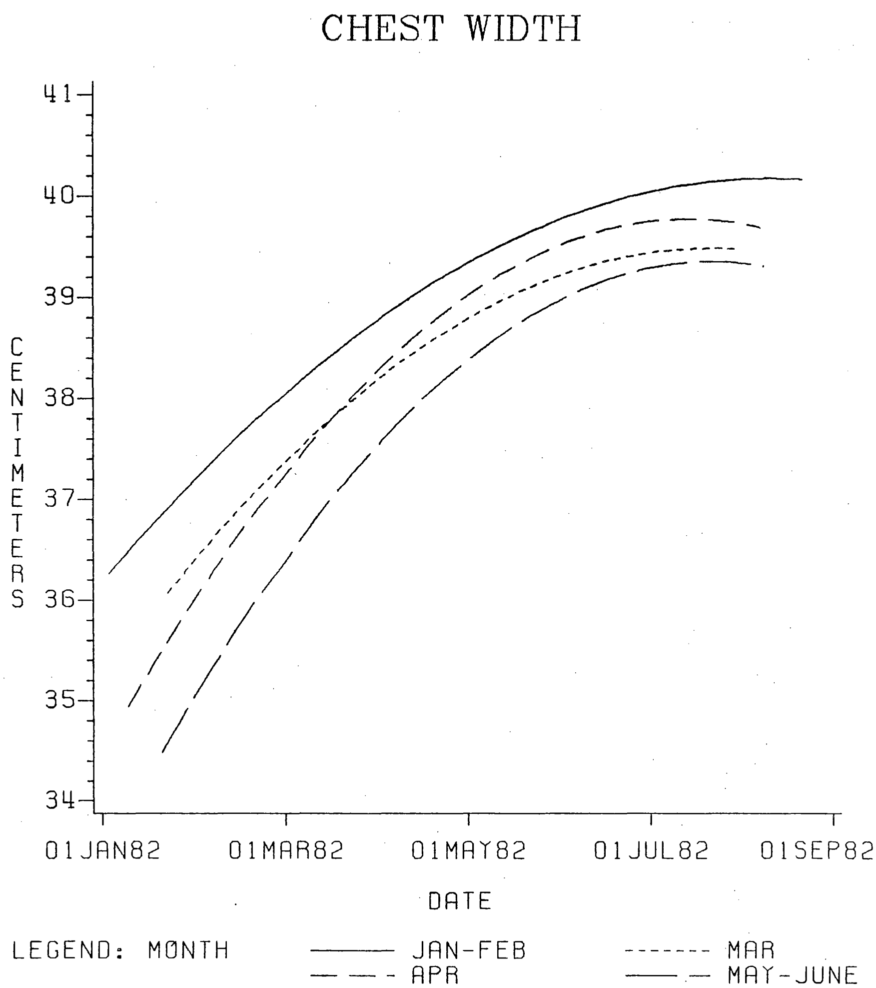


FIGURE 13. GROWTH CURVES DEPICTING THE PATTERNS OF CHEST WIDTH GROWTH OF 1981 FOALS BORN IN THE VARIOUS MONTHS.

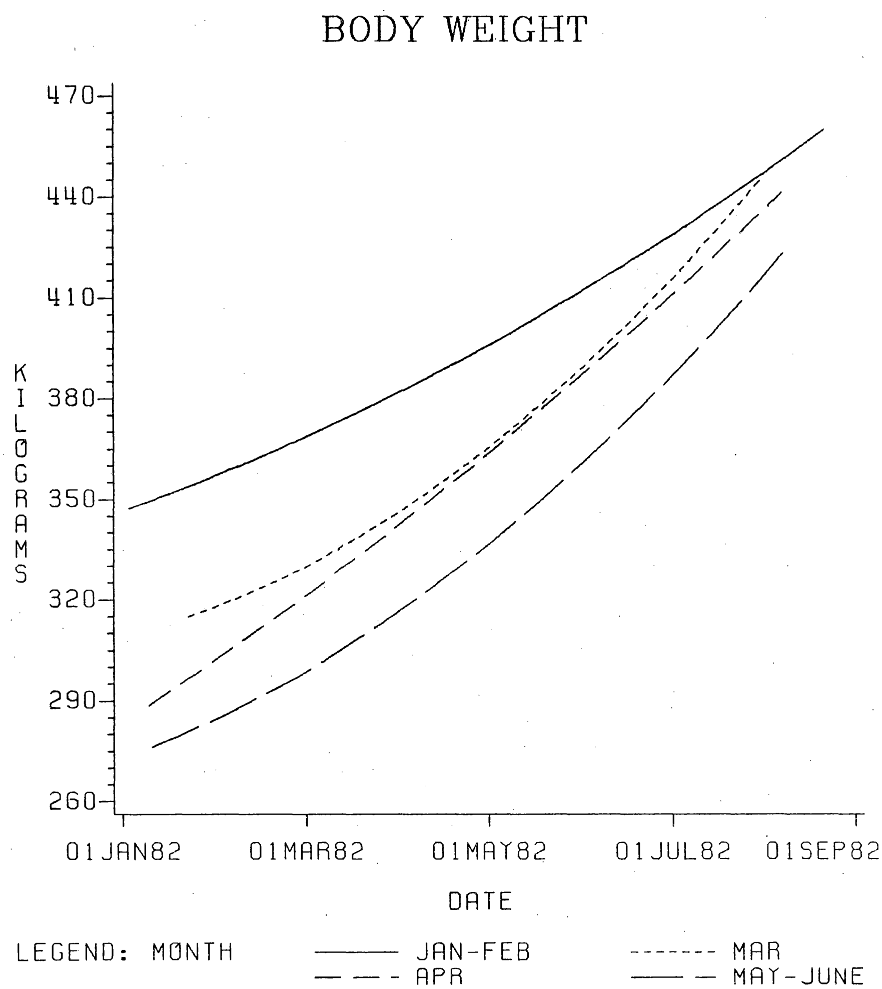


FIGURE 14. GROWTH CURVES DEPICTING THE PATTERNS OF BODY WEIGHT GROWTH OF 1981 FOALS BORN IN THE VARIOUS MONTHS.

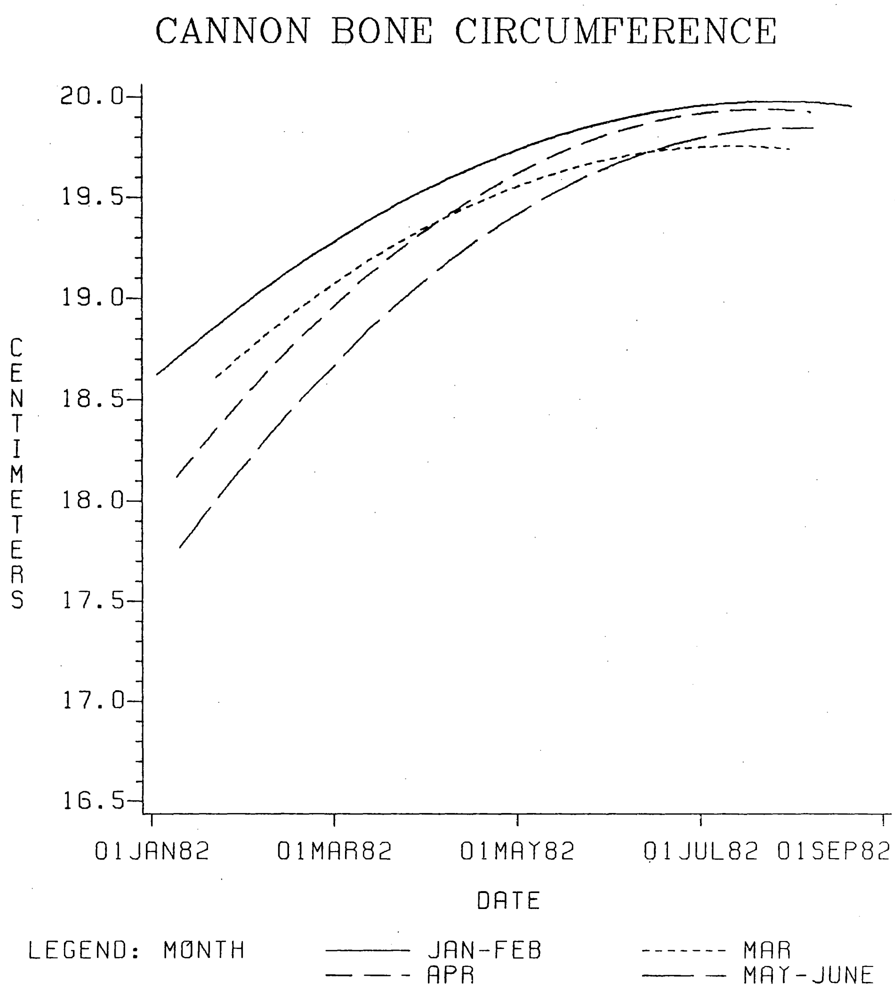


FIGURE 15. GROWTH CURVES DEPICTING THE PATTERNS OF CANNON BONE CIRCUMFERENCE GROWTH OF 1981 FOALS BORN IN THE VARIOUS MONTHS.

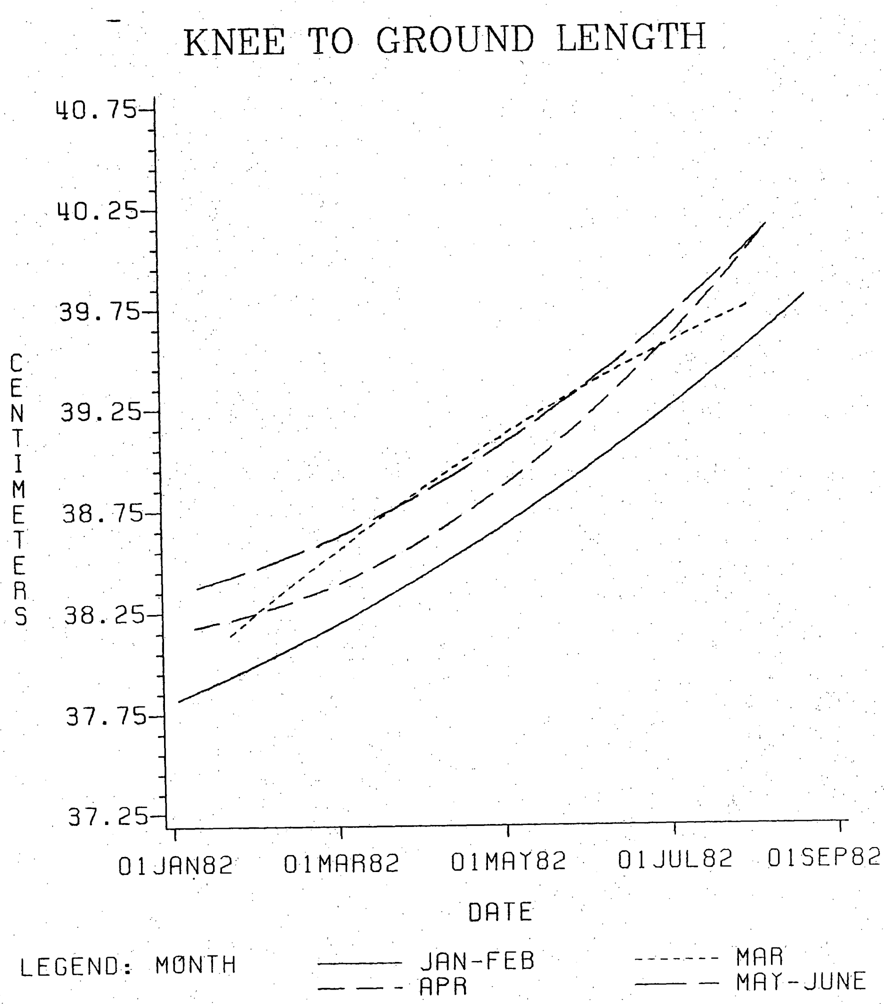


FIGURE 16. GROWTH CURVES DEPICTING THE PATTERNS OF KNEE TO GROUND GROWTH OF 1981 FOALS BORN IN THE VARIOUS MONTHS.

<u>Comparisons of body measures made at specific ages in 1981 foals born during different months.</u>

Body size of all foals was calculated at 350 or 400 d-of-age by linear interpolation. Means, standard deviations and coefficients of variation for each measurement across month of birth were determined (table 33). It was difficult to note any changing trends over time in the values obtained for standard deviations or coefficients of variation as there were only two ages investigated. However, the values at 400 d-of-age in tables 33 and 14 were compared. Foals born in 1981 and 1982 were similar in size at 400 d-of-age. Furthermore, the standard deviations and coefficients of variation for each measure at 400 d-of-age were similar in the two sets of data.

The effects of month of birth on the least squares means of body measurements of foals at 350 or 400 d-of-age were examined (table 34). There were few differences in measures due to month of birth. Month affected the measure of chest width at 350 d-of-age ($P < .06$) and the measure of heart girth ($P < .01$), the distance from knee to ground ($P < .03$) and cannon bone circumference ($P < .01$) at 400 d-of-age. The heart girth of foals born in April, May and June was 3.3 cm larger ($P < .05$) than that of foals born in January, February and March. Although the probability associated

TABLE 33. LEAST SQUARES MEANS, STANDARD DEVIATIONS (S.D.) AND COEFFICIENTS OF VARIATION (C.V.) OF THE BODY MEASUREMENTS OF 1981 FOALS THAT WERE CALCULATED AT 350 OR 400 DAYS-OF-AGE.

| | | Body measurement | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Age (days) | Calculated values | Heart girth (cm) | Chest width (cm) | Wither height (cm) | Hip height (cm) | Body length (cm) | Knee to ground (cm) | Cannon bone circumference (cm) | Body weight (kg) |
| 350 | mean | 159.1 | 37.9 | 145.8 | 149.5 | 139.4 | 38.7 | 19.2 | 336.1 |
| | S.D. | 3.7 | 1.5 | 3.4 | 3.5 | 4.0 | 1.2 | .6 | 22.9 |
| | C.V. (%) | 2.3 | 3.8 | 2.3 | 2.3 | 2.8 | 3.0 | 3.1 | 6.8 |
| 400 | mean | 165.0 | 38,8 | 148.6 | 152.3 | 143.6 | 39.1 | 19.6 | 376.2 |
| | S.D. | 3.8 | 1.6 | 3.2 | 3.2 | 3.8 | 1.1 | .5 | 39.5 |
| | C.V. (%) | 2.3 | 4.1 | 2.2 | 2.1 | 2.6 | 2.7 | 2.7 | 10.5 |

TABLE 34. LEAST SQUARES MEANS OF THE CONFORMATIONAL COMPONENTS OF 1981 FOALS, CALCULATED FROM DATA ADJUSTED TO THE CONSTANT AGES OF 350 OR 400 DAYS-OF-AGE.

| | | | Month of birth | | | | | Duncan's critical values[3] | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Body measurement | Age (days) | Probability[1] (P <) | January February | March | April | May June | SE[2] | p=2 | p=3 | p=4 |
| Heart girth (cm) | 350 | .22 | 156.7 | 159.3 | 159.7 | 160.7 | 1.2 | | | |
| | 400 | .01 | 163.2[a] | 163.5[a] | 166.5[b] | 166.7[b] | .9 | 2.44 | 2.57 | 2.65 |
| Chest width (cm) | 350 | .06 | 37.3[a] | 37.6[a] | 38.5[a] | 38.6[a] | .5 | 1.21 | 1.27 | 1.31 |
| | 400 | .13 | 38.1 | 38.7 | 39.2 | 39.2 | .38 | | | |
| Wither height (cm) | 350 | .41 | 144.7 | 145.4 | 146.4 | 147.1 | 1.10 | | | |
| | 400 | .47 | 148.0 | 148.6 | 149.3 | 149.4 | .78 | | | |
| Hip height (cm) | 350 | .56 | 148.3 | 149.4 | 149.7 | 150.8 | 1.20 | | | |
| | 400 | .73 | 151.8 | 152.2 | 152.9 | 152.8 | .78 | | | |
| Body length (cm) | 350 | .98 | 139.3 | 139.6 | 139.8 | 140.0 | 1.30 | | | |
| | 400 | .27 | 141.7 | 143.7 | 143.8 | 145.2 | .90 | | | |
| Knee to ground (cm) | 350 | .26 | 37.7 | 38.6 | 38.6 | 39.0 | .40 | | | |
| | 400 | .03 | 38.5[a] | 39.1[a] | 39.2[ab] | 39.7[b] | .25 | .97 | 1.02 | 1.05 |
| Cannon bone circumference (cm) | 350 | .24 | 19.0 | 19.3 | 19.5 | 19.6 | .18 | | | |
| | 400 | .01 | 19.3[a] | 19.6[ab] | 19.9[b] | 19.9[b] | .13 | .32 | .34 | .35 |
| Body weight (kg) | 350 | .18 | 321.1 | 336.8 | 340.3 | 347.1 | 7.68 | | | |
| | 400 | .40 | 376.4 | 366.0 | 383.8 | 381.8 | 9.35 | | | |
| Number of Horses | 350 | | 3 | 24 | 43 | 26 | | | | |
| | 400 | | 14 | 30 | 44 | 25 | | | | |

[1]Probability associated with the F-test for the main effect of month of birth.

[2]Standard error of the means averaged across birth months.

[3]Duncan's multiple range conducted when probability $\leq .10$. Means in the same row with different superscripts were significantly different ($\alpha = .05$). To conduct test, rank means in order from smallest to largest. "p" is the number of least squares means included within the range of the comparison. To compare 2 least squares means that are adjacent within the array of means, use p=2. To compare 2 least squares means ranked 1 and 3 or 2 and 4, use p=3. To compare the smallest and largest least squares means, use p=4.

with the F-test for month to cause a difference in chest width of foals was .06, Duncan's critical values were greater than the differences between measures. Foals born in April, May and June had more length from knee to ground (.9 cm) and a larger cannon bone circumference (.6 cm) than did foals born in January-February. In general, although there were not many differences in size of foals due to month of birth at either 350 or 400 d-of-age, the average size of foals born in May-June was larger and that of foals born in January-February was smaller than their contemporaries at the two constant ages.

The average sizes of 1981 and 1982 foals at 400 d-of-age was compared (table 34 vs tables 15 to 22). In general, the 1981 foals born in January, February and March were smaller than their 1982 counterparts. Also, the 1981 foals born in April, May and June were larger than their 1982 counterparts. These differences may explain why month of birth influenced the size of 1981 foals at 400 d-of-age when it did not influence the size of 1982 foals at the same age.

<u>Correlations at 350 or 400 days-of-age between body measures in 1981 foals</u>.

The relationships between size at the specific points of measure at 350 or 400 d-of-age were examined (table 35). Because there were only two ages at which values were

TABLE 35. CORRELATIONS BETWEEN MEASUREMENTS AT 350 OR 400 DAYS-OF-AGE FOR 1981 FOALS

| | | Body measurement | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Body measurement | Age (days) | Chest width | Wither height | Hip height | Body length | Knee to ground | Cannon bone circumference | Body weight |
| Heart girth | 350 | .65 | .69 | .69 | .66 | .49 | .67 | .99 |
| | 400 | .53 | .64 | .65 | .64 | .58 | .64 | .72 |
| Chest width | 350 | | .46 | .46 | .44 | .38 | .62 | .65 |
| | 400 | | .35 | .37 | .49 | .37 | .46 | .37 |
| Wither height | 350 | | | .94 | .75 | .71 | .62 | .67 |
| | 400 | | | .93 | .66 | .81 | .60 | .39 |
| Hip height | 350 | | | | .79 | .76 | .64 | .67 |
| | 400 | | | | .71 | .79 | .63 | .36 |
| Body length | 350 | | | | | .56 | .64 | .65 |
| | 400 | | | | | .62 | .64 | .40 |
| Knee to ground | 350 | | | | | | .43 | .48 |
| | 400 | | | | | | .50 | .37 |
| Cannon bone circumference | 350 | | | | | | | .66 |
| | 400 | | | | | | | .35 |

[1] All correlations were significant at $p \leq .0001$.

obtained, it was not possible to investigate trends over time. Comparisons between the values at 400 d-of-age, presented in tables 35 (1981 foals) and 24 (1982 foals) were made. The correlation coefficients were generally the same between all points of measurement. However, it was noted that the relationships between body weight and the other specific measurements were less for 1981 foals compared to those for 1982 foals.

Differences in size of 1981 colts and fillies at 350 or 400 days-of-age.

The values of all body measurements at each constant age were grouped by sex. There were no significant month x sex interactions, therefore differences between sexes, averaged across birth months, were examined. Table 36 includes the least squares means of conformational components when the main effect of sex at a specific age was significant ($P \leq .1$). The body lengths at 350 d-of-age and the chest widths, distances from knee to ground and cannon bone circumferences at 350 and 400 d-of-age of colts were consistantly larger than the same proportions of fillies. Colts were 1.42 or .47 cm wider through the chest and exhibited .95 or .55 cm more length from knee to ground than fillies at 350 or 400 d-of-age, respectively ($P < .1$). Colts were 2.27 cm longer than fillies at 350 d-of-age and had

TABLE 36. LEAST SQUARES MEANS OF BODY MEASUREMENTS OF 1981 COLTS AND FILLIES, CALCULATED FROM DATA ADJUSTED TO 350 OR 400 DAYS-OF-AGE[1].

| Body measurement | Age (days) | Probability[2] (P <) | Least squares means | | Differences between the measures of colts - fillies | SE[3] | |
|---|---|---|---|---|---|---|---|
| | | | Colts | Fillies | | Colts | Fillies |
| Chest width (cm) | 350 | .01 | 38.7 | 37.28 | 1.42 | .45 | .33 |
| | 400 | .06 | 39.03 | 38.55 | .47 | .29 | .21 |
| Body length (cm) | 350 | .06 | 140.85 | 138.58 | 2.27 | 1.19 | .90 |
| Knee to ground (cm) | 350 | .01 | 39.05 | 38.1 | .95 | .34 | .27 |
| | 400 | .02 | 39.43 | 38.88 | .55 | .20 | .16 |
| Cannon bone circumference (cm) | 350 | .01 | 19.7 | 19.0 | .7 | .17 | .15 |
| | 400 | .01 | 19.93 | 19.4 | .53 | .11 | .07 |

[1]Table includes differences between colts and fillies when the probability associated with the F-test for the main effect of sex $\leq .10$.

[2]Probability associated with the F-test for the main effect of sex

[3]Standard error of the means averaged across birth months.

larger (.53 to .70 cm) cannon bones than fillies at 350 and 400 d-of-age.

The occurances of sex differences in size were similar for the 1981 and the 1982 foals (tables 36 and 26). Therefore, the previous discussion about differences in size, due to sex, applied to both sets of data.

The age of the dam did not significantly influence the size of 1981 foals at 350 or 400 d-of-age. This was not unexpected as mare age affected only the measurements of 1982 foals that were younger than 270 d-of-age (table 27).

Comparisons of body measures obtained in July of the yearling year in 1981 foals, born during different months.

The least squares means of body measurements of 1981 foals, obtained in July of their yearling year, were determined (table 37). Month of birth influenced the size of heart girth, body length, body weight ($P < .01$) and hip height ($P < .09$). Foals born in January-February had a larger heart girth (4.4 cm) and weighed 31.3 kg more than foals born in May-June. However, the heart girths and body weights of foals born from January to April did not differ. Specific differences between the hip heights and body lengths of foals born in different months were not identified with Tukey's critical differences ($p = .05$).

There were more significant differences due to month of

TABLE 37. LEAST SQUARES MEANS OF THE CONFORMATIONAL COMPONENTS OF 1981 FOALS, CALCULATED FROM MEASUREMENTS OBTAINED IN JULY OF THEIR YEARLING YEAR.

| Measurement | Probability[1] (P <) | Month of birth: January February | Month of birth: March | Month of birth: April | Month of birth: May June | SE[2] | Tukey's critical values[3] |
|---|---|---|---|---|---|---|---|
| Heart girth (cm) | .01 | 174.9[a] | 174.4[a] | 173.0[ab] | 170.5[b] | .9 | 2.9 |
| Chest width (cm) | .70 | 40.0 | 39.7 | 39.6 | 39.7 | .25 | .73 |
| Wither height (cm) | .13 | 152.5 | 152.6 | 151.6 | 150.8 | .8 | 2.5 |
| Hip height (cm) | .09 | 155.9[a] | 156.4[a] | 155.3[a] | 154.5[a] | .73 | 2.3 |
| Body length (cm) | .01 | 151.8[a] | 151.8[a] | 149.5[a] | 149.1[a] | .98 | 3.0 |
| Knee to ground (cm) | .66 | 39.4 | 39.8 | 39.8 | 39.9 | .25 | .86 |
| Cannon bone circumference (cm) | .53 | 19.9 | 19.8 | 20.0 | 19.9 | .13 | .42 |
| Body weight (kg) | .01 | 443.8[a] | 441.3[a] | 429.2[ab] | 412.5[b] | 7.00 | 22.2 |
| Number of Horses | | 16 | 29 | 38 | 21 | | |

[1]Probability associated with the F-test for the main effect of month of birth.

[2]Standard error of the means averaged across birth months.

[3]Tukey's pairwise comparisons conducted when probability associated with the F-test for the main effect of month ≤ .10; means in the same row that differ by more than Tukey's critical value and with different superscripts are significantly different at $\alpha$ =.05.

birth in the size of 1982 foals (table 28) vs 1981 foals in July of the yearling year. However, the average sizes of the two groups of horses were similar. The later-born 1981 foals exhibited a faster growth rate during some phase of their growth than did the early-born foals. Presumably, it was prior to the period when observations were obtained. The growth rate of 1982 foals born in April, May and June was faster from birth to 210 d-of-age than of foals born in January, February and March. Differences in size of weanlings due to month of birth decreased with age. In the Thoroughbred race horse industry, July of the yearling year is a critical date as it is the time when yearlings are sold. If size is a factor in the saleability or the price of the animal, then the foaling date should have little influence on the profit margin. It seems obvious that current breeding schedules are not necessary from the standpoint of producing larger, more desirable animals.

<u>Differences in size of 1981 colts and fillies in July of their yearling year.</u>

There were differences in the chest width ($P < .01$), the distance from knee to ground ($P < .04$), cannon bone circumference ($P < .01$) and the body weight ($P < .06$) measurements of yearlings due to sex. Colts were uniformly larger than fillies. Significant differences in chest width and cannon bone circumference ranged from .52 to .75 cm. Colts were .65 cm longer from the knee to ground and weighed 13.78 kg more than fillies (table 38). The differences between the sexes were similar to those observed in the 1982 foals in July (table 29).

<u>The resemblance in the wither height of parents and their 1981 offspring</u>

The offspring-dam coefficients of regression were .21 and .22 at 350 and 400 d-of-age, respectively (table 30). The offspring-sire coefficients at the same ages were slightly larger (.43 and .33, respectively). The coefficients of regression at 400 d-of-age were not different for the 1981 and 1982 foals. This was not unexpected because many of the dams and sires were represented in both data sets. The regression coefficient for wither height of 1981 foals in July on mid-parent wither height was .46, lower than the regression coefficient for wither height of 1982 foals. Reasons for this were not apparent.

TABLE 38. LEAST SQUARES MEANS OF THE CONFORMATIONAL COMPONENTS OF 1981 COLTS AND FILLIES, CALCULATED FROM MEASUREMENTS OBTAINED IN JULY OF THEIR YEARLING YEAR[1].

| Body measurement | Probability[2] (P <) | Least squares means | | Difference between the measures of colts - fillies | SE[3] | |
|---|---|---|---|---|---|---|
| | | Colts | Fillies | | Colts | Fillies |
| Chest width (cm) | .01 | 40.15 | 39.4 | .75 | .18 | .14 |
| Knee to ground (cm) | .04 | 40.05 | 39.4 | .65 | .22 | .16 |
| Cannon bone circumference (cm) | .01 | 20.15 | 19.63 | .52 | .11 | .09 |
| Body weight (kg) | .06 | 438.63 | 424.85 | 13.78 | 5.51 | 4.16 |

[1]Table includes differences between colts and fillies when the probability associated with the F-test for the main effect of sex $\leq$ .10.

[2]Probability associated with the F-test for the main effect of sex.

[3]Standard error of the means averaged across birth months.

## SUMMARY AND CONCLUSIONS

Thirteen Thoroughbred farms in Virginia provided a total of 260 horses for this study. Body measurements including heart girth, wither and hip height, body length, chest width, the distance from knee to ground, cannon bone circumference and body weight (calculated from heart girth), were obtained at 2-mo intervals on each of 139 animals. Similar data were obtained from the remaining 121 horses at 6-wk intervals from February through July of their yearling year. The data were used to study growth patterns of Throroughbred foals and yearlings, to evaluate the influences of month of birth and sex on growth and development and to develop equations that described and predicted the growth patterns.

The statistical models that were employed to develop regression equations considered variation due to farm, sex, month of birth and the linear and quadratic effects of serial body measurements on age. The models accounted for 83 to 98% of the variation in the data (table 11). Foals born in January-February were smallest at birth while foals born in May-June were largest at birth (table 12; figures 1 to 8). All growth curves were asymptotic. The month of birth and sex of the foal differentially influenced many of the growth curves; the rate of growth in the various measures differed due to the two effects, yet the shape of the curves within a measure, determined by interactions of the quadratic effect of serial measurements on age with month of birth, generally were not different (table 11).

All data were linearly interpolated to several constant ages in order to make comparisons of measures between month of birth or between sexes (tables 15 to 22). At 30 and 90 d-of-age, foals born in January-February were the smallest foals. The differences between body measurements of foals, due to month of birth, generally dissappeared by 270 d-of-age. Measures obtained at 400 d-of-age (excluding chest width) did not differ due to birth month. Therefore, the size of foals at 400 d-of-age was designated as 100% of maximum size. At 30 and 90 d-of-age, foals born in May-June foals were 1 to 6% more mature than foals born in January-February (table 23). Therefore, the later-born foals appeared larger at birth and exhibited an initial growth rate that was greater than that of foals born earlier in the year. In terms of the relative increase from birth to 400 d-of-age, the change in skeletal size was less than the increase in body mass.

Correlations between the various measurements were determined at the specific ages. The correlations between heart girth and body weight and between wither and hip height were consistantly high ($r^2$=.76 to .99 and .90 to .94, respectively). The relationships between heart girth and chest width, wither height, hip height or body length decreased with age while the correlation between wither height and the distance from knee to ground increased with age. Cannon bone circumference was consistantly related to all measures over time ($r^2$ =.42 to .71; table 24). The changes in correlation coefficients, that were seen over time, exemplified the asynchronous growth in various parts of the body.

There were some differences in size between colts and fillies (table 26). Differences were not detected prior to 150 d-of-age. However, when the effect of sex was significant ($P \leq .1$), colts were uniformly larger than fillies.

There were several instances when mare age contributed a significant amount of variation to measurements of foals (table 27). Mares 12 to 25 yr-of-age had longer foals from 30 to 270 d-of-age than foals from mares 4 to 11 yr old. The oldest mares' foals were taller at the withers, larger around the girth and heavier than than their comtempories at 90 d-of-age.

The size of all foals in January and July of the yearling year (table 28) was studied. Foals born in January-February were consistently larger in January than foals born in April, May and June ($P < .05$). In July, month of birth influenced the measurements of heart girth, wither height, hip height, body length and body weight ($P < .01$. However, actual differences in size, due to month of birth, were smaller in magnitude than the differences observed in January. Furthermore, foals born from January to March were not different and foals born from April to June were not different in size. Thus, the differences in size, due to month of birth, diminished with time.

There were several instances when sex of the horse influenced size in January and July (table 29). In January, colts had a larger cannon bone circumference and were heavier than fillies. In July, colts were longer, wider through the chest, heavier and had larger cannon bone circumferences than fillies.

The resemblance between the wither heights of parents and their 1982 offspring increased with age and was highest in July of the yearling year (table 30). The contribution of the offspring-dam resemblance to the overall regression decreased over time.

Similar analyses were conducted using data obtained on 1981 foals. Growth curves of most body measures were asymptotic in that both the linear and quadratic components of regression were significant (table 31). The rate of growth in the various proportions was intermittantly influenced by sex or by month of birth, while the shape of the curves within a measure were fairly uniforn across sexes and month of birth (table 32; figures 9 to 16). There were few differences in the size of horses at 350 or 400 d-of-age due to month of birth (table 34). This was not unexpected as differences in the proportions of 1982 foals, due to birth month, were not observed subsequent to 270 d-of-age. The actual size of horses and the coefficients of correlation (table 35) between the various measures in each data set at 400 d-of-age were similar.

The occurrences of sex differences in the 1981 foals were similar to those in the 1982 foals (table 36). Colts had larger chest widths, body lengths, knee to ground distances and cannon bone circumferences than fillies.

Comparisons of 1981 foals by month of birth in July of their yearling year revealed differences in the size of heart girth, hip height, body length and body weight (table 37). Tukey's pairwise comparisons were made and significant differences were identified only in the heart girth and body weight measurements. Foals born in January to April did not differ in size. There were few differences in size between colts and fillies in July (table 38).

The restrictions of age and date of measurements did not allow us to identify the date when differences in size, due to month of birth, would have been statistically negligible. However, because horses were beginning to approach a similar size in July, it is necessary to consider an evaluation of current established breeding schedules. Is the advantage in growth rate of late spring-born foals enough to justify intensification of breeding within the 3-mo period from April to June? Certainly, reproductive efficiency of both the mare and stallion would be improved (Trum, 1950; Loy, 1967; Van Niekerk, 1967; Hutton and Meacham, 1968; Pickett et al., 1970; Pickett and Voss, 1972; Kenney, 1975; Jennings, 1981). Hollingsworth (1975) indicated that lifetime racing performance (AEI) of foals born in January and June was less than the average of their contemporaries born in February through May. One of the major aspects of the Thoroughbred racing industry not considered in the current study was the evaluation of ability or endurance of the animals as affected by when they are born. If month of birth did have an impact on performance, the effect would probably be confounded with training regimen and (or) trainer. When yearlings are sold, they generally begin race training in the late fall of their yearling year. By the time they are 2 yr old (January 1 of their second year), they are generally getting ready for competition. During training, it is likely that early-born foals may be treated as older or more capable animals than later-born foals. This phenomena may be even more likely if the older foal is larger than his contempories. The "advantage" of 2 to 3 mo-of-age may actually be a disadvantage to the horse in terms of longevity and life time performance. Excessive training prior to the time when long bones cease growth (table 9) can cause irrepairable damage. In order to make an unbiased management decision on the most beneficial time to breed mares and the best time for foals to be born, further economic analyses and performance tests of large numbers of horses need to be conducted.

The size of the horse in July of the yearling year probably has little impact on the Thoroughbred industry beyond its impact on the yearling sale price. Khalilov (1980) reported that correlations of body measurements (wither height, heart girth and cannon bone circumference) at 6, 12, 18, 24, 30 and 36 mo-of-age with speed over 200 m, ranged from .08 to .16, .09 to .27 and .07 to .24 for the three conformational components, respectively. On the other hand, Fabiani (1974), calculated high correlations between jumping ability and wither height (.78) and between jumping ability and the body mass index (.77) The body mass index was calculated by chest girth x 100/height at withers. There have been no major studies conducted that confirm a relationship between performance ability and a specific physique. For example, Northern Dancer, one of the most valuable stallions in the world today, was partially ignored as a yearling, due to his small size, but he was extremely sucessful at the race track. Becuase of the improbability of predicting body size and conformation that would ensure racing success, research efforts like the current study are more useful to the breeding farm managers than to prospective race horse owners.

The results of the current study were promising in that the differences in size of horses due to month of birth, diminished with time. Presumably, at a date soon after July in the yearling year, differences in size were negligible. Further studies are needed to evaluate the performance, longevity and lifetime ability of horses in relation to their month of birth. Additionally, the relationship between age and ability needs to be investigated.

It is obvious that reproductive efficiency would be improved if mares were bred in late- vs early-spring.

Facets of the overall economic structure of an early breeding schedule that need consideration include the loss of reproductive efficiency in early-spring, the increased feed cost of feeding pregnant mares in the winter vs the spring and the increased length of time that early- vs late-born foals are maintained prior to being sold in July of the yearling year. Overall, the observations in the current study, combined with the economic implications of a physiological breeding season, would certainly justify further research that would add to the current information.

## LITERATURE CITED


Barauskas, V. 1974. Investigation of the inheritance of some characters in Zemaitukai ponies. Lietuvous Veterinarijos Akademijos Darbai 10:323, (Anim Breed Abstr. 43:2:36).

Bergin, W.C., H.J. Gier, R.A. Frey and G.B. Marion. 1967. Developmental horizons and measurements useful for age determination of equine embryos and fetuses. Proc. Am. Assoc. Equine Pract. Dec. p. 179.

Brody, S. 1927. Growth and Development with special reference to domestic animals. Miss. Ag. Exp. Sta. Res. Bull. no. 97.

Brody, S. 1945. Bioenergetics and Growth. Reinhold Publ. Corp., New York.

Brown, J.E., C.J. Brown and W.T. Buts. 1972. A discussion of the genetic aspects of weight, mature weight and rate of maturing in Hereford and Angus cattle. J. Anim. Sci. 34:525.

Brown, J.B., P. Harrison and M.A. Smith. 1978. J. Biosocial Sci., Suppl. 5: 43; cited by R.V. Short. 1980. The hormonal control of growth at puberty. In: Growth in Animals. T.L.J. Lawrence. London-Boston: Butterworths.

Campbell, J.R. 1977. Bone growth in foals and epiphyseal compression. Equine Vet. J. 9:16.

Campbell, J.R. and R. Lee. 1981. Radiological estimation of differential growth rates of the long bones of foals. Equine Vet. J. 13:247.

Coffman, J.R. 1973. Epiphysitis in weanlings. Mod Vet Pract. 4:53.

Crampton, E.W. 1923a. Size in the draft horse: a consideration of its importance and of the part played in its attainment by inheritance. J. Ag. and Hort. 26:157.

Crampton, E.W. 1923b. Rate of growth of draft colts. J. Ag. and Hort. 26:172.

Cunningham, K. and S.H. Fowler. 1961. A study of growth and development in the Quarter horse. Louisiana State Ag. Exp. Sta. Bull. no. 546.

Dawson, W.M., R.W. Phillips and S.B. Speelman. 1945. Growth of horses under western range conditions. J. Anim. Sci. 4:47.

Dinsmore, W. 1939. Horse and Mule Power. Book no. 235. Horse and Mule Assoc. of America p.55.

Dusek, J. 1965. The heritability of some characters in the horse. Zivocisna Vyroba 10:449. (Anim. Breed. Abstr. 33:4:532).

Evans, J.W. 1981. The Horse. W.H. Freeman and Company, San Francisco. p. 447-537.

Fabiani, M. 1974. Early evaluation of the jumping ability of horses. I. Horses from the training establishment for horses for export in Poznan. Anim. Breed. Abstr. 42:3025.

Fitzhugh, Jr., H.A. and St. C.S. Taylor. 1971. Genetic analysis of degree of maturity. J. Anim. Sci. 33:717.

Fletcher, T.J. and R.V. Short. 1974. Restoration of libido in castrated red deer stag (Cervus elaphus) with oestradiol 17B. Nature 248:616.

Gibbs, P.G., G.D. Potter, R.W. Blake and D.G. Meadows. 1979. Diet effects on yeild and composition of milk from mares in a 150-day lactation. Proc. 6th Equine Nutr. and Phys. Symp. p 24.

Goyal, H.O., F.J. MacCallum, M.P. Brown and J.B. Delack. 1981. Growth rates at the extremities of limb bones in young horses. Can. Vet. J. 22:31.

Green, D.A. 1969. A study of growth rate in Thoroughbred foals. Brit. Vet J. 124:539.

Green, DA. 1976. Growth rate in Thoroughbred yearlings and two year olds. Equine Vet. J. 8:133.

Heinze, C.D. and R.E. Lewis. 1968. Bone growth in the horse (shetland pony) determined by orthopedic markers. Proc. 14th Ann. Conv. Am. Assoc. Equine Pract. p.213.

Heird, J. 1973. Growth parameters in the quarter horse. Proc. Third Equine Nut. and Phys. Symp. p.81.

Hintz, H.F., H.F. schryver and J.E. Lowe. 1976. Delayed growth response and limb conformation in young horses. Proc. of Cornell Nutr. Conf. for Feed Manufacturers. p.94.

Hintz, R.L., H.F. Hintz and L.D. Van Vleck. 1978. Estimation of heritabilies for weight, height and front cannon bone circumference of Thoroughbreds. J. Anim. Sci. 47:1243.

Hintz, H.F., R.L. Hintz and L.D. Van Vleck. 1979. Growth rate of Thoroughbreds, effect of age of dam, year and month of birth, and sex of foal. J. Anim. Sci. 48:480.

Hintz, H.F. and Schryver, H.F. 1976. Nutrition and bone development in horses. J. Am. Vet. Med. Assoc. 168:36.

Hintz, H.F., H.F. Schryver and J.E. Lowe. 1971. Comparison of a blend of milk products and linseed meal as protein supplements for young growing horses. J. Anim. Sci. 33:1274.

Hodge, S.L., J.L. Kreider, G.D. Potter and P. G. Harms. 1981. Influence of photoperiod on the pregnant and postpartum mare. 73rd Ann. Meeting Am. Soc. An. Sci., Raleigh. Abstr. no. 505, p.330.

Hollingsworth, K. 1975. Early foals may look good at yearling sale time, but they have no edge at the races. Bloodhorse. 101:2882.

Hughes, J.P., G.H. Stabenfeldt and J.W. Evans. 1972. Estrous cycle and ovulation in the mare. J. Am. Vet. Med. Assoc. 161:1367.

Hutton, C.A. and T.N. Meacham. 1968. Reproductive efficiency on fourteen horse farms. J. Anim. Sci. 27:434.

Jennings, S.G. 1981. A survey of management and reproductive efficiency of horse farms using artificial insemination. M.S. Thesis, VPI&SU.

Jockey Club. 1982. Principal Rules and Requirements of the American Studbook. New York.

Jordan, R.M. 1977. Growth pattern of ponies. Proc. 5th Equine Nutr. and Phys. Symp. p.63.

Jordao, L.P. and M.X. DeCamargo. 1950. Some measurements of Mangalarga horses bred at the Sao Paulo State Stud. Bol., Industr. anim. 11:81.

Joubert D.M. 1956. A study of pre-natal growth and development in the sheep. J. Agric. Sci., Cambridge. 47:382.

Joubert, D.M. 1963. Puberty in female farm animals. Anim. Breed. Abstr. 31:295.

Kalmykov, A.N. 1973. Heritability of economic traits in the Orlov trotter. Genetika 9:8:50. (Anim. Breed. Abstr. 42:1:3).

Kalmykov, A.N. 1974. The selection of Orlov trotters for body measurements. Uchenye Zapiski Kazanskogo Gosudarstvennogo Veterinarnogo Instituta 116:158 (Anim. Breed. Abstr. 44:3:120).

Kenney, R.M., V.K. Ganjam and R.V. Bergman. 1975. Non-infectious breeding problems in mares. Vet. Scope 19:16.

Khalilov, R.A. 1980. The relationship between speed and body measurements of hroses. Anim. Breed. Abstr. 48:5781

Khotov, V. 1971. Progeny testing of purebred Anglo-Karachaev saddle stallions. Doklady TSKhA. (Anim. Breed. Abstr. 42:7:397).

Kownacki, M., M. Fabiani and K. Jaszczak. 1971. Genetical parameters of some traits of Thoroughbred horses. Genetica Polonica 12:431.

Kruger, W. 1939. Growth measurements of the skeleton of limb and trunk parts of live Trakehner horses and Mecklenburg heavy horses with the aid of a specially designed technique. Z. Tierz. ZuchtBiol. 43:45; cited by Green, D.A. 1961. A review of studies on the growth rate of the horse. Brit. Vet. J. 117:181.

Lasley, J.F. 1972. Genetics of Livestock Improvement p.33. 2nd ed. Prentice-Hall, Inc. Englewood Cliffs, New Jersey.

Lawrence, J.L.T. 1980. Growth in Animals. London-Boston:Butterworths.

Lentner, M. and T.A. Bishop. 1978. An introduction to analysis of variance and experimental designs. VPI&SU, Blacksburg.

Lohman,F. and I. Marimic. 1952. About the influence of spring and autumn foaling on the development of foals. Veterinarski arhiv 22:228.

Loy, R.G. 1967. How the photoperiod affects reproductive activity in mares. Mod. Vet. Prac. 48:47.

McKeever, K., G. Heusner and D. Sperling. 1981. Quarter horse foal growth - effect of month of birth, age of dam, and sex of foal. Proc. 7th Equine Nutr. and Phys. Symp. p.149.

McNellis, R. 1945. Data concerning foals of Peruvian remount service. J. Am. Vet. Med. Assoc. 107:392.

Meakim, D.W., E.A. Ott, R.L. Asquith and J.P. Feaster. 1981. Estimation of mineral content of the equine third metacarpal by radiographic photometry. J. Anim. Sci. 53:1019.

Morgan, J.P. 1974. Radiology. In:Lameness in Horses by O.R. Adams. 3rd ed. p.462-553. Lea & Febiger, Philadelphia.

Myers, V.S.,Jr. and M.A. Emmerson. 1966. The age and manner of epiphyseal closure in the forelegs of two Arabian foals. Am. Vet. Radiol. Soc. 7:39.

Nalbandov, A.V. 1963. Symposium of Growth: Endocrine causes of growth and growth stasis. J. Anim. Sci. 22:558

NRC, 1978. Nutrient requirements for horses. National research council, Washington, D.C.

Osborne, V.E. 1966. An analysis of the pattern of ovulation as it occurs in the annual reproductive cycle of the mare in Australia. Australian Vet. J. 42:149.

Ott, E.A., R.L. Asquith, J.P. Feaster and F.G. Martin. 1979. Influence of protein level and quality on the growth and development of yearling foals. J. Anim. Sci 49:620.

Owen, J.M. 1975. Abnormal flexion of the corono-pedal joint of "contracted tendons" in unweaned foals. Equine Vet. J. 7:40.

Pickett, B.W., L.C. Faulkner and T.M. Sutherland. 1970. Effect of month and stallion on seminal characteristics and sexual behavior. J. Anim. Sci. 31:713.

Pickett, B.W. and J.L. Voss. 1972. Reproductive management of the stallion. Proc 18th Ann. Conv. of Am. Assoc. Equine Pract. p.501.

Reed, K.R. and N.K. Dunn. 1977. Growth and development of the Arabian horse. Proc., of the 5th Equine Nutr. and Phys. Symp. p.99.

Rosenfield, R.L. and V.S. Fang. 1974. Adolescent Medicine 85:830; cited by R.V. Short. 1980. The hormonal control of growth at puberty. In: Growth in Animals. T.L.J. Lawrence. London-Boston: Butterworths.

Russell, T.S. 1969. In: Animal Growth and Nutrition. Chapter 20. Ed. by E.S.E. Hafez and I.A. Dyer. Philadelphia: Lea and Febiger.

SAS, 1979. SAS User's Guide. Statistical Analysis System Institute, Cary, N.C.

Short, R.V. 1980. The hormonal control of growth at puberty. In: Growth in Animals. T.L.J. Lawrence. London-Boston: Butterworths.

Stromberg, B. 1979. A review of the salient features of osteochondrosis in the horse. Equine Vet. J. 11:211.

Sullivan, J.J., P.C. Turner, L.C. Self, H. B. Gutteridge and D.E. Bartlett. 1975. Survey of reproductive efficiency in the Quarter horse and Thoroughbred. J. Reprod. Fert., Suppl 23:315.

Tanner, J.M. 1962. Growth at Adolescence, 2nd Ed. Oxford: Blackwell Scientific Publications Ltd.

Tanner, J.M., R.H. Whitehouse, P.C.R. Hughes and B.S. Carter. 1976. Relative importance of growth hormone and sex steroids for the growth at puberty of trunk length, limb length and muscle width in growth hormone deficient children. J. Pediatrics. 89:1000.

Taylor, St. C.S. 1980. Live-weight growth from embryo to adult in domesticated mammels. Anim. Prod. 31:223.

Trenkle, A. and D.G. Topel. 1979. Relationships of some endocrine measurements to growth and carcass composition in cattle. J. Anim. Sci. 46:1604.

Trowbridge, E.A. and D.W. Chittendon. 1932. Horses grown on limited grain rations. Miss. Ag. Exp. Sta. Bull no. 316.

Trum, B.F. 1950. The estrous cycle of the mare. Cornell Vet. 40:17

Ullrey, D.E., R.D. Struthers, D.G. Hendricks and B.E. Brent. 1966. Composition of mare's milk. J. Anim. Sci. 25:217.

Van Niekerk, C.H. 1967. Pattern of the oestrous cycle of mares. J. S. Afr. Vet. Med. Ass. 38:295.

Varo, M. 1965. Some coefficients of heritability in horses. Annales Agriculturae Fenniae 4:223.

Willoughby, D.P. 1975. Growth and Nutrition in the Horse. South Brunswick and New York: A.S. Barnes and Company.

Wilson, J.D., J.E. Griffin and F.W. George. 1980. Sexual differentiation: Early hormone synthesis and action. Biol of Repro. 22:9.

Winter, J.S.D. and C. Faiman. 1972. Pediatric Research. 6:126; cited by R.V. Short. 1980. The hormonal control of growth at puberty. In: Growth in Animals. T.L.J. Lawrence. London-Boston: Butterworths.

Wojciechowski, J. 1965. Zesz. nauk. reyzsz. Szk. roln. Wrod. (1964), No 58 (Trudy mosk, vet. Akad., 12:81); cited by Green, D.A. 1969. A study of growth rate in Thoroughbred foals. Brit. Vet. J. 124:539.

APPENDIX

APPENDIX TABLE 1. THE ANALYSIS OF VARIANCE OF SERIAL HEART GIRTH MEASUREMENTS OF 1982 FOALS THAT WAS UTILIZED TO GENERATE A REGRESSION EQUATION DESCRIBING THE GROWTH CURVE FOR HEART GIRTH[1].

| Source of variation | Degrees of Freedom | Mean square | F value | Probability[4] (P <) |
|---|---|---|---|---|
| Farm | 12 | 24962.558 | 3.09 | .01 |
| Sex | 1 | 14081.435 | 1.75 | .19 |
| Month | 3 | 47997.853 | 5.95 | .01 |
| Farm x Sex | 11 | 9777.4245 | 1.21 | .29 |
| Farm x Month | 27 | 13165.790 | 1.63 | .05 |
| Sex x Month | 3 | 4554.6797 | .56 | .64 |
| Horse[2] | 83 | 8062.8321 | 4.37 | .01 |
| Age | 1 | 18528846.538 | 10051.92 | .01 |
| Age x Age | 1 | 5628333.304 | 3053.65 | .01 |
| Age x Sex | 1 | 6683.8858 | 3.63 | .06 |
| Age x Age x Sex | 1 | 3334.1389 | 1.81 | .18 |
| Age x Month | 3 | 12454.873 | 6.76 | .01 |
| Age x Age x Month | 3 | 5481.6176 | 2.97 | .03 |
| Error[3] | 909 | 1843.314 | | |
| Total | 1059 | | | |

[1]Analysis of variance for all serial body measurements follow the same model

[2]The mean square for horse was used to test farm, sex and month and their interactions

[3]The error mean square used to test horse effects, age, age x age and their interactions with sex and month; derived from a model where horse and all main effects were absorbed.

[4]Probabilities associated with the F-tests for each source of variation

APPENDIX TABLE 2. LEAST SQUARES ANALYSIS OF VARIANCE OF HEART GIRTH MEASUREMENTS OF 1982 FOALS. THE MEASUREMENTS WERE ADJUSTED TO THE CONSTANT AGE OF 30 DAYS[1].

| Source of Variation | Degrees of Freedom | Mean square | F value | Probability[2] (P <) |
|---|---|---|---|---|
| Farm | 12 | 5096.1931 | 2.62 | .01 |
| Sex | 1 | 571.1999 | .29 | .59 |
| Month | 3 | 15582.305 | 7.97 | .01 |
| Sex x Month | 3 | 5289.165 | 2.71 | .01 |
| Error | 81 | 1954.4554 | | |
| Total | 100 | | | |

[1]Analysis of variance for all body measurements at each constant age follows the same model.

[2]Probabilities associated with the F-tests for each source of variation

APPENDIX TABLE 3. LEAST SQUARES ANALYSIS OF VARIANCE USED TO TEST THE EFFECT OF MARE AGE ON HEART GIRTH MEASUREMENTS OF 1982 FOALS. THE MEASUREMENTS WERE ADJUSTED TO THE CONSTANT AGE OF 30 DAYS[1].

| Source of Variation | Degrees of Freedom | Mean square | F value | Probability[2] (P < ) |
|---|---|---|---|---|
| Farm | 12 | 5121.193 | 2.56 | .01 |
| Sex | 1 | 571.199 | .29 | .59 |
| Month | 3 | 15582.305 | 7.78 | .01 |
| Mare Age | 2 | 4495.6177 | 2.24 | .11 |
| Mare Age x Month | 6 | 2158.9836 | 1.08 | .38 |
| Error | 76 | 2003.069 | | |
| Total | 100 | | | |

[1]Analysis of variance including mare age effects, for all body measurements at each constant age, follows the same model.

[2]Probabilities associated with the F-tests for each source of variation

APPENDIX TABLE 4. LEAST SQUARES ANALYSIS OF VARIANCE OF THE HEART GIRTH MEASUREMENTS OF 1982 FOALS, OBTAINED IN JANUARY OF THEIR YEARLING YEAR.[1]

| Source of Variation | Degrees of Freedom | Mean square | F value | Probability[2] (P <) |
|---|---|---|---|---|
| Farm | 12 | 11529.672 | 7.32 | .01 |
| Sex | 1 | 141.332 | .09 | .77 |
| Month | 3 | 59834.323 | 37.98 | .01 |
| Sex x Month | 3 | 1617.577 | 1.03 | .38 |
| Error | 110 | 1575.512 | | |
| Total | 129 | | | |

[1]Analysis of variance for all body measurements obtained in January and and July of the yearling year follows the same model.

[2]Probabilities associated with the F-tests for each source of variation

APPENDIX TABLE 5. THE ANALYSIS OF VARIANCE OF SERIAL HEART GIRTH MEASUREMENTS OF 1981 FOALS THAT WAS UTILIZED TO GENERATE A REGRESSION EQUATION DESCRIBING THE GROWTH CURVE FOR HEART GIRTH[1]

| Source of Variation | Degrees of Freedom | Mean square | F value | Probability[4] (P< ) |
|---|---|---|---|---|
| Farm | 11 | 16790.244 | 3.31 | .01 |
| Sex | 1 | 1679.2364 | .33 | .57 |
| Month | 3 | 1256.2028 | .25 | .86 |
| Farm x Sex | 10 | 4793.9956 | .94 | .50 |
| Farm x Month | 23 | 4368.8265 | .86 | .65 |
| Sex x Month | 3 | 3773.8177 | .74 | .53 |
| Horse[2] | 69 | 5078.6254 | 12.36 | .90 |
| Age | 1 | 16591.064 | 40.38 | .01 |
| Age x Sex | 1 | 199.0114 | .48 | .49 |
| Age x Month | 3 | 1227.6443 | 2.99 | .03 |
| Age x Age | 1 | 7211.5819 | 17.55 | .01 |
| Age x Age x Sex | 1 | 123.5732 | .30 | .58 |
| Age x Age x Month | 3 | 992.360 | 2.42 | .07 |
| Error[3] | 315 | 410.8946 | | |
| Total | 445 | | | |

[1]Analysis of variance for all serial body measurements follows the same model

[2]The mean square for horse was used to test farm, sex, month and their interactions

[3]The error mean square was used to test horse, age, age x age and their interactions with sex and month; derived from a model where horse and the main effects were absorbed.

[4]Probabilities associated with the F-tests for each source of variation

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THE INFLUENCE OF MONTH OF BIRTH ON GROWTH AND DEVELOPMENT OF THOROUGHBRED FOALS AND YEARLINGS

Lauren Elaine Goater

(ABSTRACT)

Thirteen Thoroughbred farms in Virginia provided 260 horses for the study of growth patterns of horses from birth to July of the yearling year. Measurements included heart girth, wither and hip height, body length, chest width, knee to ground length, cannon bone circumference and body weight, as estimated by heart girth. Quadratic regression equations, adjusted for the effects of farm, sex and month were developed to describe the growth of foals. Foals born in January-February were smallest overall at birth, 30 and 90 d-of-age ($P < .01$) May-June foals were largest at birth. Differences in wither height, body length and body weight of foals born in May-June vs in January-February at 30 d-of-age, were 1.7, 3.8 cm and 21.8 kg, respectively; At 90 d-of-age, differences were 1.6, 4.9 cm and 13.3 kg, respectively. Differences in size due to birth month were apparent up to 270 d-of-age. May-June foals exhibited the fastest initial growth rate. Colts

were intermittently larger than fillies subsequent to 150 d-of-age. In January of the yearling year, birth month influenced all measurements (P< .01). Foals born in January to March were larger than foals born in April to June. In July of the yearling year, differences were identified less often and actual differences in size were smaller than in January. Average differences in heart girth and wither height of foals born in January to March compared to foals born in April to June were 8.4 and 5.1 cm in January and 5.2 and 3.6 cm in July of the yearling year. Foals born in April to June displayed larger gains during the first 7 mo of their yearling year than did early-born foals. Correlation coefficients between measures of foals up to 400 d-of-age decreased or remained the same. Thus, growth in various proportions was asynchronous. Regression coefficients that described the resemblance between wither heights of parents and offspring increased with age and were highest in July of the yearling year. Offspring-midparent regression coefficients of 1982 foals increased from .50 ±.18 at 30 d-of-age to .78 ±.14 at 400 d-of-age. The regression coefficient in July was .84 ±.15.