

Alternative adjustment of scrotal circumference for growth traits in Nellore cattle

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ABSTRACT - The objective of this study was to estimate adjustment factors of scrotal circumference for growth traits in Nellore cattle. Measurement at post-yearling of scrotal circumference from 100,107 Nellore was adjusted for six traits: age (A), body weight (BW), hip height (HH), conformation (C), precocity (P), musculature (M), and simultaneously for age and the other five traits (A-BW, A-HH, A-C, A-P, A-M), body weight and the other four traits (BW-HH, BW-C, BW-P, BW-M), and hip height and the other three traits (HH-C, HH-P, HH-M). Standard values were 500 days, 300 kg, 135 cm, and 3, for age, body weight, hip height, and visual scores, respectively. Amplitudes of adjustment factor of scrotal circumference for age, body weight, and hip height were 0.6028, 0.4869, and 0.1572, respectively. Scrotal circumference is expected to grow, on average, 8.71 cm per 100 days of age, 6.51 cm per 100 kg of body weight, and 4.81 cm per 10 cm of hip height. The results showed higher amplitude in the adjustment factor of scrotal circumference for age and body weight (0.3429) compared with age and hip height and body weight and hip height (0.1271 and 0.0443, respectively). The amplitude observed in adjustment factor of scrotal circumference for conformation, precocity, and musculature were 0.1328, 0.1175, and 0.1160, respectively. Considering different adjustment factors of scrotal circumference can be useful for identifying better selection criteria for growth and/or sexual precocity in Nellore.

Keywords: beef cattle, body weight, hip height, selection criteria, visual scores

1. Introduction

Scrotal circumference is widely used as selection criteria to improve reproductive efficiency in beef cattle breeding programs because it is easy to measure, is genetically related to reproductive traits, and its magnitude of heritability coefficient is moderate (Terakado et al., 2015; Schmidt et al., 2019). In Brazil, sire summaries usually show expected progeny difference (EPD) for scrotal circumference without adjustment, adjusted for age, or simultaneously adjusted for age and weight. According to Ortiz Peña et al. (2000), the EPD for scrotal circumference adjusted for age is useful when the objective of selection is to improve growth and sexual precocity, while the adjustment of scrotal circumference for age and body weight identifies more adequate sires for sexual precocity because growth variation is removed.

However, over the years, other growth traits started to be evaluated and used as selection criteria for beef cattle. The use of visual scores such as conformation, precocity, and musculature in the selection

process may indicate biotypes economically more efficient as they can be related to the identification of precocious animals (Koury Filho et al., 2009).

Therefore, adjusting the scrotal circumference for different growth traits related to body structure may allow the identification of precocious bulls more precisely. Since recent studies that consider alternative adjustments of the scrotal circumference are scarce, we aimed to estimate the adjustment factors of the scrotal circumference for age, body weight, hip height, and traits evaluated using visual scores in Nellore cattle.

2. Material and Methods

Data from 855,737 males born between 1983 and 2016, from the Aliança Nelore group were used. Eighteen different adjustments of the scrotal circumference for growth traits were performed, all measured at post-yearling age, as single adjustment for: age, body weight, hip height, conformation, precocity, and musculature; and as double adjustment for: age and body weight, age and hip height, age and conformation, age and precocity, age and musculature, body weight and hip height, body weight and conformation, body weight and precocity, body weight and musculature, hip height and conformation, hip height and precocity, and hip height and musculature. The visual scores of conformation, precocity, and musculature ranged from 1 to 5 and are defined according to Jorge Júnior et al. (2001) as:

Conformation – the amount of meat in the carcass, as the animal was slaughtered at the moment of the evaluation;

Precocity – the capacity of the animal to reach the minimum buildup of fat in the carcass with lower body weight;

Musculature – the development of muscle, observed at the forearm, shoulder, loin and rump.

The visual scores are treated as a continuous trait because of the methodology used to designate the scores. Three trained evaluators choose the intermediate animal (score 3) for conformation, precocity, and musculature in the management group that is being evaluated. Then, the scores for the other animals are assigned comparing them to the base animal from the group. Within the group, it should be identified the best (score 5) and the worst (score 1) animal for all the traits, even if the group is homogeneous. The number of observations per visual score, demonstrating the normal distribution, is presented in Figure 1.

Data editions and analyses were made using the software SAS (Statistical Analysis System, version 9.4). Contemporary groups were formed by company, farm of birth, weaning and yearling, birth season, sex, management group at weaning and post-yearling, and weaning and post-yearling dates.

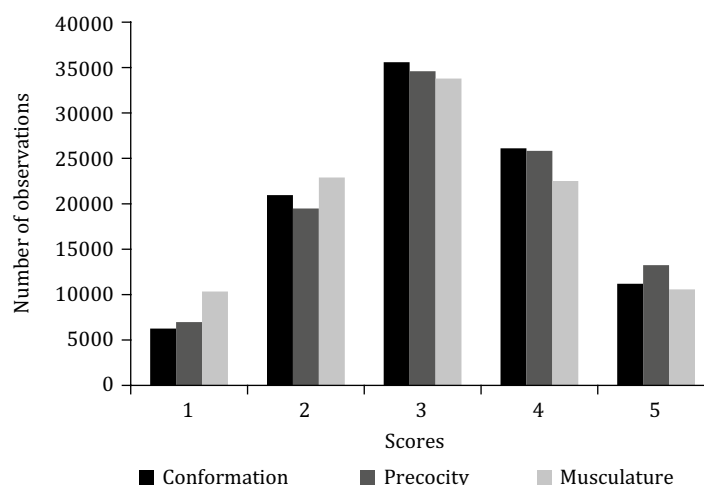


Figure 1 - Number of observations per visual score.

The contemporary groups with less than five animals were deleted. Animals without information or discrepant registry of scrotal circumference, weight at birth, weight at weaning, weight at post-yearling, age at weaning, age at post-yearling, hip height, conformation, precocity, and musculature were also removed, totaling 100,107 young bulls belonging to 4,402 contemporary groups after edition.

The regression used to determine the intercept and the linear and quadratic regression coefficients considered, as fixed, the effect of contemporary group and, as covariate, the adjustment trait, when single adjustment was performed (Equation 1), or the combination of two traits for double adjustments (Equation 2):

$$SC = GC + T_1 + T_1^2 \quad [1]$$

$$SC = GC + T_1 + T_1^2 + T_2 + T_2^2 \quad [2]$$

in which SC = observed scrotal circumference; GC = contemporary group; T_1 and T_2 = trait 1 and trait 2, respectively, used to correct the scrotal circumference.

The general equation used to predict the scrotal circumference for one trait was:

$$SC_p = \beta_0 + \beta_1 T + \beta_2 T^2 \quad [3]$$

in which SC_p = predicted scrotal circumference, β_0 = intercept, β_1 = linear regression coefficient, β_2 = quadratic regression coefficient, and T = trait used to adjust the scrotal circumference (age, body weight, hip height, conformation, precocity, and musculature).

When two traits were used in the adjustment, the general equation for the estimation of scrotal circumference adjusted for age and body weight, age and hip height, age and conformation, age and precocity, age and musculature, body weight and hip height, body weight and musculature, and hip height and conformation were:

$$SC_p = \beta_0 + \beta_1 T_1 + \beta_2 T_1^2 + \beta_3 T_2 + \beta_4 T_2^2 \quad [4]$$

in which SC_p = predicted scrotal circumference; β_0 = intercept; β_1 and β_3 = linear regression coefficients for traits 1 and 2, respectively; β_2 and β_4 = quadratic regression coefficients for traits 1 and 2, respectively; and T_1 and T_2 = trait 1 and trait 2, respectively, used to correct the scrotal circumference.

For the adjustments of scrotal circumference for body weight and conformation, body weight and precocity, hip height and precocity, and hip height and musculature, the quadratic effect was not significant for some traits. Therefore, the equations were:

$$SC_{WC} = \beta_0 + \beta_1 W + \beta_2 W^2 + \beta_3 C \quad [5]$$

$$SC_{WP} = \beta_0 + \beta_1 W + \beta_2 W^2 + \beta_3 P \quad [6]$$

$$SC_{HP} = \beta_0 + \beta_1 H + \beta_3 P \quad [7]$$

$$SC_{HM} = \beta_0 + \beta_1 H + \beta_3 M + \beta_4 M^2 \quad [8]$$

in which SC_{WC} = predicted scrotal circumference adjusted for body weight and conformation; SC_{WP} = predicted scrotal circumference adjusted for body weight and precocity; SC_{HP} = predicted scrotal circumference adjusted for hip height and precocity; SC_{HM} = predicted scrotal circumference adjusted for hip height and musculature; W = body weight at post-yearling; H = hip height; C = conformation; P = precocity; M = musculature; β_0 = intercept; β_1 and β_3 = linear regression coefficients for traits 1 and 2, respectively; and β_2 and β_4 = quadratic regression coefficients for traits 1 and 2, respectively. The adjustment factors were estimated for each single point of the trait evaluated to be applied for any animal in the herd, using the average values of the dataset, according to the equation:

$$AF_x = \frac{SC_{base}}{SC_x} \quad [9]$$

in which AF_x = adjustment factor of the scrotal circumference for each trait; SC_{base} = predicted value of scrotal circumference, in cm, adjusted for the standard value of each trait; and SC_x = predicted value of scrotal circumference, in cm, for each animal, using the equations 1 to 6, depending on the trait.

Based on the means, the references used to indicate the adjustment factor equal to 1.0 were 500 days for age, 300 kg for body weight, 135 cm for hip height (Table 1), and for the visual scores conformation, precocity, and musculature, the standard values were defined by the median, which was equal to 3 for all the traits. The values of scrotal circumference adjusted for each trait were obtained by multiplying the adjustment factors and the observed scrotal circumference.

Table 1 - Descriptive statistics of scrotal circumference (SC), age at post-yearling (A), body weight at post-yearling (BW), and hip height (HH) in Nellore cattle

Trait	N	Mean	SD	Minimum	Maximum
SC (cm)	100,107	26.89	3.58	18	38
A (days)	100,107	507.81	50.49	351	665
BW (kg)	100,107	305.10	43.80	170	442
HH (cm)	100,107	135.40	5.30	119	152

N - number of observations; SD - standard deviation

3. Results

Values of adjustment factor equal to 1 indicate the standard measure of the trait used in the adjustment (Table 2). The adjustment factor of scrotal circumference for age ranged from 1.41151 (351 days) to 0.80874 (665 days), corresponding to 0.60277 of amplitude. Values of adjustment factor of scrotal circumference for body weight ranged from 1.31688 (170 kg) to 0.82999 (442 kg), with an amplitude of 0.48689. Nevertheless, hip height had a smaller amplitude than the others (0.15715), with values ranging from 1.09618 (119 cm) to 0.93903 (152 cm). The adjustment factor of scrotal circumference for body weight at 500 days presented an amplitude of 0.34293, while the amplitude of scrotal circumference adjusted for hip height at 500 days was 0.12709 and of scrotal circumference adjusted for hip height at 300 kg was 0.04426 (Table 3).

Table 2 - Part of the adjustment factors (AF) of scrotal circumference (SC) for age at post-yearling (A), weight at post-yearling (BW), and hip height (HH) for Nellore cattle

A (days)	AF	BW (kg)	AF	HH (cm)	AF
380	1.29701	180	1.28258	-	-
400	1.23077	200	1.22040	120	1.08873
420	1.17279	220	1.16560	123	1.06767
440	1.12170	240	1.11701	126	1.04841
460	1.07642	260	1.07369	129	1.03080
480	1.03609	280	1.03489	132	1.01470
500	1.00000	300	1.00000	135	1.00000
520	0.96759	320	0.96851	138	0.98661
540	0.93838	340	0.94000	141	0.97443
560	0.91200	360	0.91413	144	0.96339
580	0.88810	380	0.89059	147	0.95342
600	0.86643	400	0.86914	150	0.94446
620	0.84675	-	-	-	-

Variations observed in adjustment factor of scrotal circumference for conformation, precocity, and musculature were 0.13279, 0.11750, and 0.11598, respectively (Table 4). For conformation, precocity, and musculature at 500 days of age, the amplitude of the adjustment factors was 0.12274, 0.10901,

Table 3 - Part of the adjustment factors (AF) of scrotal circumference (SC) for body weight at 500 days (W500), hip height at 500 days (H500), and hip height at 300 kg (H300) for Nellore cattle

W500 (kg)	AF	H500 (cm)	AF	H300 (cm)	AF
-	-	120	1.07758	-	-
-	-	123	1.05910	123	0.99213
240	1.10976	126	1.04222	126	0.99261
260	1.06933	129	1.02681	129	0.99408
280	1.03292	132	1.01277	132	0.99654
300	1.00000	135	1.00000	135	1.00000
320	0.97015	138	0.98843	138	1.00449
340	0.94300	141	0.97797	141	1.01003
360	0.91826	144	0.96858	144	1.01666
380	0.89567	147	0.96019	147	1.02442
400	0.87500	150	0.95276	150	1.03336

Table 4 - Adjustment factors (AF) of scrotal circumference (SC) for the visual scores conformation (C), precocity (P), and musculature (M) and two-trait adjustments between those and age at post-yearling, weight at post-yearling, and hip height in Nellore cattle

C	AF	P	AF	M	AF
1	1.07383	1	1.06417	1	1.06703
2	1.03478	2	1.03056	2	1.03092
3	1.00000	3	1.00000	3	1.00000
4	0.96891	4	0.97213	4	0.97356
5	0.94104	5	0.94667	5	0.95105
C500	AF	P500	AF	M500	AF
1	1.06773	1	1.05747	1	1.06239
2	1.03206	2	1.02793	2	1.02885
3	1.00000	3	1.00000	3	1.00000
4	0.97110	4	0.97355	4	0.97525
5	0.94499	5	0.94846	5	0.95409
C300	AF	P300	AF	M300	AF
1	1.01261	1	1.02004	1	1.02305
2	1.00573	2	1.00992	2	1.01087
3	1.00000	3	1.00000	3	1.00000
4	0.99537	4	0.99028	4	0.99035
5	0.99181	5	0.98074	5	0.98187
C135	AF	P135	AF	M135	AF
1	1.06919	1	1.05822	1	1.06197
2	1.03286	2	1.02829	2	1.02900
3	1.00000	3	1.00000	3	1.00000
4	0.97019	4	0.97323	4	0.97446
5	0.94307	5	0.94785	5	0.95198

C500 - conformation at 500 days of age; P500 - precocity at 500 days of age; M500 - musculature at 500 days of age; C300 - conformation at 300 kg of body weight; P300 - precocity at 300 kg of body weight; M300 - musculature at 300 kg of body weight; C135 - conformation at 135 cm of hip height; P135 - precocity at 135 cm of hip height; M135 - musculature at 135 cm of hip height.

and 0.10830, respectively, while conformation, precocity, and musculature at 135 cm of hip height presented a variation of 0.12612, 0.11037, and 0.10999 in the adjustment factor, respectively. The amplitudes of the adjustment factor for conformation, precocity, and musculature at 300 kg of body weight were 0.02080, 0.03930, and 0.04118, respectively.

Regression coefficients represent the function of testicular growth (Ortiz Peña et al., 2000). Thus, scrotal circumference is expected to grow, on average, 8.71 cm per 100 days of age (Figure 2a),

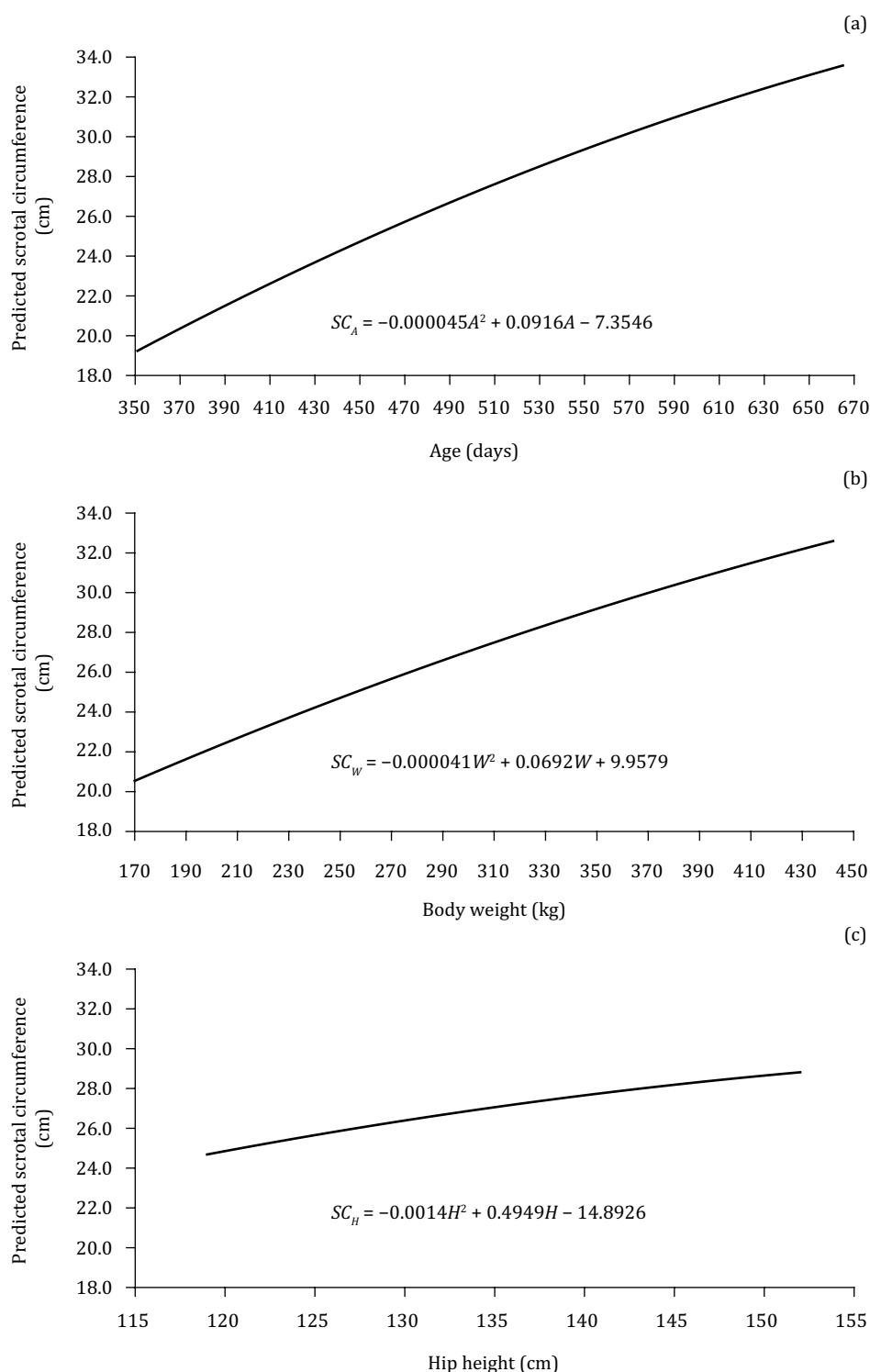


Figure 2 - Predicted scrotal circumference according to age (a), body weight (b) and hip height (c) in Nellore cattle.

6.51 cm per 100 kg of body weight (Figure 2b), and 4.81 cm per 10 cm of hip height (Figure 2c). Using double adjustments, the scrotal circumference will increase, on average, 6.10 cm when body weight at 500 days increase 100 kg (Figure 3a) and 4.59 cm for every 10 cm of hip height at 500 days (Figure 3b), while for hip height at 300 kg, the scrotal circumference will decrease 3.53 cm for every 10 cm hip height (Figure 3c).

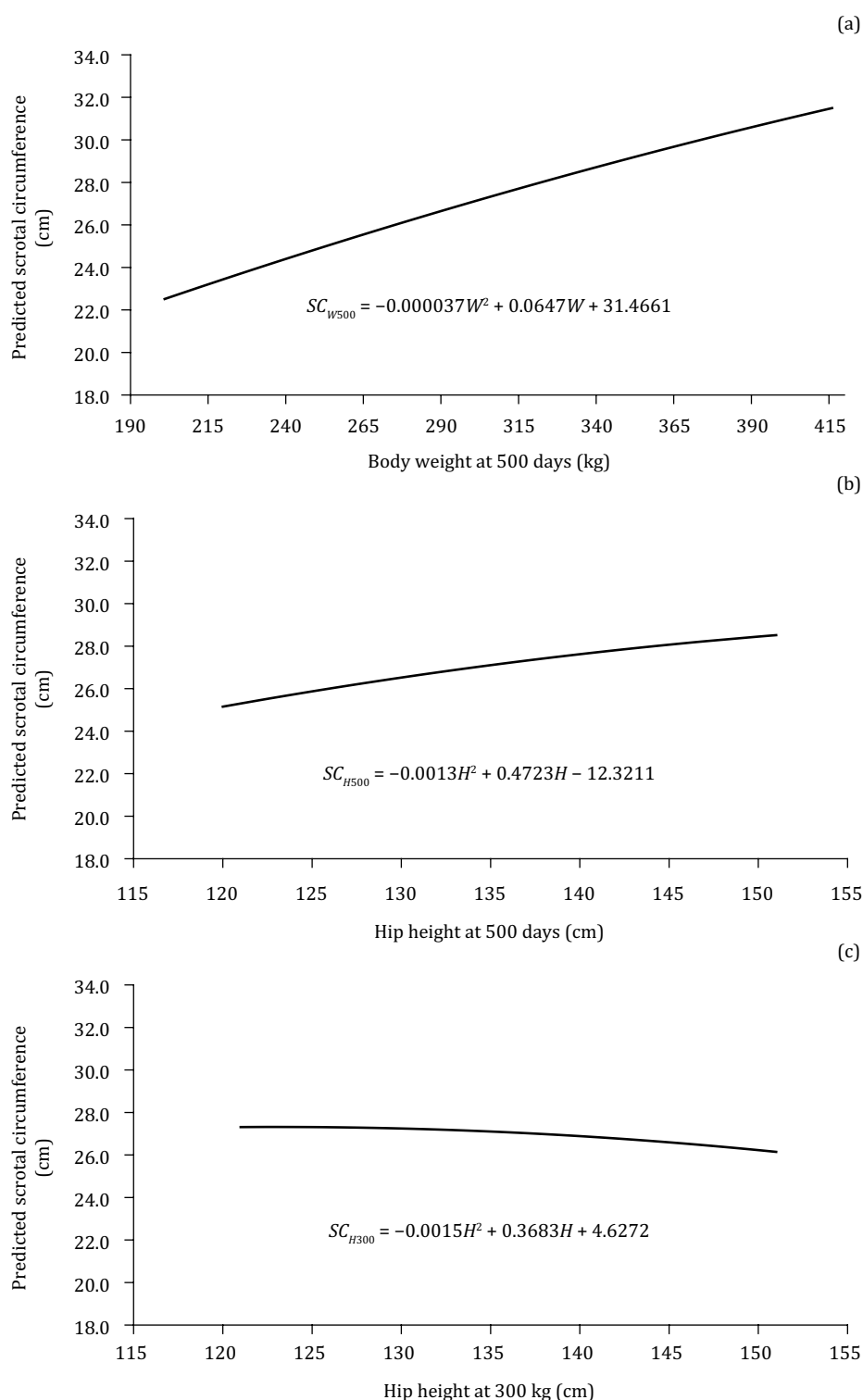


Figure 3 - Predicted scrotal circumference according to body weight at 500 days (a), hip height at 500 days (b), and hip height at 300 kg (c) in Nellore cattle.

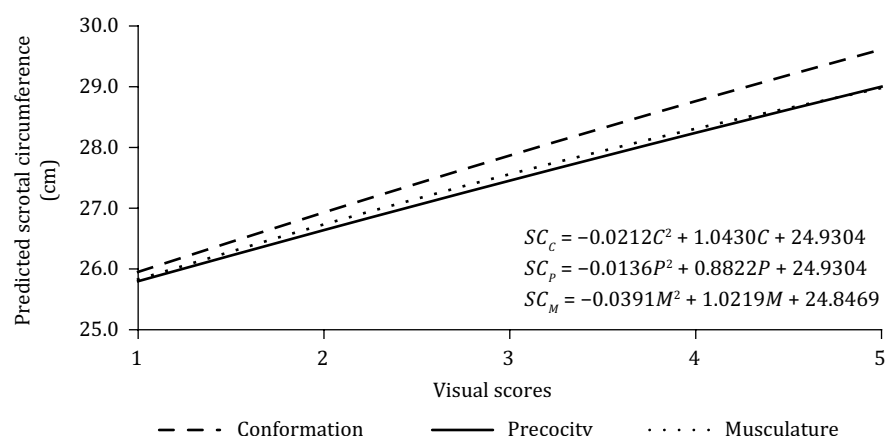


Figure 4 - Predicted scrotal circumference according to conformation (SC_C), precocity (SC_P), and musculature (SC_M) in Nellore cattle.

Using visual scores, at each additional score point, scrotal circumference is expected to grow 1.02 cm for conformation, 0.87 cm for precocity, and 0.98 cm for musculature (Figure 4). For double adjustments using visual scores, scrotal circumference is expected to increase 0.94 cm at each point of conformation at 500 days, 0.75 cm at each point of precocity at 500 days, 0.92 cm at each point of musculature at 500 days (Figure 5a), 0.21 cm at each point of conformation at 300 kg, 0.27 cm at each point of precocity at 300 kg, 0.35 cm at each point of musculature at 300 kg (Figure 5b), and 0.95 cm at each point of conformation at 135 cm of height, 0.75 at each point of precocity at 135 cm of height, and 0.88 cm at each point of musculature at 135 cm of height (Figure 5c).

For two animals with the same scrotal circumference and the same age (animals A and B), the scrotal circumference adjusted for body weight and age simultaneously favors the lighter animal (A) (Table 5). For animals C and D, with the same scrotal circumference and the same body weight, the adjustment of scrotal circumference for age and the adjustment of scrotal circumference for body weight and age simultaneously favors the younger animal (C).

When bulls E and F are compared (Table 6), it is possible to observe that the adjustment for precocity and musculature favors animal F because it will reach the same scrotal circumference and the same conformation with lower scores of precocity and musculature compared with animal E. For animals G and H, with the same scrotal circumference and the same score for precocity, the adjustment of scrotal circumference for conformation and the adjustment of scrotal circumference for musculature favors animal H, which achieves the same measures with lower scores of conformation and musculature.

4. Discussion

The results presented in this paper of the adjustment factor of scrotal circumference for age and body weight (Table 2) indicated a great heterogeneity for these traits in the population. The small amplitude observed for scrotal circumference adjusted to hip height (Table 2) can be justified by the small variation of hip height in the evaluated animals. According to Coutinho et al. (2015), the growth rate of Nellore cattle decreases around 17 months, probably because it is near their maximum bone growth. Therefore, the variation in the height tends to be smaller, as suggested by the amplitude found in this paper.

The adjustment factor of scrotal circumference for hip height at 300 kg exhibits a different behavior than the others estimated in this study (Table 3). Although all the adjustment factors decreased with a higher magnitude of the trait, which is expected for hip height at 300 kg, the adjustment factor increased with the magnitude of the measurement. This result can be explained by the difference in the development of bone tissue and muscles. Bones tend to develop earlier in the animal's life than muscles, especially when linear growth is considered (Guilbert and Gregory, 1952; Berg and Butterfield, 1976).

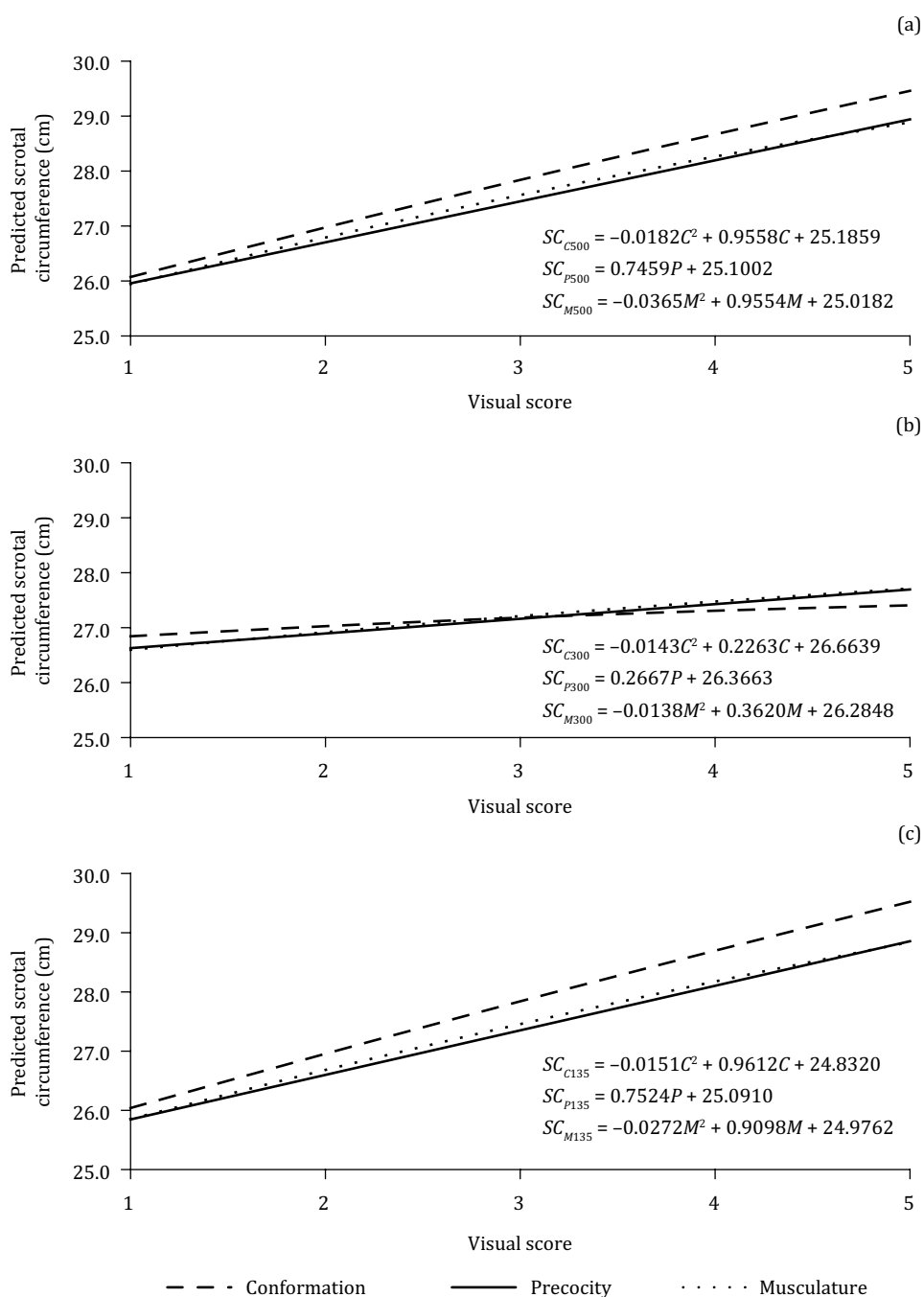


Figure 5 - Predicted scrotal circumference according to the visual scores conformation, precocity, and musculature measured at 500 days of age (a), 300 kg of body weight (b), and 135 cm of hip height (c) in Nellore cattle.

Table 5 - Example of the application of adjustment factors for age and body weight in scrotal circumference (SC) for Nellore cattle

Animal	Observed SC (cm)	Age at post-yearling (days)	Body weight (kg)	SC adjusted for age (cm)	SC adjusted for age and weight (cm)
A	26	560	340	23.71	23.55
B	26	560	400	23.71	21.92
C	24	420	330	28.15	24.72
D	24	480	330	24.87	23.33

Table 6 - Example of the application of scrotal circumference (SC) adjusted for conformation (C), precocity (P), and musculature (M) in Nellore cattle

Animal	Observed SC (cm)	C	P	M	SC _c	SC _p	SC _m
E	24	4	4	4	23.25	23.33	23.37
F	24	4	2	1	23.25	24.73	24.61
G	27	5	4	5	25.41	23.33	25.68
H	27	2	4	2	27.94	23.33	27.84

SC_c - scrotal circumference adjusted for conformation; SC_p - scrotal circumference adjusted for precocity; SC_m - scrotal circumference adjusted for musculature.

Espigolan et al. (2013), studying Hereford bulls, showed that hip height grows until 18 months, but body weight is still increasing at this age. The same behavior was observed by Coutinho et al. (2015) in Nellore cattle around 17 months. Thus, in our study, the animals were probably close to their mature hip height, but still developing in body weight. Then, the variation between the traits used to adjust the scrotal circumference led to an increase in the adjustment factor with the increase in the measurement.

The small variation in the adjustment factor of scrotal circumference for conformation, precocity, and musculature was expected because each score ranged only from 1 to 5. Consequently, small amplitudes were observed when scrotal circumference was adjusted for visual scores (Table 4). For the simultaneous adjustment of scrotal circumference for conformation at 300 kg, precocity at 300 kg, and musculature at 300 kg, the amplitude close to zero could occur due to the high genetic correlation between visual scores and body weight, as observed by Koury Filho et al. (2009) in Nellore cattle. Therefore, it is expected that other genes that affect body weight also affect conformation, precocity, and musculature.

According to Ortiz Peña et al. (2000), the adjustment of scrotal circumference for age provides gains in selection for sexual and growth precocity, while selecting bulls using scrotal circumference adjusted simultaneously for age and body weight provides genetic gains in sexual precocity. Thus, the sire summaries present both adjustments to meet different selection criteria. In the present study, comparing animals A and B (Table 5), the selection of animal A will provide a genetic gain only in sexual precocity because it reaches the same measure of scrotal circumference as animal B at the same age, but with lower body weight. For animals C and D, the adjustment of scrotal circumference for age and body weight simultaneously shows that animal C was more efficient than animal D because it reaches the same scrotal circumference at the same body weight earlier (Table 5). The selection of animal C can lead to a genetic gain in growth precocity beyond the genetic gain in sexual precocity. Therefore, scrotal circumference adjusted only for age and scrotal circumference adjusted simultaneously for age and body weight are selection criteria for different selection objectives.

Regarding the visual scores (Table 6), the present study showed that animal F reached the same scrotal circumference measure as animal E but with lower fat deposition (precocity) and muscular development (musculature). Thus, when bull F achieves the same score for precocity and musculature as animal E, its scrotal circumference will probably be bigger. It implies that animal F may have an earlier growth than animal E. Comparing animals G and H (Table 6), which have the same scrotal circumference and the same score for precocity, animal H has an earlier growth, with higher scrotal circumference when adjusted for conformation or musculature than animal G. It implies that animal H may have higher scrotal circumference when achieving higher scores of conformation or musculature, which is desirable in the Brazilian beef cattle production system.

The alternative adjustments of scrotal circumference showed that the use of different growth traits could improve the identification of sexual precocity in Nellore bulls. Therefore, it is necessary to estimate the genetic correlation between these adjustments and the age at first calving to identify which kind of adjustment provides the best information when the objective of selection is sexual precocity.

5. Conclusions

The adjustment factors estimated could be used to correct scrotal circumference for other growth traits Nellore cattle.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Conceptualization: R. Carvalheiro and L.T. Dias. Formal analysis: B.M. Nascimento and G.F. Silva. Investigation: B.M. Nascimento. Methodology: B.M. Nascimento, G.F. Silva and L.T. Dias. Project administration: L.T. Dias. Software: R.A. Teixeira. Supervision: R.A. Teixeira and L.T. Dias. Writing-original draft: B.M. Nascimento. Writing-review & editing: B.M. Nascimento and L.T. Dias.

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