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Research Article

Genetic parameters and relationships between growth traits and scrotal circumference measured at different ages in Nellore cattle

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Abstract

Records from 106,212 Nellore animals, born between 1998 and 2006, were used to estimate (co)variance components and genetic parameters for birth weight (BW), average weight gains from birth to weaning (GBW), average weight gains from weaning to after yearling (GWAY), weaning hip height (WHH), postweaning hip height (PHH) and scrotal circumferences at 9 (SC9), 12 (SC12) and 15 (SC15) months of age. (Co)variance components were estimated by an animal model using multi-trait analysis. Heritability estimates for BW, GBW, GWAY, WHH, PHH, SC9, SC12 and SC15 were 0.31 ± 0.01; 0.25 ± 0.02; 0.30 ± 0.04; 0.51 ± 0.04; 0.54 ± 0.04; 0.39 ± 0.01; 0.41 ± 0.01 and 0.44 ± 0.02, respectively. Genetic correlations between growth traits ranged from 0.09 ± 0.01 to 0.88 ± 0.01, thereby implying that, at any age, selection to increase average weight gains will also increase stature. Genetic correlations between BW and average weight gains with scrotal circumferences were all positive and moderate (0.15 ± 0.03 to 0.38 ± 0.01). On the other hand, positive and low genetic associations were estimated between hip height and scrotal circumference at different ages (0.09 ± 0.01 to 0.17 ± 0.02). The results of this study pointed out that selection to larger scrotal circumferences in males will promote changes in average weight gains. In order to obtain Nellore cattle with the stature and size suitable for the production system, both weight gain and hip height should be included in a selection index.

Key words: beef cattle, genetic correlation, hip height, average weight gain.

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Introduction

In breeding programs for Nellore cattle, traits, notably weights and weight gains obtained at different ages, are considered as selection criteria. These traits, easy to obtain, are positively correlated to others of economic interest, and respond to selection, through showing heritability estimates of medium magnitude.

With a mind to improving reproductive performance, scrotal circumference in several breeds of beef cattle is now included as a trait, from which expected progeny differences (EPDs), considered in selection indexes, can be predicted. According to several authors, the scrotal circumference, besides being easily obtainable, is both highly heritable and correlated with weight and reproductive traits, as much in males as females (Coulter *et al.*, 1976; Knights *et al.*, 1984; Toelle and Robison, 1985). Heritability estimates of scrotal circumference at the yearling and after yearling stages in Nellore bulls, ranged from 0.25 to 0.53 (Pereira *et al.*, 2001; Boligon *et al.*, 2007, Yokoo *et al.*, 2007).

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The use of body weight as a selection criterion may result in larger animals at mature ages (Boligon *et al.*, 2009), not always desirable in an extensive production system, through the possibility of unduly increasing body weight in adult females (Bullock *et al.*, 1993). In this sense, the inclusion of hip height in the selection index could be a desirable alternative for controlling animal size. This trait is easy to measure and less susceptible to changes in the environment, with a better reflection of body size when compared to measurements of live animal weight (Baker *et al.*, 1988; Hoffman, 1997). Estimates of heritability for hip height range from 0.30 to 0.73 (Vargas *et al.*, 2000, Silva *et al.*, 2003, Yokoo *et al.*, 2007).

Over recent years, several studies have reported positive genetic correlations between weights at different ages and scrotal circumference in beef cattle (Pereira *et al.*, 2001; Boligon *et al.*, 2007; Yokoo *et al.*, 2007). Similarly, the genetic correlation between hip height and weight, besides being positive, has proven to be of moderate magnitude (Vargas *et al.*, 2000, Silva *et al.*, 2003, Yokoo *et al.*, 2007). According to Vargas *et al.* (1988), multi-trait evaluation involving both hip height and weight may be a better option in size selection. However, in the case of Nellore cattle, nothing regarding genetic correlations between weight gains and hip height has been encountered in the literature.

In this sense, there is the need to examine to what extent weight gain, hip height and scrotal circumference respond to selection at different ages, as well as the magnitude of their genetic correlations. With these results at hand, it would be possible to predict changes in hip height of Nellore cattle by correlated response to those traits that are currently being considered in selection programs. Furthermore, this type of work will contribute to the decision to include hip height in Nellore cattle genetic evaluation.

This study was conducted with the objective to estimate genetic and phenotypic parameters for birth weight, weight gains from birth to weaning, weight gains from weaning to yearling, weaning hip height, postweaning hip height and scrotal circumference at 9, 12 and 15 months of age in Nellore cattle.

Material and Methods

Data

Data were collected from 106,212 Nellore animals, born between 1998 and 2006, all belonging to the Jacarezinho cattle-farm, located in Valparaíso County, São Paulo State. The main objectives of Agropecuária Jacarezinho Ltda. are the sale of young bulls and, heifers and animals for slaughter.

In the genetic breeding program developed on the farm, reproductive, growth and finishing traits are used as selection criteria. The animals are weighed at birth, weaning (around 205 days) and as yearlings (around 550 days). In addition, scrotal circumferences are measured at the widest diameter of the scrotum, these measurements being obtained in males from 6 to 22 months of age, at regular intervals of approximately 2 months. Hip height, expressed in centimeters (cm), was measured with a height measuring stick midway-between the hipbones, at a point between the last lumbar and the first sacral vertebrae, immediately before the sacral bone, and thereon to the floor. Hip-height measurement only began to be applied from the year 2003 on. The animals were selected based on empirical indexes, comprising those traits which were being evaluated during the two periods, *i.e.*, weaning and yearling weight, scrotal circumference, visual score of conformation, precocity and musculature.

The following traits were studied: birth weight (BW), average weight gain from birth to weaning (GBW) and from weaning to after yearling (GWAY), weaning hip height (WHH), postweaning hip height (PHH), and scrotal circumferences at 9 (SC9), 12 (SC12) and 15 (SC15) months of age.

In the formation of contemporary groups for BW, the variables herd, year, month and management group at birth and sex, were used. In the case of GBW and WHH, and in addition, the contemporary group herd and management group at weaning were also included, and for GWAY and PHH, the herd and management group as yearlings were added. In the case of scrotal circumference, herd, year and month of birth, as well as management group at weaning and as yearlings, were considered as variables in the contemporary group. Fixed effects considered for each trait were defined during preliminary analyses. Records for birth weight, average weight gains, hip height and scrotal circumference outside the range determined by the mean of the contemporary group, plus or minus three standard deviations, were excluded. Contemporary groups with fewer than four observations were excluded from analysis.

Statistical analysis

Variance and covariance components, and the respective estimates of heritability and genetic and phenotypic correlations, were obtained using the restricted maximum likelihood method, in a multi-trait animal model including all the traits together using the WOMBAT program (Meyer, 2006).

The matrix representation of the general model is:

$$y = Xb + Z_1a + Z_2m + Z_3p + e$$

where y = vector of observations; b = vector of fixed effects; a = vector of direct additive genetic effects; m = vector of maternal additive genetic effects; p = vector of maternal permanent environmental effects, and e = vector of residual random errors associated with observations. X, Z_1, Z_2 and Z_3 are incidence matrices related to b, a, m and p to y. It is assumed that:

$$\begin{bmatrix} a \\ m \\ p \\ e \end{bmatrix} \sim N(0,V) \quad V = \begin{bmatrix} G \otimes A & 0 & 0 \\ 0 & Ep \otimes I_{Nm} & 0 \\ 0 & 0 & R \otimes I_N \end{bmatrix}$$

where G = genetic (co)variance effects, A = relationship matrix; E_p = maternal permanent environmental (co)variance matrix, I = identity matrix, N_m = number of dams of animals with records, N = number of animals with records, R = residual (co)variance matrix, ⊗ = direct product between matrices.

For the **G** matrix:

$$G = \begin{bmatrix} Gd & 0 \\ 0 & Gm \end{bmatrix}$$

where G_d and G_m = matrices of direct additive genetic and maternal effects, respectively. Only for BW, GBW and WHH random maternal genetic and maternal permanent environment effects added to the model.

For all traits, the fixed effects of contemporary groups, and the age of cows at calving (linear and quadratic effects) were included in the model as covariables. For WHH, PHH, SC9, SC12 and SC15, the animal's age at measurement (linear and quadratic effects) was also considered as a covariable. For both GBW and GWAY, the numbers of days from birth to weaning and from weaning to after yearling, respectively, were also included as covariables (linear effect). A pedigree structure containing the identification of the animal's sire and dam was used, with the relationship matrix comprising a total of 153,600 animals.

Results and Discussion

The means observed, respective standard deviations, coefficients of variation and total numbers of observations for traits studied are presented in Table 1. In general, the means obtained for BW, GBW; GWAY; WHH and PHH are close to those described in the literature for Zebu cattle (Pereira *et al.*, 2001; Holanda *et al.*, 2004; Yokoo *et al.*, 2007; Boligon *et al.*, 2009).

The means obtained for scrotal circumference increased with age, showing greater testicular development between the ages of 9 and 12 months, with a reduction from there on in the growth rate with advancing age (Table 1). The mean values observed for measures of scrotal circumference in this study were similar to those described by Gianlorenço *et al.* (2003), Silveira *et al.* (2004) and Boligon *et al.* (2007). In animals of the Nellore breed, Yokoo *et al.* (2007) reported values for scrotal circumference measured at different ages as 20.96 cm at 12 months and 24.58 cm at 15.

Genetic and environmental variance, and heritability estimates for growth traits and scrotal circumference, obtained by multiple-trait analysis, are shown in Table 2. The direct heritability estimates obtained for BW were close to those described in the literature for Nellore cattle, with values ranging from 0.23 to 0.36 (Pereira *et al.*, 2001; Holanda *et al.*, 2004; Boligon *et al.*, 2009).

Direct heritability estimates for GBW and GWAY were 0.25 ± 0.02 and 0.30 ± 0.03, respectively (Table 2), thereby indicating that the use of these traits as selection criteria would increase the weight gain for the corresponding period. Paneto *et al.* (2002) reported heritability estimates of 0.32 (weight gains between 120 and 240 days of age), 0.16 (between 240 and 365 days), 0.21 (between 365 and 455 days) and 0.23 (between 455 and 550 days).

The direct heritability estimates for WHH and PHH (0.51 ± 0.04 and 0.54 ± 0.04, respectively) to be found in

Table 1 - Number of observations (N), mean and standard deviation (SD), variation coefficients (CV) and number of sires, dam and contemporary groups (CG) for the traits.

Traits[1]	N	Mean ± SD	CV (%)	No. of sires	No. of dams	No. CG
BW (kg)	79,735	30.85 ± 3.06	9.92	481	2,008	1,870
GBW (kg)	74,656	181.58 ± 25.56	18.05	442	1,928	1,032
GWAY (kg)	47,251	105.40 ± 30.21	31.67	408	1,574	842
WHH (cm)	13,788	117.28 ± 4.52	3.85	166	202	199
PHH (cm)	13,672	133.04 ± 5.47	4.11	190	338	320
SC9 (cm)	2,762	17.80 ± 1.55	8.73	102	1,041	144
SC12 (cm)	2,982	21.44 ± 2.69	12.54	108	1,100	173
SC15 (cm)	3,097	24.84 ± 3.16	12.70	121	1,887	165

[1]BW = birth weight; GBW = average weight gains from birth to weaning; GWAY = average weight gains from weaning to after yearling; WHH = weaning hip height; PHH = hip height at postweaning; SC9, SC12 and SC15 = scrotal circumference measured at 9, 12 and 15 months of age, respectively.

Table 2 - Genetic and environmental variance and parameter estimates for growth traits and scrotal circumference in Nellore cattle obtained by multiple-trait analysis.

Estimates[2]	Traits[1]							
	BW	GBW	GWAY	WHH	PHH	SC9	SC12	SC15
σ^2_a	2.28	49.20	91.05	5.71	6.06	0.67	1.70	2.75
σ^2_m	0.16	19.68	-	1.05	-	-	-	-
σ^2_c	0.39	41.12	-	1.31	-	-	-	-
σ^2_e	4.54	86.80	212.44	4.10	5.17	1.03	2.54	3.48
h^2_a (SEM)	0.31 (0.01)	0.25 (0.02)	0.30 (0.04)	0.51 (0.04)	0.54 (0.04)	0.39 (0.01)	0.41 (0.01)	0.44 (0.02)
h^2_m (SEM)	0.02 (0.01)	0.10 (0.01)	-	0.09 (0.01)	-	-	-	-

[1]BW = birth weight; GBW = average weight gains from birth to weaning; GWAY = average weight gains from weaning to after yearling; WHH = weaning hip height; PHH = hip height at postweaning; SC9, SC12 and SC15 = scrotal circumference measured at 9, 12 and 15 months of age, respectively.
[2]σ^2_a = direct additive genetic variance; σ^2_m = maternal additive genetic variance; σ^2_c = variance due to maternal permanent-environmental effects; σ^2_e = environmental variance; h^2_a = heritability of direct effects; SEM = standard error of the estimate; h^2_m = heritability of maternal effects.

this study were lower than the estimate of 0.73 reported by Vargas *et al.* (2000) for weaning hip height in Brahman cattle, and 0.63 ± 0.09 estimated by Yokoo *et al.* (2007) for postweaning hip height in Nellore. The estimate of maternal heritability for weaning hip height was 0.09 ± 0.01. The only comparable value for this estimate found in the literature was similar, *i.e.*, 0.10 (Vargas *et al.*, 2000).

Maternal ability is of fundamental importance in the performance of calves from the pre-natal stage (due to placental differences) to the post-natal stage (due to care and milk production levels). In the present study, this influence was evident in BW, GBW and WHH, where the contributions of maternal effects (both genetic and maternal permanent environmental) to total phenotypic variation, were 7.46, 30.89 and 21.13%, respectively (Table 2). According to Meyer *et al.* (1993), weaning traits are more influenced by maternal effects, thereby justifying their greater significance in GBW and WHH. In this sense, Alencar (1987) found that cow milk production is responsible for 26.2% and 20.3% of weight gain from birth to weaning of the calf in Canchim and Nellore cattle, respectively.

Estimates of scrotal circumference heritability, measured at different ages, were both high (Table 2) and close to those reported in the literature (Vargas *et al.*, 1998; Gianlorenço *et al.*, 2003; Boligon *et al.*, 2007; Yokoo *et al.*, 2007; Frizzas *et al.*, 2009). Heritability estimates for SC12 and SC15 were markedly higher than those obtained for SC9, thereby implying that, considering the same intensity of selection at all ages, the response to selection by scrotal circumference should be higher after 12 months.

Similarly, Yokoo *et al.* (2007) and Frizzas *et al.* (2009) indicated the possibility of selecting animals with greater scrotal circumference using only measurements at 15 and 18 months, since the selection response could be more efficient at these ages. According to Dal-Farra *et al.* (1998), genetic selection by scrotal circumference between the ages of 17 and 18 months seems to be the most appropriate, through enabling identification of males that present early testicular growth, since the growth rate gradually decreases when the animal reaches the age of puberty (around 19,4 months of age).

The estimates of genetic and phenotypic correlations between the traits studied, and their respective standard errors, appear in Table 3. The genetic correlations observed between GBW and GWAY (0.88 ± 0.01) suggest that expression of these traits is mainly influenced by the same genes. Thus, genetic gains in weight from birth to postweaning might be obtained by the correlated responses of these traits.

As genetic association between WHH and PHH was high and positive (0.87 ± 0.01), the indirect selection of one trait for another is possible. Furthermore, the strong mutual genetic correlation estimated as existing, indicates that genes regulating the rate of early skeletal development would exert a like influence on postweaning hip height. Thus, selection considering weaning hip height will also help in predicting the postweaning height.

In general, genetic correlations between scrotal circumferences obtained at different ages were positive and high, with higher values between adjacent measurements, whereas with widening intervals these decreased (Table 3). There are few studies in the literature reporting genetic correlations between scrotal circumferences measured at different ages in Nellore cattle. Yokoo *et al.* (2007) obtained genetic correlations between scrotal circumference measurements of 0.96 (365 to 450 days), 0.81 (365 to 550 days) and 0.92 (450 to 550 days).

Genetic correlations between weight gains and hip height are positive, these ranging from 0.59 ± 0.02 to 0.68 ± 0.02 (Table 3). Nevertheless, selection considering only weight gain may result in higher animals, which in certain environments, as the extensive production system in Brazil, would mean a delay in reaching an adequate height and less efficiency in terms of nutrition (Jenkins and Ferrell, 1994), thereby requiring more time to begin to reproduce and to finally reach a desirable carcass stage. In order to obtain Nellore cattle with the adequate stature and size

Table 3 - Estimates of genetic (above the diagonal) and phenotypic (below the diagonal) correlations and their respective standard errors (in parentheses) between growth traits and scrotal circumference in Nellore cattle obtained by multiple-trait analysis.

Traits[1]	BW	GBW	GWAY	WHH	PHH	SC9	SC12	SC15
BW	-	0.42 (0.02)	0.37 (0.02)	0.12 (0.03)	0.09 (0.03)	0.22 (0.02)	0.18 (0.02)	0.15 (0.03)
GBW	0.31 (0.02)	-	0.88 (0.01)	0.67 (0.02)	0.59 (0.02)	0.37 (0.02)	0.34 (0.03)	0.33 (0.03)
GWAY	0.33 (0.02)	0.67 (0.01)	-	0.64 (0.03)	0.68 (0.02)	0.34 (0.02)	0.35 (0.02)	0.38 (0.01)
WHH	0.23 (0.03)	0.52 (0.02)	0.54 (0.02)	-	0.87 (0.01)	0.17 (0.02)	0.14 (0.02)	0.10 (0.03)
PHH	0.19 (0.02)	0.48 (0.02)	0.55 (0.01)	0.66 (0.01)	-	0.09 (0.01)	0.11 (0.02)	0.13 (0.02)
SC9	0.26 (0.02)	0.33 (0.03)	0.30 (0.02)	-0.06 (0.02)	-0.02 (0.02)	-	0.84 (0.01)	0.76 (0.01)
SC12	0.21 (0.02)	0.29 (0.02)	0.31 (0.01)	-0.09 (0.02)	-0.07 (0.03)	0.75 (0.02)	-	0.89 (0.01)
SC15	0.18 (0.03)	0.31 (0.02)	0.33 (0.02)	0.01 (0.03)	0.04 (0.02)	0.61 (0.01)	0.78 (0.02)	-

[1]BW = birth weight; GBW = average weight gains from birth to weaning; GWAY = average weight gains from weaning to after yearling; WHH = weaning hip height; PHH = hip height at postweaning; SC9, SC12 and SC15 = scrotal circumference measured at 9, 12 and 15 months of age, respectively.

for a system with market requirements, both weight gain and hip height should be included together in a selection index.

The estimate of genetic correlations between scrotal circumference at different ages and weight gains (ranging from 0.33 ± 0.03 to 0.38 ± 0.01) was favorable, thereby indicating that animals with large gains in weight are genetically associated with bulls that had reached puberty earlier. Therefore, positive correlated responses, when selecting for one or more traits in the same direction, are expected.

On the other hand, estimates of additive genetic correlations between scrotal circumferences at any age, and hip height, were positive and low in magnitude. From this, it can be inferred that the inclusion of scrotal circumference in the selection index would not result in rapid genetic progression for hip height. As with us, Yokoo *et al.* (2007) reported positive genetic correlations between SC12 and PHH (0.21) and SC15 and PHH (0.12), in Nellore cattle, while in Brahman cattle, Vargas *et al.* (1998) also encountered positive genetic and low correlations between scrotal circumference at 18 months and hip height at the same age (0.19).

In the breeding programs of most tropical countries, weight is the most common way to characterize the size of beef cattle. Nevertheless, the use of weight alone could be a poor indicator of animal size, since animals with the same weight can be of different heights. The results obtained in the present study support the existence of a favorable genetic association between weight gain and skeleton size, whereby hip height, together with weight and weight gain, could be included in the selection index, to so aid in expressing Nellore body-size more advantageously. Estimates of genetic correlations between scrotal circumference and hip height were low, thus indicating that the use of scrotal circumference as a selective criterion would promote little or no change in hip height.

In conclusion, the traits weight gains, hip height and scrotal circumference have genetic variability in Nellore cattle, and thus should show a rapid response in individual selection procedure. Through scrotal circumference progressively increasing by age, sires should be selected by using scrotal circumference measurements after 12 months of age. Selection by greater scrotal circumference in Nellore cattle will result in little or no change in hip height. Long-term selection for higher weaning weight gain and/or postweaning weight gain should result in greater hip height and scrotal circumference. In order to obtain Nellore cattle with the stature and size suitable for the production system, the average weight gain and hip height should be included in a selection index.

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