ABSTRACT: Insulin-like growth factor-binding proteins-2 and -3 may play a role in age-dependent growth response to bovine ST (bST) treatment in cattle; however, samples have been collected at infrequent intervals and at limited time points. Therefore, the objective of this experiment was to examine the ontogeny of components of the somatotropic axis in Hereford calves from birth to 1 yr of age at weekly intervals to determine whether there is a certain age or time frame when the somatotropic axis may change and/or potentially become more responsive to exogenous bST administration. Blood samples and body weight measurements were collected from eight male and eight female Hereford calves once per week from birth to 1 yr of age. Serum concentrations of ST, IGF-I, IGFBP-2, and IGFBP-3 were determined. Males began to grow faster than females at approximately 16 wk of age ($P < 0.05$). Average concentrations of ST, IGF-I, and IGFBP-3 were greater in males than females ($P < 0.01$). Average concentrations of IGFBP-2 were greater in females than in males ($P = 0.05$). Concentrations of ST decrease with age ($P < 0.01$); however, the decrease occurred earlier in female calves. Concentrations of IGF-I and IGFBP-3 increased in males and females ($P < 0.01$), and concentrations of IGFBP-2 were increased in males and females ($P < 0.01$). Concentrations of IGF-I began to plateau at approximately the same time as growth rate differences were observed (16 wk of age). Following an initial increase (birth to approximately 16 wk of age), concentrations of IGFBP-3 remained constant until approximately 43 wk of age. Concentrations of IGFBP-2 increased to approximately 10 wk of age ($P < 0.05$), followed by a decrease, and then, similar to IGFBP-3, remained constant until 43 wk of age. Correlations between average daily gain, ST, IGF-I, IGFBP-2, and IGFBP-3 were determined. Average daily gain was negatively ($P < 0.01$) correlated with ST and positively ($P < 0.1$) correlated with IGF-I. In females, ST was negatively ($P < 0.01$) correlated with IGF-I. Concentrations of ST were positively correlated ($P < 0.01$) with IGFBP-2 and IGFBP-3. Concentrations of IGFBP-2 were negatively correlated ($P < 0.01$) with IGF-I and positively correlated ($P < 0.01$) with IGFBP-3. In conclusion, serum concentrations of ST, IGF-I, IGFBP-2, and IGFBP-3 differed between male and female calves. In addition, changes in components of the somatotropic axis occurred around the same time as males began to grow faster than females.

Key Words: Calves, Growth, Insulin-Like Growth Factor-I, Insulin-Like Growth Factor Binding Protein-2, Insulin-Like Growth Factor Binding Protein-3, Somatotropin

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Introduction

The somatotropic axis is important in the regulation of growth. Somatotropin, the principle compound of the somatotropic axis, interacts with membrane receptors, primarily in liver, as well as other target tissues to stimulate the production of IGF-I (Carter-Su et al., 1996). There are six IGFBP, which are responsible for transporting IGF in the blood and regulate their biological actions (Jones and Clemmons, 1995).

Serum concentrations of hormones associated with the somatotropic axis change a great deal during the first year of life and in response to exogenous ST. Concentrations of ST decrease with age, but average concentrations of ST are greater in bulls than in heifers because the age-related decrease in ST is delayed in males (Schwarz et al., 1992). Concentrations of IGF-I and IGFBP-3, the most abundant IGFBP, increase with age (Skaar et al., 1994). Concentrations of IGFBP-2 have been reported to decrease (Skaar et al., 1994) or not change (Govoni et al., 2002) with age. In response to exogenous bST, serum concentrations of ST, IGF-I,
and IGFBP-3 increase and concentrations of IGFBP-2 decrease (Rausch et al., 2002). We reported an age-dependent effect of administration of exogenous bovine ST (bST) on growth rate in cattle (Rausch et al., 2002). The IGFBP may play a role in this age-dependent effect; however, as in other experiments, few samples were collected over a short period of time and in response to different physiological states. These factors make it difficult to associate changes in IGFBP with concentrations of ST and IGF-I and their involvement in growth response to exogenous bST. Through an increase in the number of samples collected, changes in IGFBP and the somatotropic axis may be associated with differences in growth rates. Therefore, the objective of this experiment was to examine the ontogeny of the somatotropic axis, including IGF-I, IGFBP-2, and IGFBP-3, in Hereford calves, at frequent intervals, from birth to 1 yr of age.

Materials and Methods

General

Eight male and eight female Hereford calves, born within 3 wk of each other, were used. Calves were housed, with their dams, unrestrained, in covered pens (225 m²) with constant access to an exercise yard (525 m²) for 4 to 6 wk postpartum, at which time calves and dams were maintained on grass pasture (improved New England native pasture). Beginning at 8 to 10 wk of age, calves had access to a creep feeder (16% CP, 70 Mcal ME) while on grass pasture. All male calves were castrated (22 ± 1.5 wk of age) using a bloodless castration system (EZE Bloodless castrator, Wadsworth Mfg. Inc., St. Ignatius, MT). At weaning (29 ± 1.5 wk of age), calves were returned to the covered pens and fed a corn:grass (50:50) silage, supplemented with a 40% soybean-based protein supplement (1 kg/animal⁻¹·d⁻¹, as fed) formulated for calves to gain 1.2 kg/d (NRC, 1996). When housed in covered pens, calves were fed at 0730. Water was available ad libitum. The animal use protocol for this experiment was approved by the Institutional Animal Care and Use Committee at the University of Connecticut.

Sample collection began within 24 h following birth. Once per week for 52 wk, at 0800, one blood sample (10 mL) was collected by venipuncture from a jugular vein. Samples were stored at room temperature for 2 to 4 h, and then stored overnight at 4°C. Serum was harvested from the cooled samples by centrifugation at 1,800 × g (Sorval RT7; Kendro Laboratory Products, Newtown, CT) for 30 min and stored at −20°C until assayed. Following collection of each blood sample, BW was determined each week from birth to 1 yr of age, and ADG was calculated for every animal individually at each interval. These weekly calculations were used for statistical analyses involving ADG.

Serum concentrations of ST, IGF-I, and progesterone were determined by RIA. Serum ST was quantified in all serum samples (Kazmer et al., 1992). Antisera to ST (NIDDK anti-oST2; AFP-C0123080 antibody, provided by A. F. Parlow) were used at a dilution of 1:20,000. Intraassay and interassay CV averaged 14.3 and 8.5% for low (16 ng/mL) and 9.1 and 6.2% for high (36 ng/mL) pools, respectively. Concentrations of IGF-I were determined in all serum samples (Govoni et al., 2002). Insulin-like growth factor-binding proteins were separated using a glycylglycine hydrochloric acid extraction method. Intraassay and interassay CV averaged 9.6 and 7.3% for low (165.5 ng/mL) and 5.6 and 10.7% for high (420.7 ng/mL) pools, respectively. Serum progesterone was quantified in all female calves from approximately 7 to 12 mo of age (Beal et al., 1980) to determine whether the animals reached puberty by the conclusion of the experiment.

Serum IGFBP-2 and -3 were determined using Western ligand blot (Freake et al., 2001). Briefly, molecular weight markers (BioRad, Richmond, CA), recombinant IGFBP-3 (8 ng; Diagnostic Systems Laboratories, Webster, TX) and six serum samples (1 μL) were run in eight lanes on a Mini Protean II (BioRad) and then transferred to a nitrocellulose membrane. Each gel was run in duplicate. Membranes were incubated overnight with approximately 1.6-MBq ¹²⁵I-labeled IGF-I (Amer sham Pharmacia Biotech, Piscataway, NJ). Membranes were blocked with 3% Igepal (in TBS; Sigma Aldrich Corp., St. Louis, MO) in Tris-buffered saline (vol/vol), then exposed to a multipurpose phosphor screen (Packard Instrument Company, Meriden, CT), and bound radioactivity on each blot was quantified with a Cyclone Storage Phosphor System (Packard). Images were analyzed with OptiQuant acquisition and analysis software (Packard). To account for gel-to-gel variation, each binding protein was measured as digital light units per square millimeter and calculated as a percentage of the signal of the standard IGFBP-3. Each band was measured twice per gel and the four measurements for each sample were averaged together. Data are expressed as arbitrary units (AU).

Statistics

Gender and age-related changes over time for BW, ADG, ST, IGF-I, IGFBP-2, and IGFBP-3 were analyzed as repeated measures using the mixed-model ANOVA procedure of SAS (SAS Inst. Inc., Cary, NC). Gender, week, and the gender × week interaction were included in the final model. The subject used in the repeated statement was animal nested within gender and the repeated variable was week. Four covariance structures, compound symmetry (CS), heterogeneous CS (CSH), first-order autoregressive (AR [1]), and toepitz (TOEP), were examined. A goodness-of-fit statistic determined that AR (1) adequately fit the data. The Kenward-Roger procedure was selected to determine the denominator degrees of freedom. Variance components for all analyses were estimated using the restricted
maximum-likelihood method. All data are expressed as least square means ± standard error of the mean.

To more closely examine the relationships between ADG, ST, IGF-I, IGFBP-3, and IGFBP-2, correlations were determined using PROC CORR of SAS for each gender (SAS Inst. Inc.). Average values for males and females, at each period, were utilized for ADG, ST, IGF-I, IGFBP-3, and IGFBP-2.

Based on the increased growth rate observed in the males at 16 wk of age using the Bonferroni- procedure (Gill, 1986), additional analyses were performed for the periods between birth to 16 wk and 17 wk to 1 yr of age using the mixed-model procedure of SAS (SAS Inst. Inc.). Development of linear regression equations was performed using Microsoft Excel 2000.

Results

Averaged across all time points, ADG was greater (P < 0.01) in males than females (1.7 ± 0.2 vs 1.2 ± 0.02 kg) and increased (P < 0.01) from birth to 1 yr of age (0.9 ± 0.2 to 1.3 ± 0.2 kg; Figure 1). At birth, BW did not differ between males and females (41.3 ± 8.7 vs 39.9 ± 8.7 kg). From birth to 16 wk of age, ADG did not differ between males and females (1.1 ± 0.03 vs 1.1 ± 0.03 kg), but from 16 wk of age to 1 yr of age, males grew 11% faster than females (P < 0.05), such that at 1 yr of age, BW were greater (P < 0.01) in males (508.8 ± 8.7 kg) than in females (468.9 ± 8.7 kg).

Averaged across all weeks, serum concentrations of ST were greater (P < 0.01) in males than females (13.1 ± 0.7 vs 5.3 ± 0.7 ng/mL). Serum concentrations of ST decreased (P < 0.01; Figure 2) from birth to 1 yr of age in males (18.0 ± 4.3 to 3.7 ± 4.3) and female (26.1 ± 4.3 to 0.8 ± 4.3 ng/mL) calves; however, the decrease occurred earlier in females than in males. Concentrations of ST declined in females (P < 0.05) from birth to 16 wk of age (26.1 ± 5.7 to 4.7 ± 5.7 ng/mL) and decreased in males (P < 0.05) from 17 wk to 1 yr of age 11.6 ± 3.4 to 3.7 ± 3.4 ng/mL; Figure 2).

Overall, average concentrations of IGF-I were greater (P < 0.01) in males than females (236.6 ± 5.2 vs 194.5 ± 5.2 ng/mL); however, this difference was not observed until after 16 wk of age. In addition, from birth to 16 wk of age, no gender differences were observed (191.4 ± 11.6 vs 174.1 ± 11.6 ng/mL, males and females, respectively), but from 17 wk to 1 yr of age, concentrations of IGF-I were greater in males than females (257.9 ± 5.0 vs 204.1 ± 5.0 ng/mL). From birth to 1 yr of age, average concentrations of IGF-I, in males and females increased (P < 0.01) from 114.3 ± 14.2 to 217.4 ± 14.2 ng/mL (Figure 3). Concentrations of IGF-I began to plateau at approximately 16 wk of age (Figure 3), such that there were no changes in concentrations in both males and females from 17 wk to 1 yr of age (P > 0.05; Figure 3).

Similar to IGF-I, average serum concentrations of IGFBP-3 were greater (P < 0.01) in males than females (93.1 ± 1.9 vs 79.5 ± 1.9 AU). In addition, there were no gender differences observed from birth to 16 wk of age (100.4 ± 3.3 vs 95.3 ± 3.3 AU in males and females, respectively), but, similar to IGF-I, average concentrations of IGFBP-3 were greater in males than females from 17 wk to 1 yr of age (89.6 ± 2.3 vs 71.9 ± 2.1 AU). However, from birth to 16 wk of age, serum concentrations of IGFBP-3 increased (P < 0.01) in males and females (Figure 4). Beginning on 17 wk of age, there was a decrease in IGFBP-3 in both males and females, and from 25 to 43 wk of age IGFBP-3 did not change in either male or female calves (P > 0.05; Figure 4). From 43 wk to 1 yr of age, concentrations were more variable in all calves.
Average concentrations of IGF-I in male (n = 8) and female (n = 8) calves. SEM = 20.01 for males and females at each time point. Solid squares represent intact males, and open squares represent castrated males. Shaded circles represent females. Arrow indicates the time at which males began to grow faster than females (P < 0.05; 16 wk of age). Linear regressions are indicated by solid line for males (y = 1.78x + 190.42; r² = 0.49) and dotted line for females (y = 0.64x + 177.84; r² = 0.15).

Figure 4. Average serum concentrations of IGFBP-3 in male (n = 8) and female (n = 8) calves. SEM = 12.14 for males and females at each time point. AU = Arbitrary units. Solid squares represent intact males, and open squares represent castrated males. Shaded circles represent females. Arrow indicates the time at which males began to grow faster than females (P < 0.05; 16 wk of age). Linear regressions are indicated by solid line for males (y = −0.17x + 97.45; r² = 0.01) and dotted line for females (y = −0.55x + 93.72; r² = 0.12).

Average concentrations of IGFBP-2 were greater (P = 0.05) in females than males (95.1 ± 2.0 vs 89.6 ± 2.0 AU). Similar to IGF-I and IGFBP-3, gender differences in average concentrations of IGFBP-2 were only observed from 17 wk to 1 yr of age (80.5 ± 2.2 vs 89.1 ± 2.2 AU). In males and females, serum concentrations of IGFBP-2 (P < 0.01) increased from birth to approximately 10 wk of age and then decreased from 10 wk to approximately 26 wk of age (Figure 5). Similar to IGFBP-3, concentrations of IGFBP-2 did not change (P > 0.05) from 26 to 42 wk of age, and following 43 wk of age, concentrations of IGFBP-2 were more variable in all calves.

To more closely examine the association of growth rate and change in components of the somatotropic axis in males and females, correlations were determined (Table 1). Overall, serum concentrations of ST were negatively correlated (P < 0.001 and P < 0.10 for males and females, respectively) and concentrations of IGF-I were positively correlated (P < 0.001 and P < 0.05 for males and females, respectively) with ADG. Serum concentrations of ST were positively correlated with IGFBP-2 (P < 0.001) and IGFBP-3 (P < 0.10) in males and with IGFBP-3 (P < 0.05) in females. Serum concentrations of IGFBP-2 were negatively correlated (P < 0.01) with IGF-I and positively correlated (P < 0.001) with IGFBP-3.

To determine when the animals reached puberty, serum concentrations of progesterone were determined for the females. Of the eight females, only two animals had two consecutive weeks of concentrations of progesterone greater than 1 ng/mL (Wettemann et al., 1972). Therefore, estrous cycles were not initiated in all heifers by the conclusion of the experiment. However, all of the females, which remained on site (n = 7), were determined to be pregnant by 16 to 18 mo of age and had their first calf by 24 to 26 mo of age. Therefore, these females were reproductively sound.

**Discussion**

During the first year of life, rapid body growth and changes in serum concentrations of components of the...
somatotropic axis have been reported in various species. In general, these age-related changes in serum concentration of ST, IGF-I, and IGFBP-3 have been similar among species. However, gender differences, response to exogenous ST, the age at which concentrations of the hormones plateau, and changes in IGFBP-2 have been variable. Many studies have evaluated changes in serum concentrations of ST in cattle with age (Anderson et al., 1988; Schwarz et al., 1992; Govoni et al., 2002), gender (Trenkle 1971; Schwarz et al., 1992), changes in BW (Trenkle and Topel, 1978), and in response to bST administration (Rausch et al., 2002). Changes in serum concentrations of IGF-I in cattle in response to age (Kerr et al., 1991; Schwarz et al., 1992; Govoni et al., 2002) and gender (Schwarz et al., 1992) have also been determined. Very little work has been done to examine age-related changes in serum concentrations of IGFBP in male and female cattle (Skaar et al., 1994; Rausch et al., 2002; Govoni et al., 2002). In addition, much of the data reported are variable in terms of the age at which concentrations of IGF-I plateau, the age at which changes in serum IGFBP occur, and the presence or absence of gender differences in IGFBP. Much of this variation may be due to the limited number of samples collected and infrequency of collection, especially in quantification of concentrations of IGFBP. When few samples are obtained over long periods of time, it is difficult to determine age- or gender-related changes in components of the somatotropic axis, in particular IGFBP. These limited data make it difficult to associate these changes with specific physiological stages of development. Thus, by collecting weekly samples (53/animal) from each animal, we were able to describe the ontogeny of the somatotropic axis, in particular the IGFBP, in beef cattle. In addition, we could compare changes in serum concentrations of the IGFBP with physiological changes, including ADG, during the first year of life.

It was reported that male calves grow faster than female calves (Schwarz et al., 1992); however, the age at which the gender difference begins is variable. Baumgard et al. (2002) determined that Holstein bull calves began to grow faster than heifer calves at 140 d of age. In the present study, growth rates were similar between male and female Hereford calves from birth to approximately 16 wk of age, but, from 16 wk to 1 yr of age, males grew 11% faster than females. Although the males in the current experiment were castrated, castration did not occur until after the gender difference was observed. Baumgard et al. (2002) evaluated body weight every 28 d, so the delay in increased growth rate of male calves compared with calves in the current experiment may be due to differences in frequency of sample collection or they may be due to differences between Hereford and Holstein cattle.

Similar to previous experiments (Anderson et al., 1988; Zinn et al., 1989; Schwarz et al., 1992), ST decreased with age in the current study. In addition, average concentrations of ST were greater in males than females due to a delay in the age-related decline in ST, as reported in bull calves (Schwarz et al., 1992). In animals treated with exogenous bST, there is an increase in serum concentrations of ST as well as growth rate (Rausch et al., 2002). Therefore, the gender difference we observed in growth rate may be associated with greater overall serum concentrations of ST in the male calves.

The age-related increase in concentrations of IGF-I observed in male and female calves is similar to previous reports in beef cattle (Schwarz et al., 1992; Rausch et al., 2002), dairy cattle (Kerr et al., 1991; Skaar et al., 1994; Govoni et al., 2002), pigs (Harrell et al., 1999), and lambs (Gatford et al., 1996). In the present study, concentrations of IGF-I began to plateau at 17 wk of age. The timing of this plateau is earlier than previous reports in dairy cattle, where the plateau occurred at 8 (Govoni et al., 2002) or 9 (Kerr et al., 1991) mo of age. However, in these studies, samples were only obtained every 1 (Govoni et al., 2002) or 3 (Kerr et al., 1991) mo, making it difficult to determine the precise age at which this plateau may have initially been reached. The difference in age at which the plateau occurred may also be due to differences between beef and dairy cattle. Similar to Kerr et al. (1991), differences in concentrations of

| Table 1. Correlations from birth to 1 yr of age for male and female Hereford cattle |
|-----------------|---------|---------|---------|---------|
| Item            | Variable | ADGa    | STa     | IGF-Ia  | IGFBP-3a |
| Males           | ST       | −0.18***| —       | —       | —        |
|                 | IGF-I    | 0.21*** | −0.15** | —       | —        |
|                 | IGFBP-3  | 0.02 NS  | 0.09†   | −0.06 NS| —        |
|                 | IGFBP-2  | −0.02 NS | 0.17*** | −0.20***| 0.77***  |
| Females         | ST       | −0.09†  | —       | —       | —        |
|                 | IGF-I    | 0.12a   | −0.18***| —       | —        |
|                 | IGFBP-3  | 0.02 NS  | 0.12*   | −0.02 NS| —        |
|                 | IGFBP-2  | −0.04 NS | 0.03 NS | −0.14** | 0.78***  |

aFor ADG, n = 416, and for ST, IGF-I, IGFBP-3, and IGFBP-2, n = 424.

NS = not significant, P > 0.10.
IGF-I between males and females were not observed until the onset of the plateau.

Insulin-like growth factor-binding protein-3 is the most abundant IGFBP and responsible for carrying IGF-I in the blood (Jones and Clemmons, 1995), so it is expected that concentrations of IGFBP-3 will have age-related changes similar to those of IGF-I. Parallel with IGF-I, concentrations of IGFBP-3 increased from birth to approximately 16 wk of age. This age-related increase was also observed in dairy calves from 1 to 45 wk of age (Skaar et al., 1994), in pigs from 10 to 125 d of age (Harrell et al., 1999), and in lambs from 81 to 158 d of age (Gatford et al., 1996). However, in those experiments, few samples were collected at infrequent intervals, so it is not possible to determine the precise duration of the increase. After 17 wk of age, concentrations of IGFBP-3 began to decrease and then remained constant at approximately the same time as concentrations of IGF-I began to plateau. In addition, gender differences in concentrations of IGFBP-3 were similar to IGF-I such that concentrations of IGFBP-3 were greater in males following 17 wk of age. Similarly, in sheep (Gatford et al., 1996) and in pigs (Owens et al., 1999), concentrations of IGF-I and IGFBP-3 were greatest in intact males, intermediate in castrated males, and least in females.

After approximately 43 wk of age, concentrations of IGFBP-3 were variable, which may be a result of the onset of puberty, at least in the females. Although heifers did not initiate estrous cycles by the conclusion of the experiment, serum concentrations of progesterone were elevated in two animals around 11 to 12 mo of age, indicating the onset of puberty, at least in the females. It was reported previously that serum concentrations of IGF-I and IGFBP-3 increase during puberty in primates (Crawford and Handelsman, 1996) and cattle (Jones et al., 1991; Renaville et al., 1993; 2000). Therefore, the onset of puberty in these females may have played a role in the increased variation in concentrations of IGFBP observed near 1 yr of age.

In the current experiment, concentrations of IGFBP-2 increased from birth to 10 wk of age and then declined over the next 14 wk, which is in agreement with Skaar et al. (1994). Similar to IGFBP-3, concentrations of IGFBP-2 remained constant until approximately 43 wk of age. Following 43 wk of age, concentrations of IGFBP-2 were also variable, which may be due to the onset of puberty. Average concentrations of IGFBP-2 were greater in females than males. Similar to IGFBP-3, this gender difference was observed during the period (23 to 43 wk of age) when concentrations remained relatively constant. Greater concentrations of IGFBP-3 in males and greater concentrations of IGFBP-2 in females may be related to growth rate. Similarly, Skaar et al. (1994) and Rausch et al. (2002) reported that increased concentrations of IGFBP-3 and decreased concentrations of IGFBP-2 were associated with increased growth rate, which may explain why males grew faster than females (Rausch et al., 2002).

Serum concentrations of IGF-I increase in growing cattle (Schwarz et al., 1992; Skaar et al., 1994; Govoni et al., 2002) and pigs (Harrell et al., 1999). As expected, we observed a positive correlation between ADG and serum concentration of IGF-I in male and female calves in the current experiment. Concentrations of ST decrease with age in cattle (Schwarz et al., 1992), and therefore we would expect a negative correlation of ST with increased ADG. However, when examined more closely in these animals, the negative correlation between ST and ADG was only significant during the first 16 wk of age when the decline in concentrations of ST occurred in the female calves. Similar to the results of Doherty et al. (2002), IGFBP-2 was negatively correlated with IGF-I. The positive correlation between ST and IGFBP-2 and IGFBP-3 in the males is potentially due to the delayed decrease in concentrations of ST.

The present study has provided a detailed description of the changes in serum concentrations of IGFBP-2 and IGFBP-3 in cattle during the first year of life as well as their association with growth rate, ST, and IGF-I. The delayed decrease in concentrations of ST and greater average concentrations of ST, IGF-I, and IGFBP-3 and decreased concentrations of IGFBP-2 in males compared with females are associated with the increased growth rates in males beginning at 16 wk of age. At the time differences in growth rates were observed, concentrations of IGF-I began to plateau and concentrations of IGFBP-2 and IGFBP-3 began to remain constant. Gender differences in concentrations of IGF-I, IGFBP-2, and IGFBP-3 occurred following the separation in growth rates between males and females. In conclusion, the age-related changes in the components of the somatotropic axis are associated with gender differences in growth rates.

Implications

With a more detailed description of the changes in the insulin-like growth factor-binding proteins-2 and -3 in calves, we may be able to pinpoint an age at which administration of bovine somatotropin will be more effective in beef cattle. The present study provided evidence that changes occur in insulin-like growth factor binding proteins-2 and -3 during the first year of life, which are associated with changes in growth rate. Although we cannot determine the exact age at which bovine somatotropin would be more effective, we know that, around 16 wk of age, changes in growth rate between males and females occur, as do changes in insulin-like growth-I, and insulin-like growth factor-binding proteins-2 and -3. Therefore, this may be an appropriate age to begin administration of bST.

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