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Live Weight and Linear Skeletal Growth from Birth to 14 Months of Age in Holstein Friesian Female Calves

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Abstract: *This study describes the live weight, wither height and linear skeletal growth from birth to 14 months of age. Dam parity was recorded for each calf as primiparous (group 1: n=18 for multiparous; group 2: n=20).The linear skeletal growth comprised thoracic height, radius height, metacarpal length and toe height (including metacarpophalangeal joint). The live weight and wither height increased with age. Proportions of thoracic height, radius height, metacarpal length and toe height in relation to wither height were calculated. At 80 kg live weight, radius height made up the largest proportional of the wither height of all female calves. After 160 kg live weight thoracic height made up the largest proportion of overall height. As heifer live weight increased the contribution of the distal forelimb to increases in height decreased, and the contribution of the proximal forelimb to increases in height increased, but at a slowed rate. This raises the possibility that growth restriction due to feed availability after 14 months of age could influences the development of the proximal forelimb. Farmers should ensure if adequate feed supply is provided.*

Keywords: *dairy female calves, forelimb growth, stature, live weight.*

1. Introduction

The increase in size and live weight is affected by many factors such as genetics, nutrition, and management. Every annual has an inherent mature body size toward which it grows at a genetically controlled rate accelerated or delayed by environmental factors resulting in little influence on mature body size.

The association of growth and future production in dairy cattle has been well described within the literature [1, 2].

The effect of growth and environment on subsequent bone development in dairy heifers has been over looked [3].

As live weight increases, bone must increase in size and strength to maintain mechanical strain within physiological limits [4].

The application of this theory has been supported by research looking into the relationship between bone and strain where increases in live weight result in a rise in bone strength [5].

Singh et al., [6] described the role of estrogen in bone growth and formation. At the onset of puberty estrogen is secreted from the ovaries in low concentration. In early stages of puberty, the increase in growth and sex hormones causes elongation of long bones („growth spurt") [6]. Distal portions of the limbs such as the metacarpus have limited longitudinal growth potential compared to proximal bones such as the humerus [7]. In late puberty, higher concentrations of estrogen inhibit bone resorption by reducing the number of osteoclasts produced and limiting osteocyte apoptosis [8].

Inadequate bone growth prior to puberty and bone maturity can result in a smaller bone size and limited bone strength. A potential cause for reduced bon size is a period of malnutrition, where bone growth ceases and the physis is temporarily sealed. When bone growth resumes, the seal and the physis is displaced and is observed histologically and on radiographs as growth arrest line (Harris line) [9].

The peripheral quantitative computative tomography (pQCT) provides a non-invasive technique of determining bone parameters and measures of bone geometry and thus, calculation of precise measures of bone strength and resistance to fracture [10].

Humeral fractures in first lactation dairy heifers were first reported in 2008 in New Zeeland [11] and approximately 5000dairy replacements each year may be affected. The risk factors for humeral fracture are multifunctional, but a major contributor is believed to be poor nutrition in early life of female calves [10].

Holstein Friesian animals are known to have a larger mature weight, requiring a faster growth rate [11].

Animals with heavier weight tend to mature later than those with lighter mature weight [12]. A large and faster growth rate requires higher dietary energy intake making them more susceptible to disruptions in growth from feed shortages [13].

To understand how the heifer grows at a whole-body level, research has been undertaken to examine changes in stature up until 21 months of age. Seiber et al, [14] reported relationships between body measurements, body weight and productivity in Holstein Dairy cows. Hendcock et al (2021) [15], proposed a relationship between wither height, body length and girth. The proportion of wither height change contributed by leg (metacarpus and radius) versus thoracic growth (humerus and scapula) must be investigated.

The aim of this study was to describe proportional changes in stature with live weight in Holstein Friesian calves from birth to 14 months of age when puberty is likely to have been achieved.

2. Material and Methods

2.1. Animals, Feeding and Facilities

This experiment was conducted at Agricultural Research and Development Station (ARDS) Șimnic – Craiova, Romania (182 m above sea level, 4°19’ N, 23°48’ E).

Female calves were recruited at birth and monitoring until 14 months of age. All female calves were removed from their dam within 24 h of birth. Dam parity was recorded for each calf as primiparous (n=18) or multiparous (n=20).

All 38 Holstein Friesian female calves were born during 2019-2020 at ARDS’s Dairy Farm. Calves were housed indoors in clean sanitized wooden hutches arranged in rows of 12 hutches until weaning. Female calves were farm reared under farm management involving fresh maternal first-milking colostrum with Brix reading 25% or higher or with Brix reading between 18-24%suplemented with colostrum powder for the three days of life, followed by 7 L/day of whole cow milk split over two feeds for 7 weeks, then 4 L per day until weaning.

Female calves were weaned at approximately 90 kg live weight and 71 to 90 days of age. Ad libitum access to calf starter and fresh water was offered. Calf starter with 20% crude protein, 3% fat, 13 MJ/kg ME was fed for 5 months of age, followed by calf starter 18% crude protein, 3% fat, 12.5 MJ/kg ME after that.

After being removed from the calf hutches, calves were managed by farm personal as two groups: Group 1 = calves from primiparous cows and group 2 = calves from multiparous cows. Calves were fed under farm management with diets formulated to meet or exceed nutritional requirements. Additionally all heifers has access to pasture.

2.2. Sampling and Measurements

Calves were measured using a method described by Gibson et al., (2021) [5] fortnightly from birth (within first 48 hours of life) until weaning, and monthly until 14 months of age. On each measurement day, the calves were weighted using a platform weighing scale with weight cage to the nearest kg. Linear measurements were obtained using a flexible tape measure to the nearest cm.Linear measurements were taken by a research personnel. Wither height from ground to the high point of the back (between shoulder blades), thoracic height (at forelegs), and wither – ramp length (wither to tuber ischii).

Leg measure of the left forelimb consisted of leg length (from ground to the point of olecranon), toe height (from ground to the metacarpophalangeal joint), knee height (from ground to the antebrachiocarpal joint) and the circumference of the metacarpus bone midlength. Thoracic height was equal to wither height minus leg length, radial-ulna length was equal to leg length minus knee height, and metacarpus length (including the carpal bones) was equal to knee height minus total height.

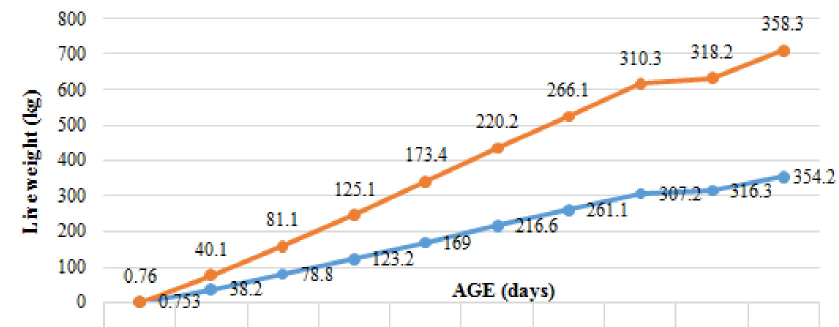
2.3. Statistical Analysis

The data were entered into Microsoft Excel computer program 2007 STATA version 14 was used to summarize the data and descriptive statistics were used to express the results. The results were tested one way ANOVA.

Means values, standard deviations and phenotypic correlation indices were calculated. The differences between the means were tested with Duncan's multiple range test (DMRT).

3. Results and Discussion

The live weight increased with age (fig. 1).



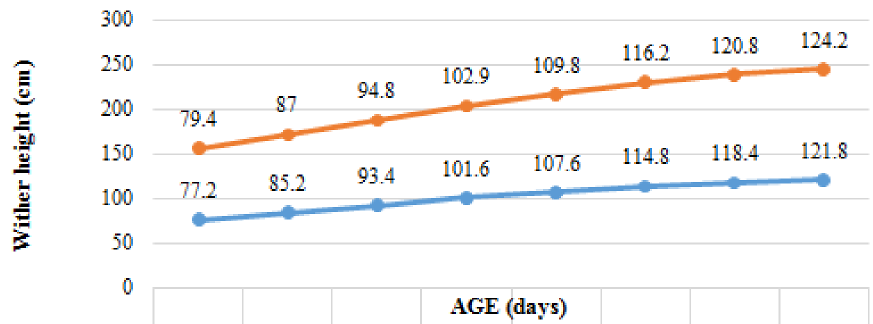
Group 2	0.76	40.1	81.1	125.1	173.4	220.2	266.1	310.3	318.2	358.3
Group 1	0.753	38.2	78.8	123.2	169	216.6	261.1	307.2	316.3	354.2

Figure1. *Live weight (kg) versus age (days) in Holstein Friesian heifers*

Group 1 of heifers had a lighter live weight at all ages than Group 2 of heifers. Group 2 of heifers had a greater overall growth rates (0.760 kg/day) compared with group 1 (0.753 kg/day) of heifers. The differences were non-significant.

At 14 months of age heifers were approximately 60% of mature weights.

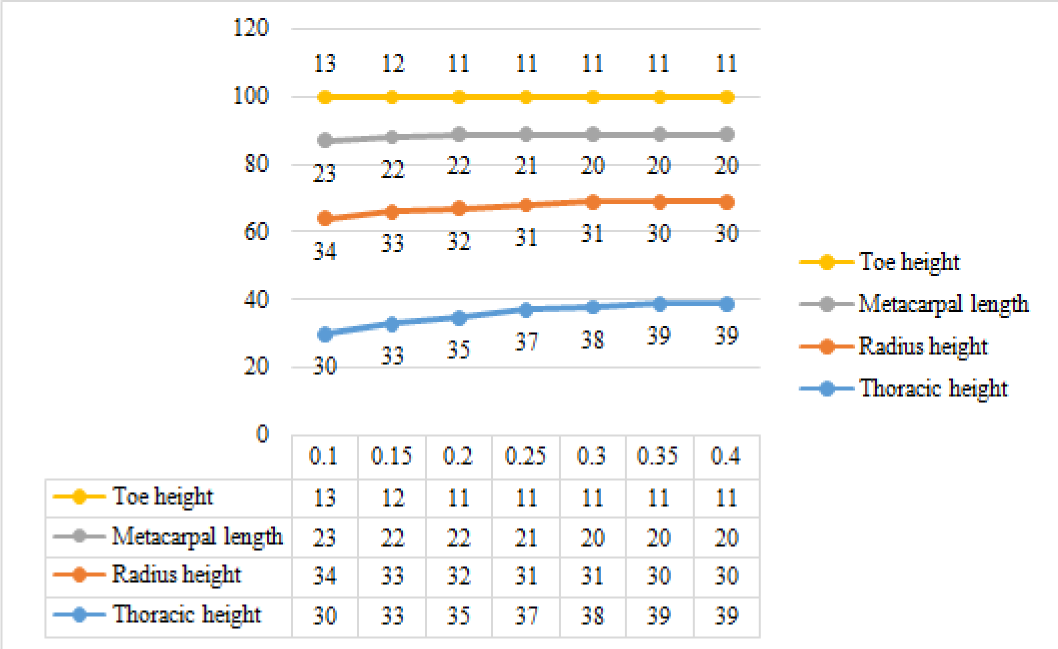
The wither height also increased with age (fig. 2). Group 1 of heifers had a little shorter wither height compared with group 2 of heifers, but the differences were non-significant.



Group 2	79.4	87	94.8	102.9	109.8	116.2	120.8	124.2
Group 1	77.2	85.2	93.4	101.6	107.6	114.8	118.4	121.8

Figure2. *Wither height (cm) versus age (days) in Holstein Friesian heifers Group 1 of heifers and Group 2 of heifers*

Proportion of thoracic height, radius height, metacarpal length and toe height in relation to wither height of heifers from birth to 14 months of age are presented in figure 3.



	0.1	0.15	0.2	0.25	0.3	0.35	0.4
Toe height	13	12	11	11	11	11	11
Metacarpal length	23	22	22	21	20	20	20
Radius height	34	33	32	31	31	30	30
Thoracic height	30	33	35	37	38	39	39

Figure3. *Proportion of thoracic height, radius height, metacarpal length and toe height in relation to wither height of heifers*

At 80 kg radius height made up the largest proportion (34%) of the wither height of all female calves. The effect of dam parity (primiparous or multiparous) regarding proportions of thoracic height radium height, metacarpal length and toe height in relation with wither height was tested and the results were not significant between group 1 and group 2 of heifers.

Thoracic height made up the largest proportion of overall wither height after 160 kg live weight (fig. 3).

Feed supply on dairy farm of ARDS Șimnic Craiova is not a problem. In pasture dairy systems the pasture availability and quality change dependent on the time of year [13]. In the current study, live weight gain in female calves was linear and live weight at 14 months was between 354.2 and 358.3 kg.

Therefore the female calves in this study were well grown.

A linear growth pattern promotes continuous appositional and longitudinal bone growth and mineralization to achieve peak bone mass [16].

Increase in animal size cause a greater strain on bone, requiring an increase in bone strength to maintain strain within physiological limits [4].

Early in a heifer's life, increases in live weight are mainly comprised of growth in long bones resulting in an increase wither height [17]. In current experiment at approximately 240 kg leg measures showed and remained constant.

After a year of age increases in compressional forces are moderate so changes in bone size in the metacarpus is limited. In the humerus torsional forces from surrounding muscles act on bone resulting a much stronger bone than in metacarpus and the humerus continues to increase in size with increases in axial body growth [18] with proximal limb development still occurring at 14-15 month age bone within the proximal limb will be susceptible to change in growth trajectory.

4. Conclusions

In this investigation approximately 88% of wither height is achieved in the first year of life, in Holstein Friesian female calves.

The growth in the metacarpus is restricted after 200-240 kg, whereas growth in the humerus continues. This raises the possibility that growth restriction due to feed availability after 14 months of age could influences the development of the humerus. Farmers should ensure if adequate feed supply is provided.

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