Chapter 5

Influence of Testosterone on Body and Testicular Development in Zebu Cattle in the Tropical Climate

Marcelo Chacur, Alex Arikawa, Eunice Oba,
Camila Souza and Luis Roberto Gabriel Filho

Additional information is available at the end of the chapter

http://dx.doi.org/10.5772/intechopen.76706

Abstract

The Brahman cattle is mainly used for breeding and the meat industry. The present chapter had the objective of evaluating the physical and testicular development, and the serum testosterone level of 8–18 months old male Brahman cattle on grazing weight gaining performance tests. In *Bos indicus*, puberty usually occurs between the ages of 16 and 18 months. Variables such age, weight, and scrotal circumference were equally important in the estimation of sexual maturity in male *Bos indicus.* An increase in serum testosterone level occurred between 12 and 14 months of age, followed by testicular and body growth. An elevation in testosterone levels is an indicator that an acceleration in physical and testicular growth is approaching. The variables body weight and scrotal circumference which are important in the estimation of sexual maturity are dependent on testosterone levels in zebu cattle according to literature. It is recommended to calculate body mass index and testicular volume to follow male growth due to the high correlation between these variables.

Keywords: hormone, *Bos indicus*, body measurement, scrotal circumference, testicular volume

1. Introduction

Brahman cattle are known for their extreme tolerance to heat and are widespread in tropical regions. The rapid physical development and acceleration of weight gain during the puberty of male specimens of beef cattle breeds stems from the increase in testosterone [1]. Zebu beef cattle breeds exhibit greater adaptability to tropical climates, as their relative testosterone decrease is smaller than that of European breeds during the summer [2]. The study of puberty in young zebus is of great importance, due to selection of sexually precocious (i.e. below the average herd age) future breeders [3]. In *Bos indicus*, puberty usually occurs between the ages of 16 and 18 months [4, 5], but these males are seldom used for breeding purposes before the age of 2 [6, 7]. Variables such as age, weight, and scrotal circumference were equally important in the estimation of sexual maturity in male *Bos indicus* [8]. The variables body weight and scrotal circumference which are important in the estimation of sexual maturity are dependent on testosterone levels in zebu cattle according to literature.

The American Brahman was the first beef cattle breed developed in the United States. The Brahman is mainly used for breeding and the meat industry. It has been crossbred extensively with *Bos taurus taurus* (European) beef breeds of cattle.

The climatic factors has been studied with a focus on physical characteristics and sperm morphology in cattle in the tropics, describing the decline in semen quality can occur due to thermal discomfort of the animals on high temperatures [9]. The decrease in semen motility, the reduction of concentration and increase the percentage of abnormal spermatozoa are caused by a moderate elevation of scrotal temperature [10]. In Brazil, a higher percentage of abnormal sperm after high temperature and relative humidity observed a higher ejaculate volume in the rainy season [11]. Studying the Nellore cattle concluded that semen characteristics may be affected by environment, by high ambient temperature, air humidity and photoperiod [12]. Studies on the environmental influence on semen quality in bulls have been conducted in farmers with bulls in permanent regime of semen collection [8]. There was a positive correlation between serum testosterone concentration and *potentia coeundi* of bulls, it was also found that animals with higher sperm motility showed, on average, higher concentration of testosterone [13]. Considering the predominance of extensive farming and natural mating in Brazil becomes important to investigate the seasons influence on semen characteristics of bulls raised on tropical climate.

The study of bovine physical development involves serial data collection of body and testes biometrics associated with hormonal concentrations [14]. The male reproductive organs develop rapidly during puberty in cattle [15]. Physical development studies of zebus mainly evaluate body weight and average weight gain [16, 17]. For proper sperm production, transport, maturation and storage, one of the factors that should be considered is the preserved anatomy of the organs of scrotal contents, which is associated with the proper production of testosterone. In [18], reported that the temperature of the testes of cattle should be below body temperature for the production of morphologically viable sperm cells and that elevated ambient temperatures cause a reduced quality of semen from bulls with incompetent testicular thermoregulation.

For the Nellore males, a decrease in testosterone levels in hot summer, possibly due to the freedom of bulls to physical activity, associated with a higher ambient temperature (26.8°C). In winter season, with ambient temperature lower (21.1°C), associated with decreased quality of pasture, testosterone levels were lower similar to [19]. The level of individual adaptation to climate can influence testosterone levels, being studied by this consideration in male bovines [20], reporting different levels of testosterone with 24.04 ± 5.89 ng/dL for the ambient temperature group and 49.85 ± 6.83 ng/dL for the thermal stress group. The results of this study

http://dx.doi.org/10.5772/intechopen.76706

in Brahman raised in Brazil were similar to [21] who performed measurements of testosterone levels in cattle, describing the winter average of 50 ng/dL, in the fall 70 ng/dL, and in the spring and summer of 130 ng/dL.

According to [14], the testicular volume (TV) is one of the important variables when studying reproductive performance of male cattle. In [22] suggested measuring the scrotal circumference in beef cattle from weaning as a way to assist the selection of future breeders. In [14] reported that testes grow rapidly during bovine puberty due to the significant increase in serum testosterone concentration.

The importance of the present chapter on young male Brahman cattle stems from the need to expand knowledge inherent to this breed, as the use for natural breeding in extensive farming system increases, from the transfer to females returning to estrus after hormonal protocol for fixed time with artificial insemination, and from the need to sexual precocity. Many beef cattle breeders still select animals for natural breeding by measuring scrotal circumference and weight gain, without knowledge of variables related to body morphometry, reproductive system, and testosterone level that add helpful information in the choice of these bulls for breeding. In Brazil, the study of body morphometry, the reproductive system, and the serum concentration of testosterone from weaning to the age of 1 year old in the Brahman breed is still underdeveloped.

1.1. Description of the animal model

Male Brahman cattle (n = 40) with a mean age of 259.76 ± 26.15 days and body weight (BW) of 239.71 ± 33.94 kg were evaluated simultaneously during a collective grazing weight gaining performance (WGP) tests, maintained with *Brachiaria brizantha*, mineral mixture and water *ad libitum* (Capacity 0.8–1.0 AU ha^{-1}). The WGP was held on a rural property belonging to the municipality of Uberaba-MG, latitude 19°44′52″S, longitude 47°55′55″W, altitude of 823 m, with high altitude tropical climate, between the months of June and April, for a total of 294 days.

We have previously published part of this work [19]. The present chapter had the objective of studying the morphological and testicular development, and the serum testosterone concentration of 8–18 months old Brahman males on grazing weight gaining performance tests, to assist in the selection of young bulls. The results could be extrapolated from a global context.

2. Correlation of testosterone with body weight and morphometry of the reproductive system

An increase in serum testosterone level occurred between 12 and 14 months of age, followed by testicular and body growth. An elevation in testosterone levels is an indicator that an acceleration in physical and testicular growth is approaching. For body weight (BW), scrotal circumference (SC) and girth (G), there were differences ($P < 0.05$) between the ages of 12, 14, and

16 months, with increasing values (**Table 1** and **Figure 1**). At 10 months of age, all variables exhibited similar behaviors, with increase observed between 12 and 16 months.

The behavior emphasizes the importance of verifying the correlation between these variables, which can be seen in **Table 2**.

Collection	Age (months)	Weight (kg)	SC (cm)	G (m)
1	8	239.71 ± 33.94 C	.....	.....
2	10	261.76 ± 29.76 C	21.31 ± 1.83 C	1.46 ± 0.06 C
3	12	252.38 ± 30.16 C	22.11 ± 2.14 C	1.48 ± 0.06 C
4	14	298.46 ± 27.78 B	23.96 ± 2.55 B	1.55 ± 0.06 B
5	16	353.60 ± 29.66 A	26.76 ± 2.58 A	1.65 ± 0.05 A
6	18	378.16 ± 31.49 A	27.77 ± 2.77 A	1.70 ± 0.08 A

Legend: A, B, C - Capital letters in different columns differ among themselves (P <0.05).

Table 1. Mean values and standard deviations for body weight (W), scrotal circumference (SC) and girth (G) measured every 56 days in male Brahman breed animals aged between 259 days (1st collection) and 497 days (6th collection), created extensively in collective grazing weight gaining performance tests, Uberaba-MG.

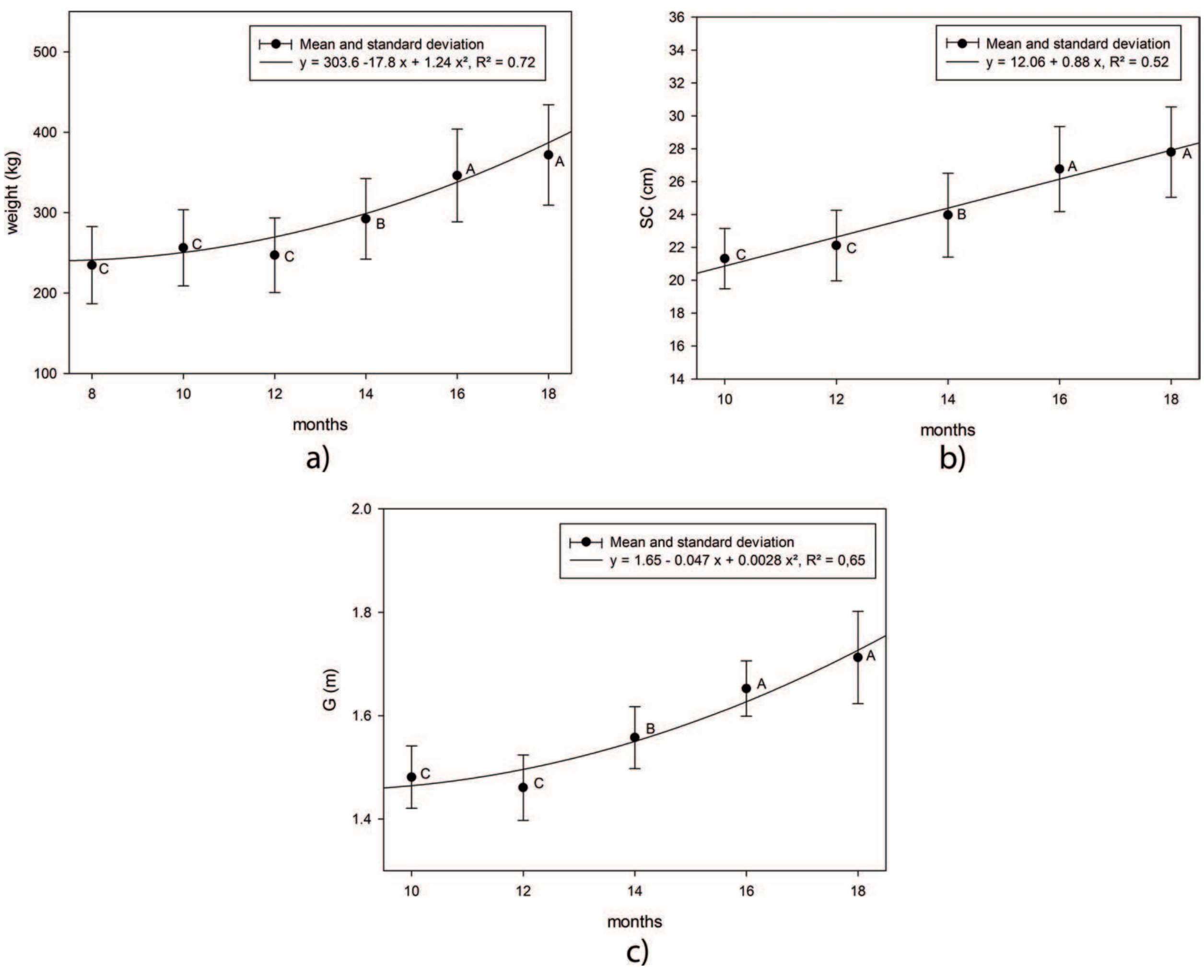

Figure 1. Polynomial models of body weight (W) (quadratic), scrotal circumference (SC) (linear) and girth (G) (quadratic) as a function of animal age. (A) Weight, (B) SC and (C) G.

	SC	G	WH	BL	BMI	ADG	RTL	RTH	LTL	LTH	TV	ST
Weight	0.83	-	-	-	0.76	0.36	0.64	0.81	0.56	0.75	0.71	0.56
SC		-	-	-	0.65	0.50	0.79	0.91	0.75	0.90	0.91	0.41
TP			1	1	-0.46	-	-	-	-	-	-	0.34
WH				1	-0.46	-	-	-	-	-	-	0.39
BL					-0.46	-	-	-	-	-	-	0.40
BMI						0.62	0.43	0.61	0.42	0.62	0.52	0.40
ADG							0.54	0.65	0.45	0.56	0.57	-
RTL								0.74	0.85	0.70	0.89	-
RTH									0.68	0.93	0.87	0.23
LTL										0.72	0.87	-
LTH											0.87	0.21
TV												0.22

Legend: variable pairs with a positive correlation coefficient tend to increase together; variable pairs with negative correlation coefficients, one variable tends to decrease as the other increases. For pairs with the "-" symbol, there is no relationship between the two variables, P <0.05.

Table 2. Significant correlations (P < 0.01) between the physical and testicular biometric characteristics measured every 56 days in male Brahman cattle aged between 259 days (1st collection) and 497 days (6th collection), raised extensively in collective grazing weight gaining performance tests, Uberaba-MG. 2012/2013.

The same table shows correlation between these variables, between scrotal circumference and body weight (0.85). Thus, a curve for the prediction of scrotal circumference as a function of body weight can be generated, creating a prediction model to help producers and researchers determine scrotal circumference as a function of body weight (**Figure** 2**a**). It is worth mentioning the correlation between the variables body weight and testosterone level (ST), the highest correlation (0.56) found for the latter variable, which similarly justified a testosterone level prediction curve as a function of body weight (**Figure** 2**b**).

As the Brahman bulls kept growing, several significant positive correlations between body morphometry and reproductive organs variables were expected. According to **Table 2**, there was a high correlation between testicular volume (TV) and body weight ($r = 0.70$; $P < 0.01$); TV × scrotal circumference ($r = 0.90$; $P < 0.01$), and TV × body mass index ($r = 0.93$; $P < 0.01$). Positive correlations ($P < 0.01$) were also observed between scrotal circumference and age ($r = 0.72$), body weight ($r = 0.83$), testicular length ($r = 0.74$), and testicular height ($r = 0.89$).

Positive correlations asserted the influence of testosterone on body morphometry: testosterone ST × G ($r = 0.38$; $P < 0.01$); testosterone ST × weight WH ($r = 0.38$; $P < 0.01$); testosterone ST × right testicle RTH ($r = 0.23$; $P < 0.05$); testosterone ST × left testicle LTH ($r = 0.21$; $P < 0.01$); and testosterone ST × testicular volume TV ($r = 0.22$; $P < 0.008$) (**Table 2**).

For height at the withers (WH), body length (BL), and body mass index (BMI), the behavior is analogous to mean differences with male age, with differences ($P < 0.05$) between 14 and 16 months (**Table 3** and **Figure 3**). It is worth noting that the only correlation with scrotal circumference is given by the body mass index variable ($r = 0.76$) (**Table 2**). This result is expected, since body mass index is obtained directly from the body weight, and also by the

Collection	Age (months)	WH (m)	BL (m)	BMI (kg. m^{-2})
1	8	.....	.....	.....
2	10	1.16 ± 0.03 B	1.19 ± 0.04 B	193.15 ± 16.74 B
3	12	1.17 ± 0.03 B	1.21 ± 0.04 B	181.55 ± 16.80 B
4	14	1.18 ± 0.03 B	1.21 ± 0.04 B	212.05 ± 15.60 B
5	16	1.24 ± 0.04 A	1.29 ± 0.03 A	227.90 ± 17.05 A
6	18	1.26 ± 0.03 A	1.29 ± 0.04 A	236.87 ± 18.02 A

Legend: A, B, C - Capital letters in different columns differ among themselves ($P < 0.05$).

Table 3. Mean values and standard deviations for height at the withers (WH), body length (BL), and body mass index (BMI) measured every 56 days in male Brahman cattle aged between 259 days (1st collection) and 497 days (6th collection), raised extensively in collective grazing weight gaining performance tests, Uberaba-MG.

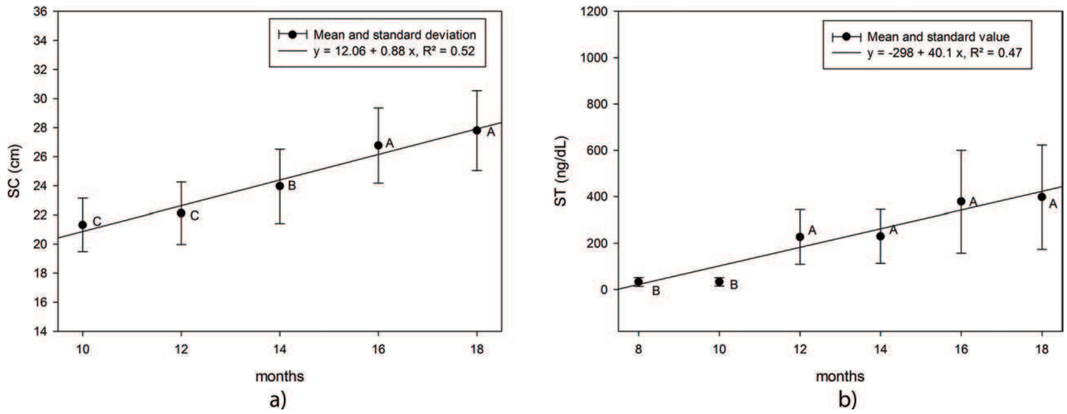

Figure 2. Linear models of scrotal circumference (SC) and testosterone (ST) as a function of weight. (A) SC and (B) ST.

similarity of these variables according to the Dendrogram of **Figure 4**. The correlation of the latter variable with scrotal circumference greater than that between body mass index and scrotal circumference, which does not justify the need to create a model for scrotal circumference prediction at this point.

The analysis of the Dendrogram (**Figure 3**) emphasizes the similarity of the cluster of variables related to the weight (weight, body mass index BMI, ADG), with the group of variables related to the morphology of the reproductive tract (scrotal circumference SC, testicular volume TV, right testicle RTH, left testicle LTH, right testicle length RTL, left testicle length LTL) and the group of variables related to physical morphometry (G, WH, BL); the lack of similarity of testosterone (ST) to any other variable is also noted. Thus, correlations between variables of different groups are of great interest as they reveal relationships that, unlike the correlation between body mass index and weight, are not obvious.

Specifically, it is possible to relate the four groups. Multiple polynomial regression was employed to predict the level of testosterone (ST) using one (1) variable from each group, in search of the one with the highest correlation to ST. According to **Table 2**, such variables and their correlations are weight (0.56), scrotal circumference (0.41), and body length (0.40), thereby generating the polynomial:

http://dx.doi.org/10.5772/intechopen.76706

$$ST = 9236 - 21.8\,x_1 - 271\,x_2 - 9545\,x_3 + 0.01\,x_1^2 + 0.6\,x_2^2 + 952\,x_3^2 + 0.46\,x_1 x_2 + 18.8\,x_1 x_3 + 282\,x_2 x_3 - 0.61\,x_1 x_2 x_3 \quad (1)$$

With $R^2 = 0.23$ ($P < 0.001$), and x_1, x_2 and x_3 representing the variables weight, scrotal circumference SC, and body length BL, respectively. **Figure 5** shows the ST behavior upon variation of two (2) independent variables, with the third kept constant. It is thus possible to observe that in males with high scrotal circumference and low weight, or in males with low scrotal circumference and high weight, higher levels of testosterone were observed (**Figure 5a**). One can also observe that higher body length values correlate with higher testosterone levels (**Figure 5b**). The same figure shows that testosterone levels remain mostly unchanged with weight. Finally, it is worth noting that high body length values imply increased levels of testosterone (**Figure 5c**).

With respect to the height of the testes (horizontal axis), there were differences ($P < 0.05$) between 12, 14 and 16 months of age. Testes length (vertical axis) differed ($P < 0.01$) between 12 and 16 months (**Table 4** and **Figure 6**).

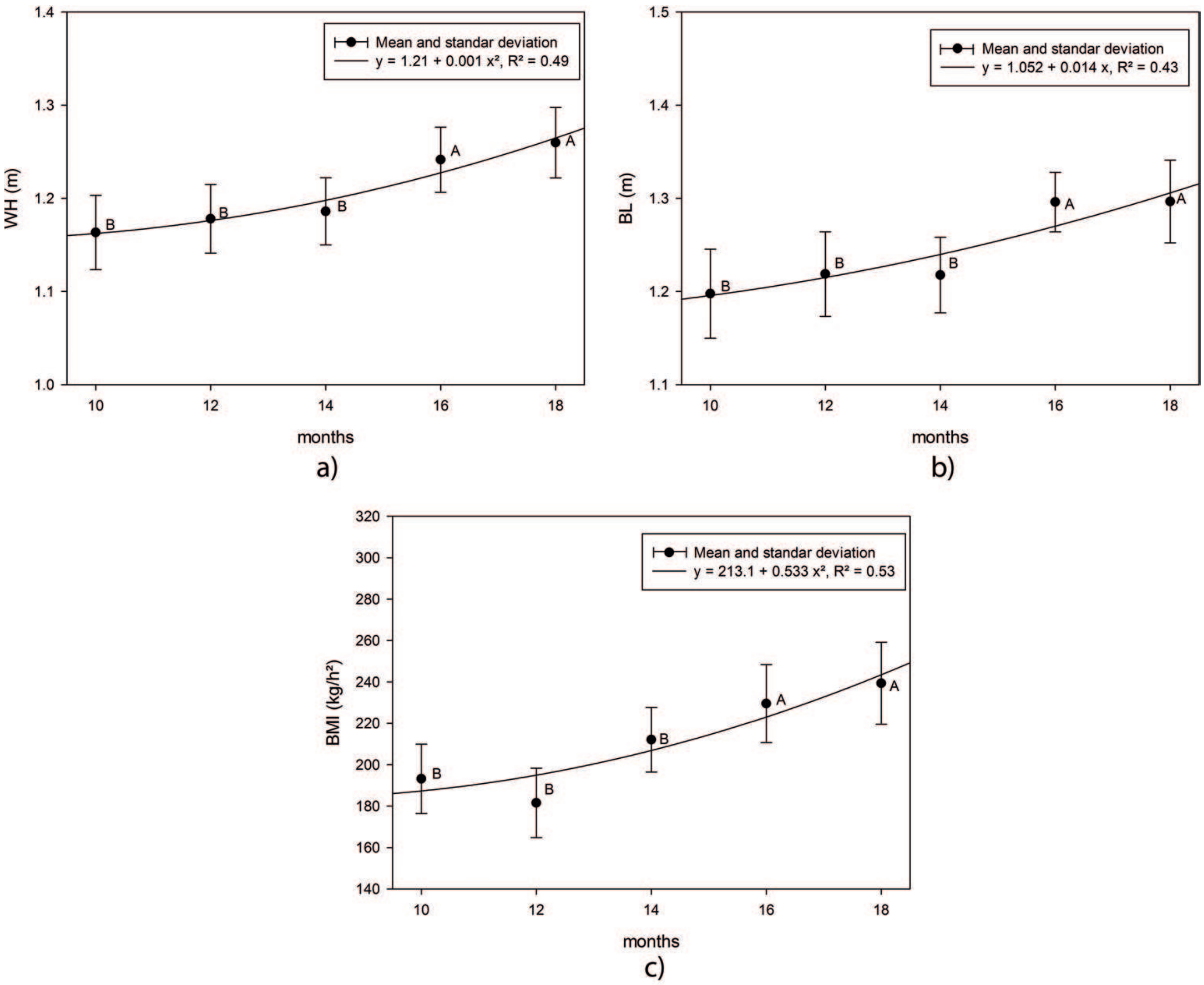

Figure 3. Polynomial (quadratic) models for height at the withers (WH), body length (BL) and body mass index (BMI) as a function n of animal age. (A) WH, (B) BL and (C) BMI.

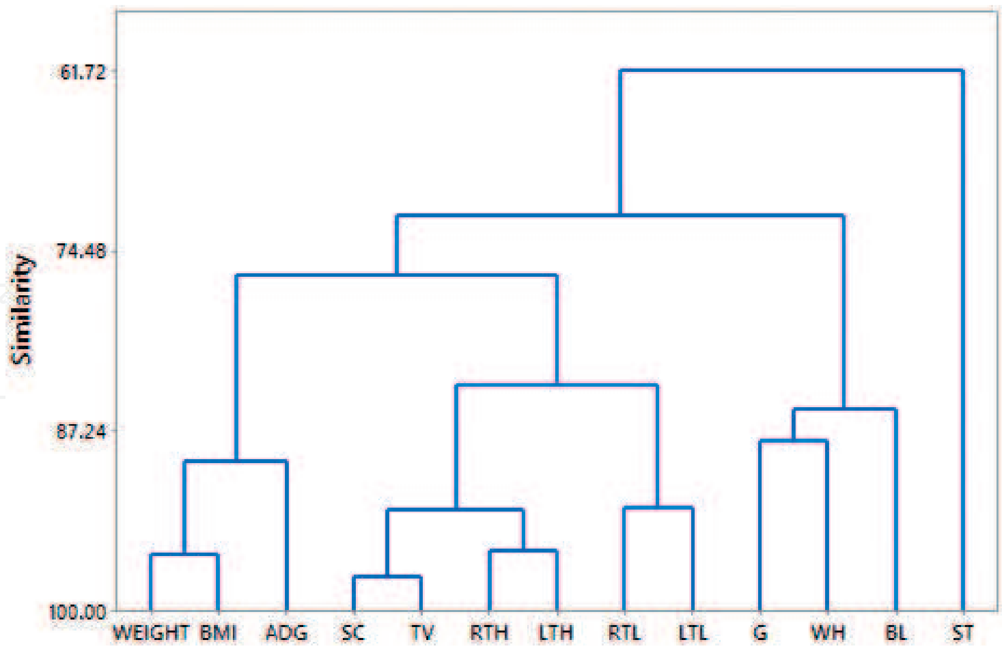

Figure 4. Dendrogram generated by multivariate analysis of variables between the body and testicular biometric characteristics in Brahman cattle males aged from 379 days (third collection) to 497 days (sixth collection).

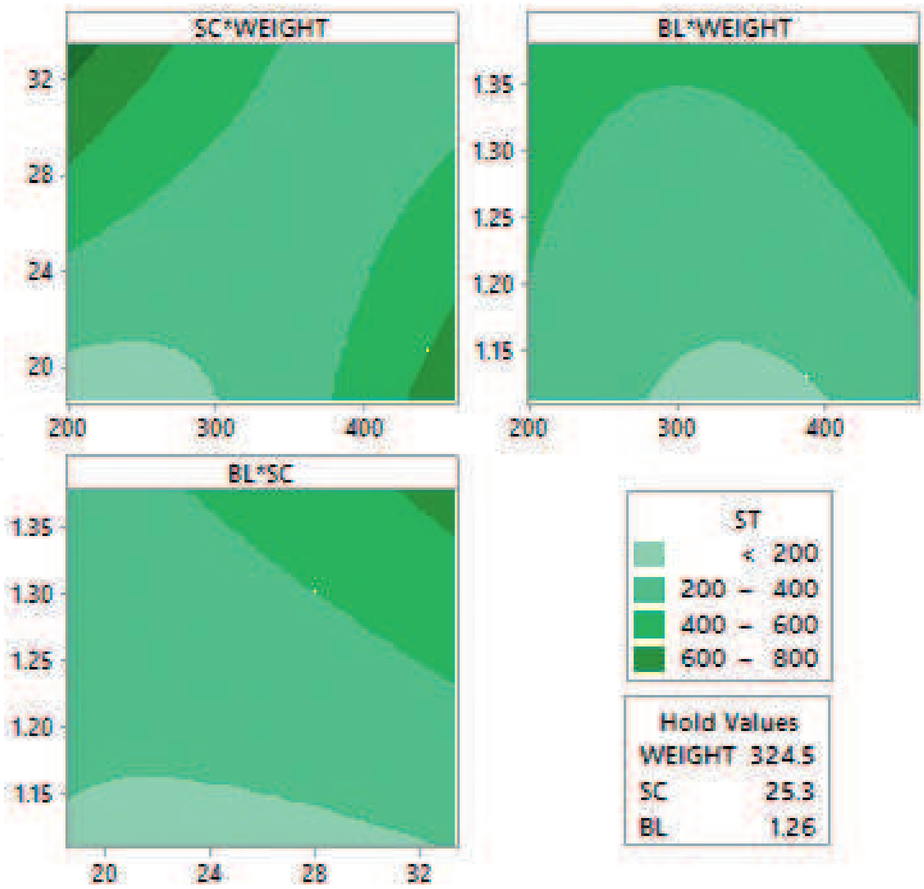

Figure 5. Surface contour maps generated by the multiple polynomial regression function at the clipping planes (a) weight = 324.5, (b) SC = 25.3, and (c) BL = 1.26.

Collection	Age (months).	RTL (cm)	RTH (cm)	LTL (cm)	LTH (cm)
1	8	.....	.....	.....	.....
2	10	.....	.....	.....	.....
3	12	7.79 ± 1.03 B	3.74 ± 0.56 C	7.74 ± 1.06 B	3.90 ± 0.49 C
4	14	8.27 ± 1.44 B	4.60 ± 0.64 B	8.11 ± 1.42 AB	4.57 ± 0.64 B
5	16	9.15 ± 1.37 A	5.11 ± 0.60 A	8.84 ± 1.21 A	5.03 ± 0.59 A
6	18	9.35 ± 1.33 A	5.44 ± 0.68 A	9.09 ± 1.36 A	5.29 ± 0.71 A

Legend: A, B, C - Capital letters in different columns differ among themselves (P <0.05).

Table 4. Mean values and standard deviations for right testicular length (RTL), right testicular height (RTH), left testicular length (LTL) and left testicle height (LTH) measured every 56 days in male Brahman cattle aged between 259 days (1st collection) and 497 days (6th collection), raised extensively in collective grazing weight gaining performance tests, Uberaba-MG.

3. Relation of testosterone with testicular volume

The daily weight gain (ADG) increased between 8, 10, 12 and 14 months of age ($P < 0.05$), but not between 14, 16 and 18 months of age ($P > 0.05$). Testicular volume differed ($P < 0.05$) between 14 and 16 months. The serum testosterone level differed ($P < 0.05$) between 10 and 12 months (**Table 5** and **Figure 7**).

Collection	Age (months)	ADG (g/day)	TV (cm³)	Testosterone (ng/ dL)
1	8	0.79 ± 0.10 A	.....	32.97 ± 19.31 B
2	10	0.69 ± 0.06 B	.....	33.40 ± 18.27 B
3	12	0.56 ± 0.07 C	154.68 ± 47.59 B	226.80 ± 117.60 A
4	14	0.69 ± 0.05 B	193.80 ± 74.90 B	229.40 ± 116.40 A
5	16	0.73 ± 0.04 AB	263.10 ± 88.60 A	378.80 ± 221.40 A
6	18	0.69 ± 0.07 B	288.80 ± 96.10 A	398.00 ± 224.50 A

Legend: A, B, C - Capital letters in different columns differ among themselves (P <0.05).

Table 5. Averages and standard deviations for average daily gain (ADG), testicular volume (TV) and testosterone (ST) measured every 56 days in male Brahman cattle aged between 259 days (1st collection) and 497 days (6th collection), raised extensively in collective grazing weight gaining performance tests, Uberaba-MG.

4. Considerations and practical application

Studies of body growth in zebu cattle focus mainly on body weight and daily weight gain evaluations [16, 17]. Body morphometry, although subjected to fewer studies, is useful in the assessment of physical growth and development [17]; body development in bulls must be assessed by testicular volume increase [14].

Assuming that the set of physical morphometry measurements opens more possibilities to evaluate body growth in young bulls, the present study measured data from regions of the

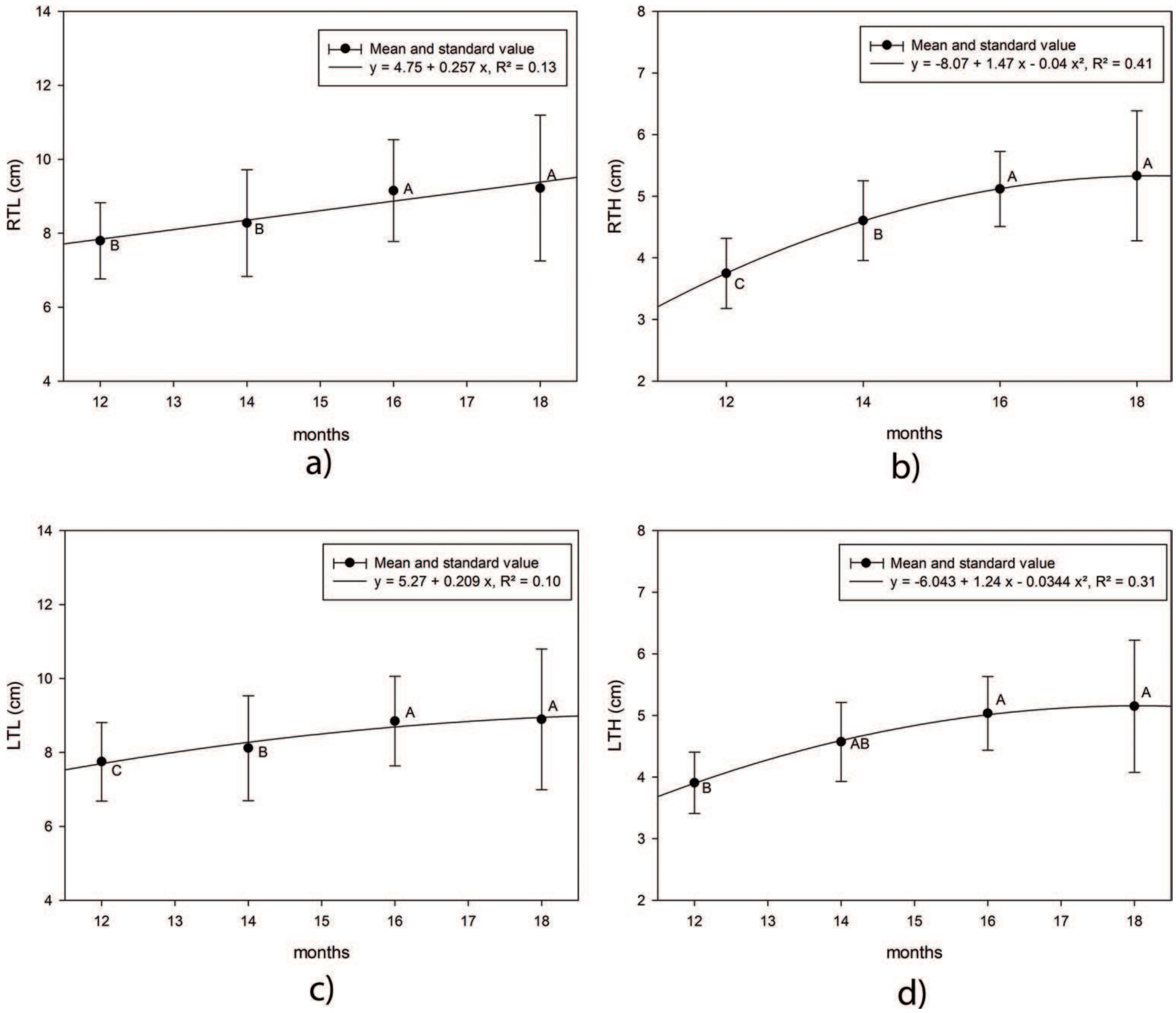

Figure 6. Polynomial models of the right testicular length (RTL) (linear), right testicular height (RTH) (quadratic), left testicle length (LTL) (quadratic) left testicular height (LTH) (quadratic) as a function of animal age. (A) RTL and (B) RTH, (C) LTL and (D) LTH.

body of Brahman bulls. Body weight and girth (G) differed ($P < 0.05$) between 12, 14 and 16 months (**Table 1**) in Brahman bulls; these differences were only observed from 14 months of age onwards in Nellore males [15]. The body weight and girth of Brahman cattle at 12 and 14 months of age (**Table 1**) were higher in Brahman males than in Nellore males [15, 23] and in dual-use Guzerat zebus [17] in the same age groups.

The body weight was lower ($P < 0.05$) at 12 months of age, compared to 10 months of age, probably due to the exclusive feeding on grazing: the quality of grass varies throughout the different seasons, and in the present study the dry season coincided with this age group, in agreement with [23] who evaluated Nellore in grazing weight gaining performance tests. However, there was no difference ($P > 0.05$) between 10 and 12 months of age for the scrotal circumference. Sexual precocity is more related to body weight than to the chronological age of bovines; thus, the analysis of several morphometric characteristics is important to guide

http://dx.doi.org/10.5772/intechopen.76706

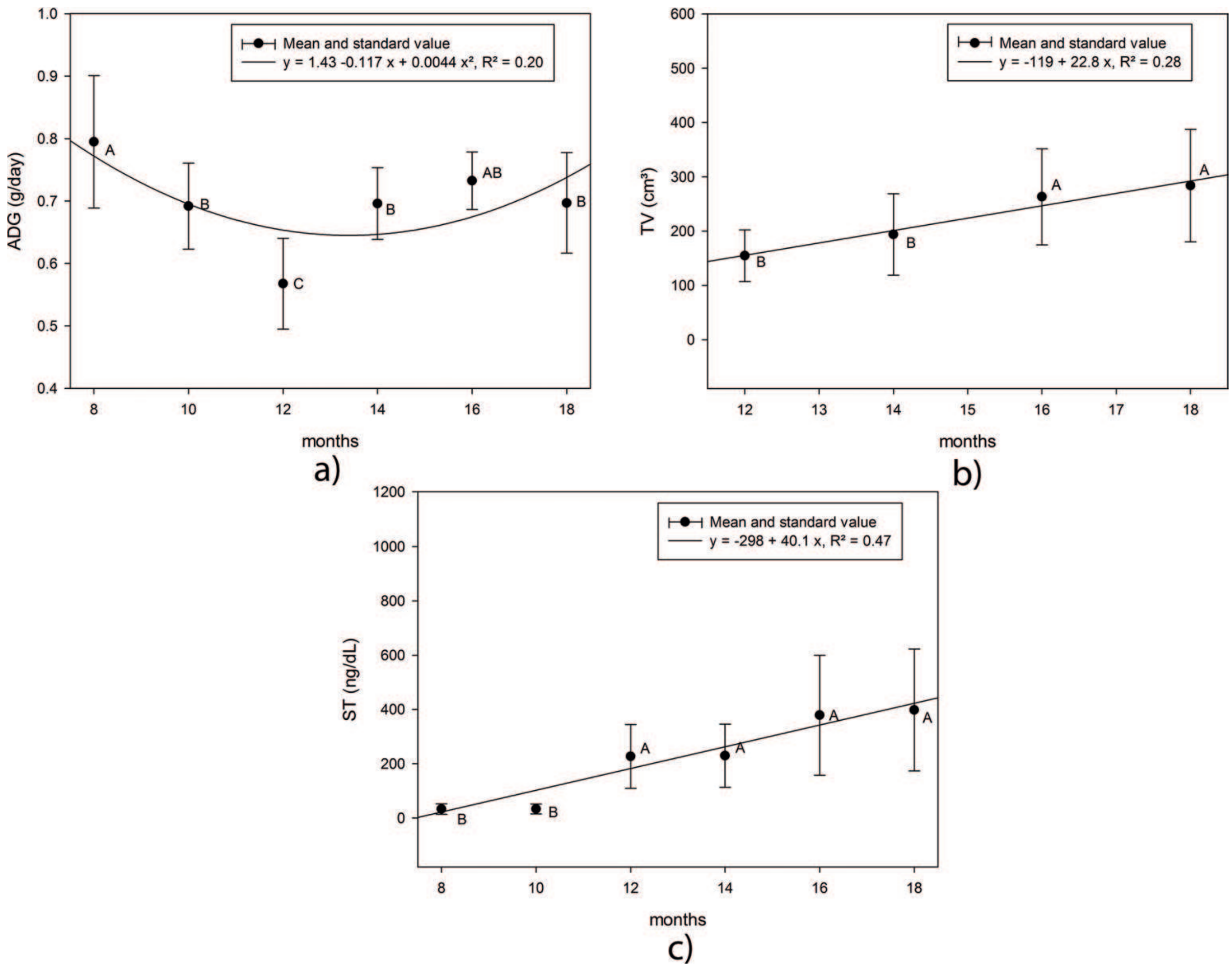

Figure 7. Polynomial models of the average daily gain (ADG), testicular volume (TV) and testosterone (ST) as a function of animal age. (A) ADH, (B) TV and (C) ST.

the selection for genetic improvement purposes [1, 3, 19]. Sexual precocity was described in Nellore cattle aged between 500 and 580 days and between 620 and 740 days of age [8]. The different studies suggest that weight differences at similar ages in young Zebus may be related to the feed composition and distinct genetic lineages.

The scrotal circumference is the body morphometry variable that best estimates the puberty phase in *Bos indicus* males [8]. Mean SC values differed ($P < 0.01$) at 12, 14 and 16 months of age (**Table 1**), similar to the report by [16] in similarly-aged Nellores. However, scrotal circumference values were higher in the present study than in [8, 15, 22]. The significant increase of scrotal circumference from 12 to 16 months in Brahman cattle is similar to that observed in Nellore cattle, probably because both are zebu breeds. On the other hand, the results of the present study revealed that significant scrotal circumference increases occur at a later age than that reported by [24] in Nellore, who reported a significant increase from nine to 12 months of age. Also in Nellore, puberty occurred at a mean age of 526 days with a mean weight of 280 kg and mean scrotal circumference of 22 cm in young bulls classified as sexually precocious [8]. There is a wide variation in scrotal circumference in relation to the age of the Zebu bulls; in the present study, Brahman males with an average weight of 240 kg at 12 months of age reached a mean scrotal circumference value of 22 cm, suggesting satisfactory sexual precocity.

There was a positive correlation between weight and scrotal circumference ($r = 0.83$; $P < 0.01$) (**Table 2**), similar to that reported by [23, 25, 26, 27] in Nellore cattle; in Brahman cattle [28, 29]; and in Guzerat cattle [30].

A correlation ($r = 0.90$; $P < 0.01$) was found for scrotal circumference × testicular volume (**Table 2**), in agreement with [31] for growing cattle, suggesting that scrotal circumference is influenced by race, body condition score, age at puberty, and breeding system; the increase in testicular weight is proportional to the increase of body weight. [32] recommended measuring the scrotal circumference to follow testicular growth in Brahman cattle. Due to the elongated shape of testes in Brahman, the calculation of the testicular volume was efficient: although the males may have slightly lower scrotal circumference, the testicular volume is compensated by the length of the gonad.

The testicular volume variable correlated with body weight ($r = 0.70$; $P < 0.01$), justifying the importance of successive weightings at fixed time intervals in growing male animals. The present study also revealed a high positive correlation ($r = 0.93$; $P < 0.01$) between testicular volume and body mass index, with the calculation of the latter being useful in monitoring animal growth, for identifying average height individuals with increased testicular volume, which can positively influence in the semen concentration. This reasoning derived from the present study, which supports and complements the report by [31] relating body weight and testicular weight; the present study supports the inclusion of the height at the withers variable to track the growth of Brahman males.

With the expansion of *Fuzzy* logic studies aimed at breeding animals [33, 34], one can mathematically model physical morphometric variable studies, attempting to predict how that variable behaves with time. Thus, the present study calculated the body mass index. In Brahman cattle, the body mass index suffered a significant increase between 14 and 16 months. The variable is easy to obtain, as it requires only body weight and measurement of height at the withers as the animal is contained in the cattle crush. By using the body mass index scoring nomenclature for the age of the animals in the present study, adopting the score published for adult zebu cattle with application of the *fuzzy* logic system according to [33, 34], the mean body mass index at ages 10 and 12 months (**Table 3**) fall in the "very low body mass index" category; the age of 14 months is classified as "low body mass index"; and the ages of 16 and 18 months are classified as "high body mass index". Brahman animals in the present study were young, with continuous increase in body mass index due to the increase in height at the withers in conjunction with gains in body weight. Fifteen animals in the present study had a body mass index greater than 242.8 kg m^{-2} at the age of 18 months (**Table 3**). The body mass index was easily accessible, requiring only a scale and a graduated metric tape; it is recommended to calculate the body mass index of young bulls, where 15 animals from a total of 40 showed a body mass index score above average, suggesting a good weight-height ratio. The collection of body mass index data for growing zebu bulls must be expanded, to allow the construction of an ideal physiological variation for each age group.

Body length, like height at the withers and body mass index, showed a significant increase between 14 and 16 months due to the rapid increase of those variables. Testes length and height showed differences ($P < 0.05$) between 12, 14 and 16 months (**Table 4**). These differences were obtained at younger ages than those reported by Freneau et al. [15] in Nellore (15–17 months old).

Zebu physical development studies mainly evaluate body weight and average weight gain [16, 17, 35]. The average daily weight gain of the present study was similar to that described by [35] in Brahman cattle in the same age groups, and higher than the daily weight gain reported in Nellore by [36]. The present study showed differences ($P < 0.05$) between 12, 14 and 16 months of age for body weight, and between 12 and 14 months for daily weight gain. Body weight values were achieved at a younger age than those reported in Nellore by [29], who exhibited a significant increase in body weight between 15 and 16 months of age. Although both the Brahman and Nellore breeds are zebu breeds, the difference may stem from the different geographical locations of the studies.

Testicular volume was described as a suitable variable for the evaluation of post-pubertal *Bos indicus* males [8]. Measurements of the length, width and height of the testes axes are useful for evaluating testicular symmetry and calculating testes volume [23, 37]. At 12 and 18 months of age, the length, width and volume of testes were higher than the values reported in Nellore cattle by [23] at the same age groups. The testicular volume differed ($P < 0.05$) between 14 and 16 months (**Table 5**). This difference was obtained later than in the studies by [26], who described larger testicular development between 10 and 16 months of age, with a significant development between 10 and 11 months, and [29] who observed a greater variation of the SC from 10 months of age. Since the scrotal circumference is used in the calculation of the testicular volume, the former influences testicular volumetry; thus, In [23] suggested that in Zebus, who generally exhibit elongated testes, testicular volume and scrotal circumference should be adopted simultaneously to evaluate growth.

The rapid body development and acceleration of weight gain in the puberty of male beef breed cattle is associated with the increase in testosterone production [1]. Zebu breeds exhibit greater adaptability to the tropical climate, with a lower relative testosterone decrease in the summer compared to European breed bulls [38].

The serum testosterone differed ($P < 0.05$) between 10 and 12 months (**Table 5**), preceding a significant increase in morphological variables. At 12 months of age, the serum testosterone concentration in Brahman males was similar to that found in Nellore cattle aged 31 and 35 months by [37], and in crossbred Holstein × Thaparkar males between 9 and 12 months of age by [3]. In the present study, Brahman males produced similar levels of testosterone at younger ages than Zebus [37], and in the same age group as crossbred cattle [3], revealing sexual precocity.

High correlation ($r = 0.74$) between scrotal circumference and serum testosterone was observed, highlighting the hormonal influence on the development of testes. In agreement with [14, 29], the elevation of testosterone occurs prior to the rapid growth of the testes. Testicular development occurs slowly before the significant increase of the testosterone; gonad growth peaks during puberty, followed once more by slow growth, indicative of sexual maturity. In the present study, the high positive correlation between the concentration of testosterone and scrotal circumference renders measurement of the latter a good indicator of puberty, confirming reports by [1, 2, 8].

In growing Brahman males, the evaluated morphometric variables were useful to follow the physical development. From 12 to 14 months, body weight, scrotal circumference and girth increased rapidly, while the other variables rose significantly at 14 months of age. Due to the growth of the animals, high positive correlations were found between physical and testicular morphometric variables. There was a correlation between age and weight ($r = 0.80$; $P < 0.01$), similar to that described in Brahman cattle [32]. At the ages of 16 and 18 months, scrotal circumference and body weight values were similar to and higher than those reported in Nellore by [38], respectively.

5. Conclusions

In young Brahman bulls an increase in serum testosterone level occurred between 12 and 14 months of age, followed by testicular and body growth. An elevation in testosterone levels is an indicator that an acceleration in physical and testicular growth is approaching. The testicular development and the serum testosterone concentration differ between Brahman and *Bos taurus*. In view of the results presented herein, the present chapter contributes with the Brahman breed with mean values and significant correlations on body and reproductive tract morphometry variables, which are useful in practical use and in the selection of young bulls bred in extensive management feeding on grass and mineral mix. Regarding puberty, it is clear that the increase in serum testosterone occurs to prepare the reproductive tract for rapid anatomical development. The results of this study provide new knowledge and should be considered in the field of bovine reproduction.

Acknowledgements

Foundation for Research Support of São Paulo State (FAPESP), National Council for Scientific and Technological Development and the Brazilian Association of Zebu Breeders.

Author details

Marcelo Chacur[1]*, Alex Arikawa[2], Eunice Oba[3], Camila Souza[2] and Luis Roberto Gabriel Filho[4]

*Address all correspondence to: marcelo.chacur@uol.com.br

1 University of Western São Paulo, UNOESTE, President Prudente, Brazil

2 UNOESTE, President Prudente, Brazil

3 University of São Paulo State, UNESP, Botucatu, Brazil

4 University of São Paulo State, UNESP, Tupã, Brazil

References

[1] Reddy VB, Sivakumar AS, Jeong DW, Woo YB, Park SJ, Lee SY, Byun JW, Kim CH, Cho SY, Hwang I. Beef quality traits of heifer in comparison with steer, bull and cow at various feeding envinronments. Animal Science Journal. 2014;**86**:1-16. DOI: 10.1111/asj.12266

[2] Quezada-casasola A, Martínez-armendáliz KE, Carrera-chávez JM, Pérez-eguía E, Rodríguez-alarcón CA, Avendaño-reyes L. Effect of season on scrotal circumference, semen characteristics and testosterone serum concentration in Mexican Corriente and other beef breed bulls. Animal Reproduction. 2016;**13**:787-794. DOI: 10.21451/1984-3143-AR805

[3] Kumar B, Pandita S, Prakash BS, Mallick S, Mili B. Responsiveness of prepubertal crossbred bull calves to exogenous GnRH and its impacts on reproductive hormones under on tropical conditions. Springer Plus. 2016;**8**:288-292. DOI: 10.1186/s40064-016-1956-4

[4] Wolf FR, Almquist JO, Hale EB. Prepuberal behaviour and puberal characteristics of beef bulls on high nutrient allowance. Journal of Animal Science. 1965;**24**:761-765 https://doi.org/10.2527/jas1965.243761x

[5] Lunstra DD, Ford JJ, Echternkamp SE. Puberty in beef bulls: Hormone concentrations, growth, testicular development, sperm production and sexual aggressiveness in bulls of different breeds. Journal of Animal Science. 1978;**46**:1054-1062. DOI: 10.5433/1679-0359.2017v38n4Supl1p2561

[6] Chenoweth JP, Chase CC Jr, MJD T, Wilcox CJ, Larsen RE. Breed and other effects on reproductive traits and breeding soundness categorization in young beef bulls in Florida. Theriogenology. 1996;**46**:1159-1170 https://doi.org/10.1016/S0093-691X(96)00287-7

[7] ValefilhoVR,BergmannJAG,AndradeVJ,QuirinoCR,ReisSR,MendonçaRMA.Andrologic characterization of Nelore bulls selected for the first breed season. Revista Brasileira de Reprodução Animal. 1997;**21**:42-44. DOI: 10.5433/1679-0359.2017v38n4Supl1p2561

[8] Brito LFC, Silva AEDF, Unanian MM, Dode MAN, Barbosa RT, Kastelic JP. Sexual development and early- and late-maturing *Bos indicus* and *Bos indicus* × *Bos taurus* crossbred bulls in Brazil. Theriogenology. 2004;**62**:1198-1217 https://doi.org/10.1016/j.theriogenology.2004.01.006

[9] Galina CS, Arthur GH. Review of cattle reproduction in the tropics. Part 6. The male. Animal Breeding Abstract. 1991;**59**:403-412

[10] Kastelic JP, Cook RB, Coulter GH. Insulating the scrotal neck affects semen quality and scrotal/testicular temperatures in the bull. Theriogenology. 1996;**45**:935-942 https://doi.org/10.1016/0093-691X(96)00023-4

[11] Silva AR, Ferraudo AS, Perecin D. Effect of the age of the bull and the sêmen collection periods on physical and morphological semen characteristics of European and zebu breeds. Revista Brasileira de Zootecnia. 2009;**38**:1218-1222 http://dx.doi.org/10.1590/S1516-35982009000700009

[12] Fonseca VO, Franco CS, Bergmann JAG. Reproductive and economic potential of Nellore bulls mating in the proportion bull:cow 1:80. Arquivo Brasileiro de Medicina Veterinária e Zootecnia. 2000;**52**:77-82 http://dx.doi.org/10.1590/S0102-09352000000100017

[13] Anderson M. Relationship between GnRH-induced sperm motility and fertility in Ayrshire bulls. Animal Reproduction Science. 1992;**27**:107-111 https://doi.org/10.1016/0378-4320(92)90050-N

[14] Bergmann JAG. Seleção de zebuínos para precocidade sexual. In: Simpósio de produção de gado de corte; 1999. Belo Horizonte: UFMG; 1999. pp. 51-54

[15] Freneau GE, Vale filho VR, Marques JRAP, Maria WS. Puberdade em touros Nelore criados em pasto no Brasil: características corporais, testiculares e seminais e de índice de capacidade andrológica por pontos. Arquivo Brasileiro de Medicina Veterinária e Zootecnia. 2006;**58**:1107-1115 https://doi.org/10.1590/S0102-09352006000600020

[16] Lôbo RNB, Villela LCV, Lobo AMBO, Passos JRS, Oliveira AA. Parâmetros genéticos de características estimadas da curva de crescimento de ovinos da raça Santa Inês. Revista Brasileira de Zootecnia. 2006;**35**:1012-1019 Suplemento. https://doi.org/10.1590/S1516-35982006000400011

[17] Pacheco A, Quirino C, Pinheiro O, Almeida JVC. Medidas morfométricas de touros jovens e adultos da raça Guzerá. Revista Brasileira de Saúde e Produção Animal. 2008;**9**:426-435. ISSN 1519 9940

[18] Coulter GH, Serenger PL, Bailey DRC. Relationship of scrotal surface temperature measured by infrared thermography to subcutaneous and deep testicular temperature in the ram. Journal of Reproduction and Fertility. 1988;**84**:417-423. DOI: 10.1530/jrf.0.0840417

[19] Chacur MGM, Aurélio PTF, Oba E, Laposy CB, Scalon Júnior O, Inague L, Kronka S.N. Influency of one nutraceutic on semen, testosterone, cortisol, eritrogram and body weight in young bulls Bos taurus indicus. Semina Agrárias. 2010;**31**:439-450. DOI: http://dx.doi.org/10.5433/1679-0359.2010v31n2p439

[20] Chacur MGM, Oba E. Heat stress in buffalo bulls Bubalus bubalis, evaluations of reproduction phisiologycal characteristics. Veterinária Notícias. 2005;**11**:111-112

[21] Jimenez-Severiano H, Quintal-Franco J, Veja-Murillo V. Season of the year influences testosterone secretion in bulls administered luteinizing hormone. Journal of Animal Science. 2003;**81**:1023-1029. DOI: 10.2527/2003.8141023, 10.2527/2003.8141023x

[22] Neves ALA, Delrei AJ, Santos MP. Crescimento testicular de touros da raça Nelore. Livestock Research for Rural Development, Cali. 2011;**23**(4) Available from: http://www.lrrd.org/lrrd23/4/neve23093.htm. [Accessed: 2017-06-05] Acesso em: 05 jun. 2017

[23] Unanian MM, Silva AEDF, McManus C, Cardoso EP. Características biométricas testiculares para avaliação de touros zebuínos da raça Nelore. Revista Brasileira de Zootecnia. 2000;**29**:136-144. DOI: 10.1590/S1516-35982000000100019

[24] Boligon AA, Baldi F, Albuquerque LG. Genetic parameters and relationship between growth traits and scrotal circumference measured at different ages in Nellore cattle. Genetics and Molecular Biology. 2011;**34**:225-230 http://dx.doi.org/10.1590/S1415-47572011005000004

[25] Valentim R, Arruda RP, Barnabe RC, Alencar MM. Biometria testicular de touros Nelore (Bos taurus indicus) e touros cruzados Nelore-europeu (*Bos taurus indicus* × *Bos taurus taurus*) aos 20 e 24 meses de idade. Brazilian Journal of Veterinary Research and Animal Science. 2002;**39**:113-120. DOI: http://dx.doi.org/10.1590/S1413-95962002000300001

[26] Forni S, Albuquerque LG. Avaliação das características biométricas de testículos de bovinos Nelore. In: simpósio da sociedade brasileira de melhoramento animal. Vol. 2004. Pirassununga: Editora da Sociedade Brasileira de Melhoramento Animal; 2004. pp. 1-3

[27] Pastore AA, Toniollo GH, Lôbo RB, Fernandes MB, Vozzi PA, Vila RA, Galerani MAV, Elias EP, Cardilli DJ. Características biométricas, testiculares, seminais e parâmetros genéticos de touros pertencentes ao programa de melhoramento genético da raça Nelore. ARS Veterinária. 2008;**24**:134-141. DOI: http://dx.doi.org/10.15361/2175-0106.2008v24n2p134-141

[28] Mota MF, Souza JC, Machado CHC, Pinto Neto A, Freitas JÁ, Cezaro FR. Evolução Fenotípica de características produtivas e reprodutivas avaliada pela biometria corporal de machos da Raça Brahman. In: Congresso mundial da raça brahman, 2010. Uberaba: ABCZ; 2010. pp. 1-5

[29] Moura AAA, Rodrigues GC, Martins filho R. Desenvolvimento ponderal e testicular, concentrações periféricas de testosterona e características de abate em touros da raça Nelore. Revista Brasileira de Zootecnia. 2002;**31** Suplemento:934-943. DOI: https://doi.org/10.1590/S1516-35982002000400017

[30] Dias J, Andrade V, Emerick L, Martins JÁ, Vale Filho VR, Silva MA. Teste da libido em touros jovens Guzerá e suas associações com características reprodutivas e níveis séricos de testosterona. Archives of Veterinary Science. 2009;**14**:204-213. DOI: http://dx.doi.org/10.5380/avs.v14i4.16202

[31] Menegassi SRO, Barcellos JOJ, Peripolli V, Pereira PRRX, Borges JBS, Lampert VN. Measurement of scrotal circumference in beef bulls in Rio Grande do Sul. Arquivo Brasileiro de Medicina Veterinária e Zootecnia. 2011;**63**:87-93. DOI: http://dx.doi.org/10.1590/S0102-09352011000100014

[32] Vásquez L, Vera O, Arango J. Testicular growth and semen quality in peripuberal Brahman bulls. Livestock Research for Rural Development, Cali. 2003;**15**(10). Available from: http://www.lrrd.org/lrrd15/10/vasqcit.htm) Accessed: 2017-06-05

[33] Gabriel Filho LRA, Cremasco CP, Putti FF, Chacur MGM. Application of fuzzy logic for the evaluation of livestock slaughtering. Engenharia Agrícola. 2011;**31**:813-825. DOI: http://dx.doi.org/10.1590/S0100-69162011000400019

[34] Gabriel Filho LRA, Putti FF, Cremasco CP, Bordin D, Chacur MGM, Gabriel LRA. Software to assess beef cattle body mass through the fuzzy body mass index. Engenharia Agrícola. 2016;**36**:179-193. DOI: http://dx.doi.org/10.1590/1809-4430-Eng.Agric.v36n1p179-193/2016

[35] Olmedo DO, Barcellos JOJ, Canellas LC, Velho MMS, Paniagua P, Horitá I, Tarouco JU. Desempenho e características da carcaça de novilhos terminados em pastejo rotacionado ou em confinamento. Arquivo Brasileiro de Medicina Veterinária e Zootecnia. 2011;**63**:348-355. DOI: https://doi.org/10.1590/S0102-09352011000200012

[36] Ribeiro ELA, Hernandez JÁ, Zanella EL, Mizubuti IY, Silva LDF, Reeves JJ. Desempenho e características de carcaça de bovinos de diferentes grupos genéticos. Revista Brasileira de Zootecnia. 2008;**37**:1669-1673. DOI: https://doi.org/10.1590/S1516-35982008000900020

[37] Ruediger FR, Chacur MGM, Alves FCPE, Oba E, Ramos AA. Digital infrared thermography of the scrotum, semen quality, serum testosterone levels in Nellore bulls (Bos taurus indicus) and their correlation with climatic factors. Semina: Ciências Agrárias. 2016;**37**:221-232. DOI: 10.5433/1679-0359.2016v37n1p221

[38] Lopes JS, Rorato PRN, Weber T, Comin JG, Araújo RO. Fatores de correção para perímetro escrotal ao sobreano para tourinhos mestiços Aberdeen Angus x Nelore. Arquivo Brasileiro de Medicina Veterinária e Zootecnia. 2009;**61**:413-419. DOI: https://doi.org/10.1590/S0102-09352009000200019