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ANIMAL SCIENCE

Early growth, backfat thickness and body condition has major effect on early heifer pregnancy in Nellore cattle

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Abstract: The aim was to evaluate the association between growth, carcass and visual scores traits with precocious calving in Nellore cattle. Birth weight (BW), weight at 120, 210, 365 and 450 days of age, pre and post-weaning average daily gain, rib eye area, backfat thickness (BF), rump fat thickness and visual scores obtained at 18 months were used for the analysis. Records from 700 females born between 2009 and 2015, exposed to mating starting at 11 months of age were analyzed. Discriminant analyzes were performed with the software Statistica. BW and BF showed the highest (P>0.01) discrimination value for early heifer pregnancy (EP). Extreme intrauterine growth retardation can result in slower growth, which reflects in the worst reproductive performance, confirmed by the variation in BW between precocious and conventional heifers. The results also demonstrate that the level of body fat affects begin of puberty. Bone structure, musculature, depth, tail insertion and rump scores presented the highest discrimination value for EP. These traits can be used as selection tools to improve sexual precocity in female Nellore cattle. The results obtained in this study would support farmers to guide the heifer management and decisions in order to enhance the EP.

Key words: age at first conception, carcass evaluation, multivariate analyzes, weight performance, Zebu.

INTRODUCTION

The beef cattle economic profitability is directly related to reproductive efficiency and age at puberty, since reproductive traits determine the number of calves available for market (Baldi et al. 2008). Selection for sexual precocity reduces the production costs, due to the anticipation of the reproductive life of heifers, reducing the interval between generations increasing the selection response (Perotto et al. 2006).

The zebu beef breeds are considered non-precocious, since the age at puberty varied from 22 to 36 months, which reflects age at first calving (AFCa) ranging from 34 to 45 months (Dias et al. 2004, Azevedo et al. 2006). This pattern is attributed, mainly, to the use of body weight near the mating season as the main criterion for the reproduction of heifers, which a minimum of heifer weight of 70% of adult weight is adopted, and often results in a late exposure of heifers and late AFCa. This is one of the main reasons of the low economic result of beef cattle breeding systems in tropical regions. In addition, lower selection pressure for reproductive efficiency related traits was observed in zebu cattle in relation to taurine cattle (Azevedo et al. 2006).

The expression of puberty and sexual maturation requires, basically, a combination of two factors: age and weight (Dias et al. 2004). In addition to the body weight, weight gain and the phase of animal's life at which occurs can influence the age heifers reach puberty and consequently attain the first conception (Canellas et al. 2012). However, there is no consensus about which phase of heifer development would have high influence on the onset of puberty (Azevedo et al. 2006). In addition, the weight gain and body weight, as well as the age at first conception are correlated with other traits of economic importance such as carcass and visual scores, since these traits are related to tissue development and body composition, influencing the sexual precocity of beef heifers (Canellas et al. 2012).

Understanding the associations between live weight and live weight gain at different phases of animal's life, and the response on other traits related to body composition, would help to predict the future female reproductive performance. An alternative way to understand these associations is to evaluate the phases of female development (body weights and weight gains), as well as the other traits related to tissue development and body composition simultaneously. In this sense, the multivariate analysis, as discriminant analysis, is an adequate strategyis and statistical tool to evaluate these inter-relationships, since all traits are considered and analyzed at the same time, and it is possible to identify which ones would be more related to early puberty expression (Hair Junior 2006). Our hypothesis is that growth, carcass and visual scores traits evaluated at young ages in heifers can be used to identify those with higher potential for sexual precocity and that will present lower age at first calving, since they are related to the unleashing of puberty. The aim of this study was to evaluate the association between growth, carcass and visual scores traits with occurrence of precocious calving in Nellore cattle by discriminant multivariate analysis, in order to give support to management reproductive decisions in beef cattle systems.

MATERIALS AND METHODS

Data set description

The collection of phenotypic information is not categorized as an experiment, since the interventions are related to farming practices, according to the law No 11.794 (8 October 2008; Brazilian Constitution), which lays down procedures for the scientific use of animals. Hence, this study was not submitted to an ethics committee, considering that a data set from a commercial production system was used.

Growth, reproductive and carcass traits were provided by the "Fazenda Vera Cruz", farm located in Barra do Garças, Mato Grosso State and from the Nellore Brazil breeding program coordinated by Associação Nacional de Criadores e Pesquisadores (ANCP). The region has a tropical climate, latitude 15º53'24'' south of Ecuador and longitude 52°15'24'' west of Greenwich Meridian. Records from 700 Nellore females born between 2009 and 2015 were used.

The mating season (service period) was between November to February. All heifers were time-fixed artificial inseminated (AI). The first service took place when heifers had 11 months of age and heavier than 250 kg by October, before the beginning of the breeding season. Age at puberty in Zebu heifers has been shown older than 11 months (Cardoso 2011). *Bos indicus* heifers, reared in tropical regions and in extensive systems like the one in this study, become pubescent at around 13 months of age (Cardoso 2011). The first service at a younger age allows the identification of heifers with the potential for sexual precocity. Pregnancy diagnosis was performed by ultrasound 28 days after each artificial insemination, to identify females that did not become pregnant and re-submit them to a new AI protocol. At the end of the breeding season, ultrasound was also performed, with the aim to confirm the gestation period and if there were any problems related to pregnancy, such as abortion or fetal absorption. Final pregnancy rate was determined 28 days after the end of the mating period. Heifers that got pregnant before the age of 20 months of age were classified as precocious and the other ones were classified as conventional.

In relation to nutritional management, females were evaluated through three stages and management group: lactating with creep feeding (1 to 7 months of age - pre-weaning), post-weaning (8 to 10 months) and mating season (from 11 months). All management groups (lactating, post-weaning and mating season) were kept under rotational grazing managements with *Brachiaria brizantha* cv. Marandu and *Panicum maximum* cv. Mombaça pastures. The average pasture nutritional composition during the rainy season was 49% of total digestive nutrients, 7.3% of crude protein and 79.0% of neutral detergent fiber. During lactation, calves were offered 0.5 kg of dry matter (DM) of a commercial high-protein concentrate per 100 kg of live weight as a supplementary feed (creep feeding). Calf weaning was performed when they reached seven months of age. After weaning, the females' calves were supplemented with 1 kg of DM per 100 kg of live weight of a high-protein (40% of crude protein) commercial concentrate until they were pregnant. After that, they were supplemented with 0.2 kg of DM per 100 kg of live weight of a low-protein concentrate (18% of crude protein). The pre-weaning animals' diet was composed of corn (70%), soybean meal (27%) and mineral mix (3%). The post-weaning animals' diet was composed of corn (50%), soybean meal (38%), mineral mix (5%), urea (6%) and ammonium sulfate (1%). The mating season animals' diet was composed of corn (80%), soybean meal (15%), mineral mix (1%), urea (2%), ammonium sulfate (0.5%) and calcium carbonate (1.5%). Females were weighed every three months with a previous 12 hours fasting. The contemporary group (CG) were composed by animals born in the same year-season of birth and same management group.

Health management was performed based on the technical recommendations of the prophylactic calendar of the state health agency of Mato Grosso, and ectoparasites and endoparasites control as well as any required treatment was performed by the veterinarian responsible for the farm.

Traits analyzed

Growth traits analyzed included birth weight (BW), adjusted weight at 120 (W120), 210 (W210), 365 (W365) and 450 days of age (W450), pre-weaning weight gain (PREWG) and post-weaning weight gain (POSTWG). The weight adjusted to age was calculated according to the equation proposed by Garnero et al. (2001), and the average daily gain was obtained according to equation proposed by Vozzi (2008). Posteriorly, the weight at standard age and the carcass traits was adjusted to remove the CG's random effect, using a Best Linear Unbiased Estimator model, with SAS (2002) and considering the mean of the observations, CG as fixed effect and random effect of the residue. The adjustment of the weight at standard ages and for CG was done with the aim of allowing a fairer comparison of the animals in relation to the body weight grouping, by evaluating them under the same parameter.

Ultrasound measurements of rib eye area (REA), backfat thickness (BF) and rump fat thickness (RF) were performed at 18 months.

These measurements were taken in the *Longissimus dorsi* muscle between 12th and 13th rib (REA and BF), and in rump area between the ischium and the ileum, measured at the intersection of the *Gluteus medius* and *Biceps femoris* (RF). Ultrasonography was performed using ALOKA 500V, with linear rig of 17.2 cm and 3.5 MHz and an acoustic coupler with an image capture system. The collected images were interpreted by Aval Serviços Tecnológicos S/C, following a quality standard of the Ultrasound Guidelines Council, using the "Biosoft Toolbox software" (Biotronics Inc., Ames, IA, USA) (Yokoo et al. 2009).

The data from visual score evaluations was assessed at approximately 18 months of age, following the methodology of the Nellore Qualitas breeding program, being realized by the comparative method within the CG (Bosman & Scholtz 2010). The visual score traits considered in the discriminant analysis are presented in Table I and Figure 1 (Qualitas 2016).

Quality control, statistics and discriminant multivariate analysis

In all traits, CGs with less than four records were excluded, as those with records exceeding 3.5 standard deviations above or below the mean in continuous traits. The descriptive statistical analysis was performed using the PROC MEANS and PROC UNIVARIATE of SAS (2002). T-test at 1% of significance was applied in order to compare the performance of the precocious and conventional females. The mean age at first conception and first calving was 16±2.06 and 25±2.07 months of age for the precocious females, and 27±4.37 and 36±3.05 months for the conventional females, respectively.

Descriptive statistics and t-test comparison for growth, carcass, and for visual scores traits in Nellore females according to early pregnancy heifer diagnostic are presented in Tables II and III.

A discriminant multivariate analysis was employed to identify continuous and categorical traits (growth, carcass and visual scores traits) that performed a better separation between pregnant and non-pregnant heifers, using Statistica software (2004). The analyses were based on Fisher's linear discriminant function. This is achieved by the statistical decision rule of maximizing the between-group variance relative to the within-group variance.

The linear combinations between the observed variables were identified, highlighting those that were more representative in the classification of early pregnancy, using as p-value of 0.05. In addition to the p-level, Wilk's Lambda, partial lambda and F-remove were also obtained in the discriminant analysis. Wilk's Lambda is a direct measure of the proportion of variance in the combination of dependent variables, is used to denote the statistical significance of the discriminatory power of the analysis model and smaller values of Wilks' lambda indicate greater discriminatory ability of the function. Partial lambda also indicates discriminatory power, but in this case it is the unique contribution of the respective variable to the discrimination between groups. F-remove indicates the decrease of the discrimination if the analyzed variable were removed from the model, thus, the greater the value the greater the importance attributed the trait to discriminate the groups (Klecka 1980).

The phenotypic correlations between the evaluated traits were estimated using the Pearson method and SAS (2002) software.

Table I. Visual score traits evaluated in Nellore females, using the method of evaluation of the program Nellore Qualitas.

Traits	Evaluation	Range of score	Ideal score
1 - Rump angle	Evaluated by rump inclination. Score one means excessively inclined rump, and score five means flat rump.	1 -5	3
2- Structure foundation	Evaluated by lateral view of structure foundation and by the back of the animal. Extremely angular structure foundation received score one and to straights structure foundation received five.	1 - 5	3
3- Mouth	Evaluated through the visualization of the animal's mouth. The grades attributed were one to a small mouth and five to a larger mouth.	1 – 5	3
4- Frame	Evaluated based on the height of the animal. Score one is attributed to small animals and score five to tall animals.	1 – 5	3
5- Tail insertion	Evaluated by the height of the tail insertion.	1 – 5	5
6- Muscularity	Estimated by the grades of muscularity verified in two points: forearm perimeter and region of rectus femoris, vastus lateralis, vastus medialis and vastus intermedius muscles. If these muscles were prominent the grade assigned was higher.	1 – 6	6
7- Bones	Based on bone thickness. Score one was thin bone structure and five thick bone structure.	1 – 5	3
8- Fur/ Pigmentation	Based on animal fur. Score one was used for depigmentation and four to pigmented animals that had black testicles or vulva.	1 – 4	2,4
9- Depth	Measured by the bending and the length of the ribs.	1 – 5	5
10- Reproduction	Evaluated by the reproductive conformation of the heifers, which includes traits like delicate head, if they present extremely developed muscularity and if the external genitals (vulva) are well developed.	1 – 6	6
11-Temperament	It is estimated by animal's reactivity. The higher the score, more docile was the animal.	1 – 5	5
12- Udder	This trait is evaluated by back visualization of the animal, the teats development is verified, and if the animal presents leather on the udder.	1 – 6	6
13- Navel	Evaluated by the navel length. The score one is given to animals with a short navel, and five to a very large navel.	1 – 5	3
14- Racial	The trait is evaluated by racial patterns from Nellore breed.	1 - 5	5

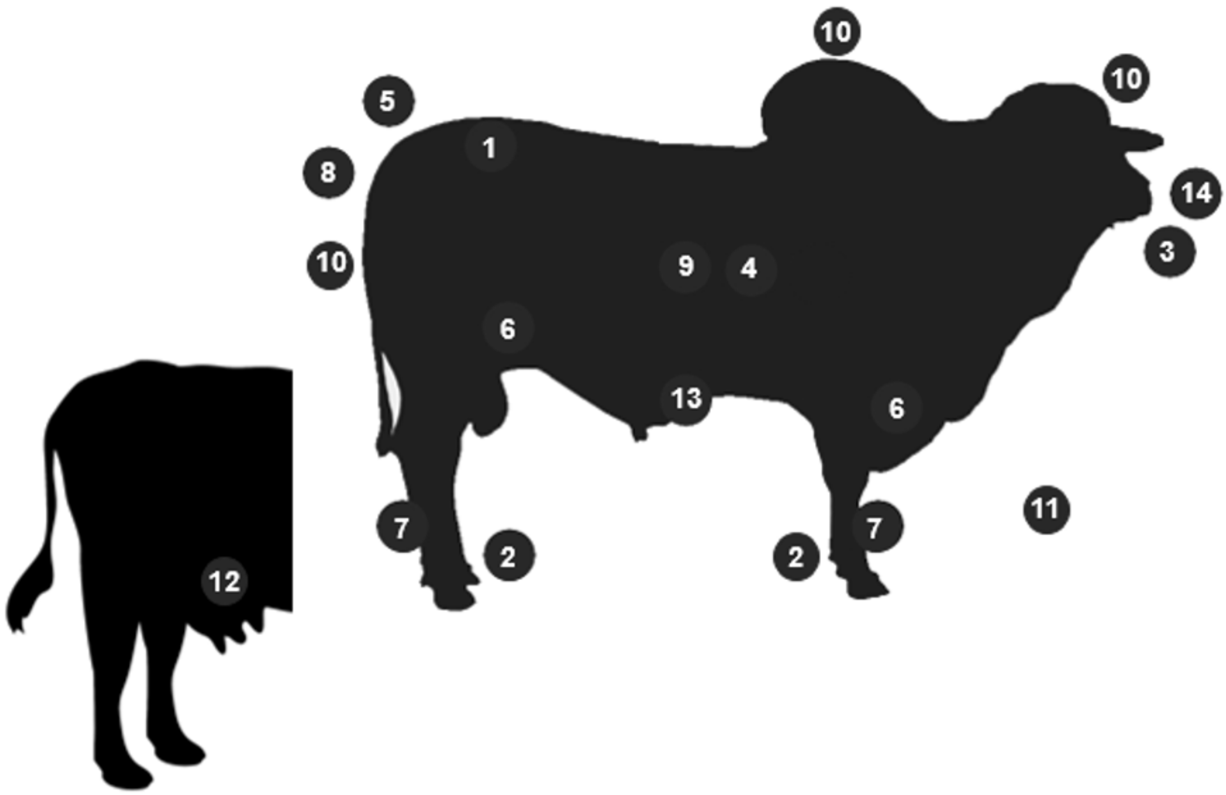

Figure 1. Visual scores evaluation of Nellore Qualitas Program. 1 = rump angle; 2 = structure foundation; 3 = mouth; 4 = frame; 5 = tail insertion; 6 = muscularity; 7 = Bones; 8 = Fur/pigmentation; 9 = depth; 10 = reproduction; 11 = temperament; 12 = udder; 13 = navel; 14 = racial. Adapted from: Nellore Qualitas (Qualitas 2016).

RESULTS

For all the growth and carcass indicator traits, the group of sexually precocious heifers showed higher least square mean values (P < 0.01) than those observed for conventional heifers (Table II). These results pointed out that the early puberty is a reflection of the overall superior performance of precocious heifers.

The least square mean values for W120 and W210 of precocious heifers group were higher than conventional heifers group (135.25 and 207.11 kg *vs* 128.03 and 186.76 kg, respectively) (Table II). These results shown higher pre-weaning average gain of the precocious group. Higher values (P < 0.01) was also observed for rump fat thickness.

A significant difference (P < 0.01) was observed between precocious and conventional heifers for the structure foundation, bone structure, depth, navel (umbilicus), mouth, tail insertion and temperament scores traits (Table III). For the structure foundation (2.53 *vs* 2.07), depth (3.86 *vs* 3.66), tail insertion (2.11 *vs* 2.00) and temperament (3.10 *vs* 2.93) scores traits, the group of precocious heifers showed higher averages. While for bone structure (2.24 *vs* 1.71), navel (3.32 *vs* 3.16), mouth (3.17 *vs* 2.97) scores traits, conventional heifers presented superiority. These results indicated that the difference in morphological evaluation of heifers would influence and can be used as indicators of the age at puberty.

The discriminant analysis results for the association between early pregnancy in heifer

Table II. Descriptive statistics and variance analysis results of t-test for growth and carcass traits for conventional and precocious heifers.

Traits	N	Mean	SD	CV (%)	Minimum	Maximum	Mode
	Conventional females*						
BW (kg)	189	30.94b	2.55	8.23	28.00	38.00	29.00
W120 (kg)	189	128.03b	15.44	12.06	68.00	165.00	123.00
W210 (kg)	189	186.76b	21.49	11.51	103.00	250.00	193.00
W365 (kg)	189	236.28b	27.51	11.64	165.00	311.71	232.00
W450 (kg)	189	272.13b	31.70	11.65	191.00	375.44	258.00
PREWG (kg)	189	0.69b	0.15	21.29	0.26	1.05	0.79
POSTWG (kg)	189	0.43b	0.22	50.49	-0.47	1.00	0.52
REA (cm^2)	189	46.53b	7.17	15.41	24.46	68.66	47.86
BF (mm)	189	2.25b	0.86	38.45	1.01	6.22	1.82
RF (mm)	189	3.70b	1.47	39.60	1.32	9.65	2.63
Precocious females*							
BW (kg)	133	34.17a	2.66	7.79	27.00	43.00	36.00
W120 (kg)	133	135.25a	14.18	10.49	99.56	175.07	138.00
W210 (kg)	133	207.11a	20.78	10.03	125.00	262.42	218.00
W365 (kg)	133	288.99a	34.02	11.77	214.00	388.72	273.00
W450 (kg)	133	324.35a	40.38	12.45	244.00	435.12	292.00
PREWG (kg)	133	0.84a	0.14	16.45	0.40	1.23	0.95
POSTWG (kg)	133	0.50a	0.22	44.92	0.01	1.09	0.28
REA (cm^2)	133	57.37a	8.32	14.50	31.75	79.43	56.18
BF (mm)	133	3.95a	2.23	56.48	-1.32	12.15	2.24
RF (mm)	133	5.98a	2.66	44.45	1.32	16.25	4.39

N = number of animals; SD = standard deviation; CV = coefficient of variation; BW = birth weight; W120 = standard weight at 120 days of age; W210 = standard weight at 210 days of age; W365 = standard weight at 365 days of age or yearling weight; W450 = standard weight at 450 days of age; PREWG = pre-weaning weight gain; POSTWG = post-weaning weight gain; REA = rib eye area; BF = subcutaneous fat thickness; and RF = rump fat thickness. *The mean age at first conception and first calving was 16 and 25 months of age for the precocious females, and 27 and 36 months for the conventional females, respectively.

with growth and carcass traits are presented in Table IV. Birth weight had the highest discriminating value for early pregnancy ($P < 0.05$). The birth weight of precocious female group was 10% higher ($P < 0.01$) than the conventional female group (Table II). For this trait, the P-level observed was 0.009 and the F-remove was 6.898, indicating high discriminatory power for early performance in Nellore heifers. In this sense, W120, W210, W365, W450, PREWG, POSTWG showed lower discriminant power.

Among the carcass traits, BF was the one that presented the highest discriminant power evaluated by Wilk's lambda and F-remove, in

Table III. Descriptive statistics and variance analysis results of t-test for visual scores traits for conventional and precocious heifers.

Traits	N	Mean	SD	CV (%)	Minimum	Maximum	Mode
	Conventional females*						
Reproduction	99	3.95	0.81	20.58	2.00	6.00	4.00
Udder	99	2.01	0.54	27.06	1.00	3.00	2.00
Muscularity	99	3.74	0.78	20.79	2.00	5.00	3.00
Frame	99	3.69	0.49	13.22	3.00	5.00	4.00
Structure foundation	99	2.07b	0.29	14.23	1.00	3.00	2.00
Bone structure	99	2.24a	0.52	23.05	1.00	3.00	2.00
Depth	99	3.66b	0.67	17.37	2.00	5.00	4.00
Rump	99	2.65	0.61	23.10	2.00	4.00	3.00
Navel (umbillicus)	99	3.32a	0.57	17.10	2.00	5.00	3.00
Mouth	99	3.17a	0.69	21.62	2.00	4.00	3.00
Tail insertion	99	2.00b	0.14	7.14	1.00	3.00	2.00
Fur/Pigmentation	99	3.00	0.52	17.17	2.00	4.00	3.00
Temperament	99	2.93b	0.54	18.41	1.00	4.00	3.00
Racial	99	3.22	0.69	21.52	1.00	4.00	3.00
Precocious females*							
Reproduction	245	3.86	0.79	20.39	2.00	9.00	4.00
Udder	245	2.02	0.71	35.35	1.00	4.00	2.00
Muscularity	245	3.82	0.96	25.15	2.00	5.00	4.00
Frame	245	3.76	0.59	15.62	2.00	5.00	4.00
Structure foundation	245	2.53a	2.12	23.79	1.00	9.00	2.00
Bone structure	245	1.71b	0.59	34.39	1.00	3.00	2.00
Depth	245	3.86a	0.80	21.76	2.00	5.00	4.00
Rump	245	2.52	0.62	24.54	1.00	4.00	2.00
Navel (umbillicus)	245	3.16b	0.66	20.74	1.00	4.00	3.00
Mouth	245	2.97b	0.67	22.68	1.00	4.00	3.00
Tail insertion	245	2.11a	0.39	18.71	1.00	3.00	2.00
Fur/Pigmentation	245	3.11	0.49	15.68	2.00	4.00	3.00
Temperament	245	3.10a	0.58	18.67	1.00	5.00	3.00
Racial	245	3.11	0.58	18.58	1.00	4.00	3.00

N = number of animals; SD = standard deviation; and CV = coefficient of variation. *The mean age at first conception and first calving was 16 and 25 months of age for the precocious females, and 27 and 36 months for the conventional females, respectively.

addition to the lower p-level (0.1842), being therefore considered the main carcass trait for identification of heifers with potential for sexual precocity. The other carcass traits (RF and REA) did not present significant discriminant power.

The visual scores traits that presented the highest discriminating power were bones structure, muscularity, depth, tail insertion and rump, which the p-level was 0.0000, 0.0001, 0.0067 and 0.0225, respectively (Table V). On the other hand, udder, structure foundation, frame, navel, temperament, pigmentation, mouth, reproduction and racial scores did not present significant discriminant power.

The phenotypic correlations between growth and carcass traits with early pregnancy heifer are present in Table VI. Overall, the correlations between growth traits were moderate to high (0.21 to 0.78), except between POSTWG with BW and W120; and PREWG with W450. The correlations between carcass with pre-weaning weight were low to moderate (-0.12 to 0.37); and with post-weaning weight were moderate (0.34 to 0.65). The correlations between early pregnancy with post-weaning weight (-0.25), post-weaning gain (-0.15), REA (-0.29) and RF (-0.30) were low, and; with pre-weaning weight (-0.43 to 0-.53), pre-weaning gain (-0.32) and BF (-0.53) were moderate.

The phenotypic correlations between visual scores traits with early pregnancy heifer are present in Table VII. Overall, the correlations observed between visual scores traits were low, except between racial, mouth, reproduction, udder, muscularity, frame and depth. The phenotypic correlation between racial score with mouth score was moderate (0.35). The estimates obtained between depth score with reproduction score (0.33), udder score (0.38), muscularity score (0.68), and frame score (-0.41) were moderate. The phenotypic correlations between muscularity score with udder score (0.32) and frame score (-0.42) were moderate. Between udder score and reproduction score was observed correlation moderate (0.46). For early pregnancy, phenotypic correlations with muscularity score (-0.52), depth score (-0.57), and tail insertion score (-0.38) were moderate; and for other visual scores traits were low (-0.17 to 0.18).

Table IV. Discriminant analysis between growth and carcass traits with early pregnancy heifer diagnostic.

Traits	Wilks' Lambda	Partial Lambda	F-remove	P-level
BW (kg)	0.7272	0.9619	6.899	0.0094
W120 (kg)	0.7244	0.9655	6.212	0.0136
W210 (kg)	0.7227	0.9678	5.790	0.0172
BF (mm)	0.7066	0.9899	1.778	0.1842
PREWG (kg)	0.7062	0.9904	1.689	0.1954
RF (mm)	0.7018	0.9966	0.590	0.4433
W450 (kg)	0.7017	0.9968	0.556	0.4570
REA (cm^2)	0.7011	0.9977	0.407	0.5245
POSTWG (kg)	0.7000	0.9993	0.130	0.7193
W365 (kg)	0.6999	0.9994	0.112	0.7385

BW = birth weight; W120 = standard weight at 120 days of age; W210 = standard weight at 210 days of age; BF = subcutaneous fat thickness; PREWG = pre-weaning weight gain; RF = rump fat thickness; W450 = standard weight at 450 days of age; REA = rib eye area; POSTWG = post-weaning weight gain; and W365 = standard weight at 365 days of age or yearling weight.

Table V. Discriminant analysis between visual scores traits with early pregnancy heifer diagnostic.

Traits	Wilks' Lambda	Partial Lambda	F-remove	P-level
Bone structure	0.8619	0.8669	50.5320	0.0000
Muscularity	0.7818	0.9556	15.2992	0.0001
Depth	0.7640	0.9778	7.4546	0.0067
Tail insertion	0.7590	0.9843	5.2599	0.0225
Rump	0.7570	0.9870	4.3489	0.0378
Udder	0.7546	0.9901	3.2921	0.0705
Structure foundation	0.7523	0.9931	2.2955	0.1307
Frame	0.7516	0.9940	1.9855	0.1598
Navel (umbillicus)	0.7515	0.9941	1.9543	0.1631
Temperament	0.7514	0.9942	1.9042	0.1685
Fur/Pigmentation	0.7499	0.9962	1.2481	0.2647
Mouth	0.7479	0.9989	0.3540	0.5523
Reproduction	0.7478	0.9991	0.2967	0.5863
Racial	0.7473	0.9997	0.0973	0.7553

Table VI. Pearson correlations between growth and carcass traits with early pregnancy heifer.

Traits	BW	W120	W210	W365	W450	PREWG	POSTWG	REA	BF	RF	EP
BW		0.28	0.39	0.49	0.38	0.25	0.09	0.29	0.05	-0.12	-0.53
W120			0.78	0.53	0.50	0.36	0.18	0.29	0.16	0.16	-0.44
W210				0.66	0.55	0.55	0.24	0.37	0.30	0.18	-0.43
W365					0.77	0.21	0.30	0.65	0.45	0.49	-0.25
W450						0.16	0.44	0.55	0.50	0.49	-0.25
PREWG							0.31	0.11	0.25	0.18	-0.32
POSTWG								0.38	0.35	0.34	-0.15
REA									0.55	0.77	-0.29
BF										0.83	-0.53
RF											-0.30

BW = birth weight; W120 = standard weight at 120 days of age; W210 = standard weight at 210 days of age; W365 = standard weight at 365 days of age or yearling weight; W450 = standard weight at 450 days of age; PREWG = pre-weaning weight gain; POSTWG = post-weaning weight gain; REA = rib eye area; BF = subcutaneous fat thickness; RF = rump fat thickness; and EP = early pregnancy heifer.

Table VII. Pearson correlations between visual scores traits with early pregnancy heifer (EP).

Traits	Reproduction	Udder	Muscularity	Frame	Structure foundation	Bone structure	Depth	Rump	Navel	Mouth	Tail insertion	Pigmentation	Temperament	Racial	EP
Reproduction		0.46	0.27	-0.14	0.02	0.25	0.33	0.00	0.20	0.27	-0.13	-0.06	0.07	0.19	-0.17
Udder			0.32	-0.09	-0.07	0.25	0.38	0.00	0.26	0.26	0.03	0.04	0.04	0.14	0.05
Muscularity				-0.42	-0.11	0.25	0.68	0.14	0.10	0.23	0.12	0.06	0.09	0.17	-0.52
Frame					0.01	-0.04	-0.41	-0.16	-0.03	-0.14	-0.09	0.02	0.07	-0.01	0.25
Structure foundation						-0.14	-0.11	-0.06	0.08	-0.02	-0.02	0.01	0.05	-0.08	0.18
Bone structure							0.28	-0.03	0.16	0.42	-0.07	0.02	-0.05	0.29	-0.22
Depth								0.13	0.15	0.23	0.09	0.01	0.06	0.11	-0.57
Rump									0.13	-0.07	0.14	-0.09	-0.04	0.06	-0.25
Navel										0.09	0.01	-0.08	0.01	0.10	-0.08
Mouth											-0.06	0.02	-0.08	0.35	-0.13
Tail insertion												0.05	0.10	0.05	-0.38
Pigmentation													0.06	0.07	0.12
Temperament														-0.08	0.08
Racial															-0.15

DISCUSSION

The results observed in this study demonstrated that birth weight showed higher discrimination power, and as the female's age advances, the discrimination power of post-weaning weights was lower. The moderate phenotypic correlations between pre-weaning weight and gain with early pregnancy support these results. The estimates obtained indicate that environmental and non-additive factors are acting simultaneously on these traits, so changes in the environment and management that increase the animals' pre-weaning weights and gain would also reduce the age at puberty, anticipating sexual maturity. Probably, there was a variation in fetal development, confirmed by the variation in birth weight between precocious and conventional heifers, which influenced the occurrence of precocious pregnancy.

Extreme intrauterine growth retardation can result in slower growth rate and birth weight, which reflects in a worst performance in post natal life (Greenwood & Cafe 2007). Besides that, the development of reproductive tissues begins during the fetal phase, so this can be altered by maternal dietary or by the cow genetic potential, affecting the future reproductive performance of the progeny (Du et al. 2010). The growing and differentiation of the principal tissues, organs and systems of bovine fetus occur between the 15th and 45th gestational day, and the development of the reproductive system begins in the 5th week and it is more expressive in the 9th gestational week (Henderson 1973). In addition, around the 3rd to 4th month of gestation, fibrillar myogenesis occurs. In this process the number of muscular fibers is defined, being of great importance for traits related to development and, consequently, reproductive efficiency (Du et al. 2010).

In the present study, about 70% of the dams from precocious females went through the first third of gestation, which is the period when the development of the reproductive organs begins, between December and February, and 63% of the conventional female dams went through this period between March and May. This way, it can be implied that during the development of the reproductive organs in the fetal phase, the dams of the precocious females received a better quantity and quality of forage. However, the dams of conventional females went through the first third of gestation during the transition between the raining and dry season. In this period (dry season) the forage production and quality declines (Penso et al. 2009). Probably, the dams of precocious females were submitted to a better nutritional condition, while the dams of conventional females went through a restriction period, when their fetus were in muscular fibers development stage, affecting the birth weight.

Jonhston et al. (2008) evaluated Brahman and Tropical Composite heifers, and related a large nutrition interaction effects on the age at puberty. These authors also reported a very low growth rate in dry-season, affected both the age and weight at puberty depending on the month birth of the heifers. They reported that heifers born in fall had a lower puberty rate than heifers born in spring, due to reduced pasture availability that would delay puberty in heifers.

It is important to highlight that most of the precocious heifers were born earlier in the calving season. This pattern would also be related to higher fertility of dams and heifers that, born early, have faster development and would inherit genes for improved fertility (Johnston et al. 2008).

The influence of fetal development and also birth weight on reproductive performance and age at first pregnancy were also observed by Freetly et al. (2000). Funston et al. (2008) observed higher number of heifers born from cows with adequate nutritional level reaching puberty before the first breeding season and higher pregnancy rate compared to non-supplemented cows. Martin et al. (2010) demonstrated that the variation of the female nutritional level during the gestation can affect oocyte quality or embryo formation. This fact resulting in a change in reproductive performance of the progeny, as a higher pregnancy rate observed in heifers born from cows with better nutritional levels during the first third of the gestation, which may have occurred in the present study.

As well as the development of reproductive tissues, the beginning of reproductive organs development, like the ovaries and the endocrine control of reproduction in hypothalamic-hypophyseal-gonadal axis, happens during fetal period, and it is affected by the female nutrition (Martin et al. 2010). Hence, there is a reduction of the follicular stimulating hormone (FSH) concentration at the pre-pubertal phase, which affects the testicular development in males, and the ovaries and corpus luteum in heifers, and it also affects the puberty triggering in animals (Martin et al. 2010, Long 2012). Similar results were reported by Cushman et al. (2014), who evaluated heifers from dams receiving different nutritional levels, and observed that the heifers from dams with higher nutritional level had the first conception earlier than the heifers from dams with lower nutritional levels.

Traditionally, the Nellore breeders used to apply different management strategies for heifers after weaning in order to attain a minimum weight of 250 kg at the beginning of mating season to achieve and adequate corporal development and obtain high pregnancy rates. However, the results obtained in this study demonstrated that as the age of females advances, the discrimination power of weights and weight gains is reduced. The results of this study showed that the most adequate phase to evaluate the sexual precocity potential would be before weaning. This information was confirmed by the low correlation between early pregnancy with post-weaning weights and live weight gain traits. The breeders should focus on management strategies during this phase in order to guarantee early heifer pregnancy, through strategic supplementation or offering an appropriate nutrition level to the dams, strategies related to fetal programming that could be directed to guarantee the fetal development.

Among the carcass traits evaluated after weaning, the BF had the highest discriminant power for early pregnancy heifer. In agreement, between carcass traits, the highest phenotypic correlation with early pregnancy was observed with BF. Thus environmental and management changes aimed at increasing fat deposition would reduce the age at puberty. The higher deposits of subcutaneous fat may indicate an earlier finish, also resulting in animals that present their first conception and first calving at a younger age. On the other hand, management techniques that increase the rib eye area and rump fat thickness may not result in changes in early pregnancy, since these traits show low correlation. Indeed, Jones et al. (2018), evaluating pregnancy rates of Angus heifers, observed that heifers divergent in BF present differences in pregnancy rates, reporting that fat depth were the largest contributing factor to variation in pregnancy rates, and age and pre-joining weight gain were not significant.

In Nellore heifers, early pregnancies can be obtained under 18 months of age, dams that can be pregnant until 20 months of age are considered precocious, mainly in grass feed tropical system. There are two subcategories of precocious dams, heifers that got pregnant between 18 to 20 months of age and outside the conventional mating season; and heifers considered super-precocious, that got pregnant up to 17 months of age and in the same conventional mating season as the herd. Thus, the use of BF at 18 months can be an effective indicator of sexual precocity for the first precocious group, especially in commercial herds, which age at puberty is not regularly measured.

This association between early pregnancy and BF can be explained by the influence that the body fatness level has on reproduction, through improvement of energetic status, steroidogenesis, insulin modulation and synthesis of leptin and prostaglandins (Leaflet 2001). The bovine female ovulates only after accumulates a minimum body fat reserve, this is a survival mechanism, but also the energy accrue to supply the nutritional requirements of gestation and lactation (Bronson & Manning 1991). The BF discriminant power compared with the other carcass traits can also related to with the growth curve of the animals, since the beginning of fat deposition is related to the reduction of muscle growth and the approach of physical maturity. The metabolic changes, associated with the growth curve of heifers, result in metabolic signals that are able to unleash puberty (Kinder et al. 1995).

Studies demonstrated that the body condition is a key point in reducing the age at first conception (Marques 2009). Buskirk et al. (1996) and Leaflet (2001), reported a positive relation between the fat thickness and the percentage of cycling Angus-Simmental crossbred heifers before mating. Buskirk et al. (1996) observed that 93% of the heifers with 5.88 mm of subcutaneous fat were cycling at the beginning of mating season, while only 32% of the heifers with 2.9 mm of fat thickness were cycling. The results of this study showed that in order to increase the proportion of early puberty heifers is important to monitor the heifer fat thickness before the mating season.

The bone score is used like an indicator of animal structure. Median bone structure is aimed, avoiding the excessively thin or thick bones (Qualitas 2016). The body size and height (frame-size) are used as determinant factors in sexual puberty between animals. Thus, it is inferred that the higher bone scores may be related to higher size and possibly late potential, while median bone scores may be indicative of smaller body size upon reaching sexual maturity (Meyer 1995). In fact, taller animals may be late in muscle development and subcutaneous fat accumulation, therefore being less precocious (Koury Filho et al. 2009). This result can be also confirmed by Pereira et al. (2010), which cited that larger animals might be later and less reproductively efficient.

Another trait that has shown to be more objective to discriminate precocious and conventional females was muscularity score, which is related to muscular development, carcass yield and body condition. The muscularity score can also be an indicative that the animals will deposit external fat during adult age, and it can be evaluated in younger animals (Qualitas 2016). Johnston et al. (2008) also related association of body condition score with age at puberty in Brahman and Tropical composite heifers.

The results observed in this study pointed out that animals with higher development of muscular mass also displayed higher heifer pregnancy, with lower age at first calving. In fact, several studies evaluating the association between muscularity and sexual precocity demonstrated strong and positive correlation estimates in Nellore cattle (Souza 2003, Koury Filho et al. 2009). In agreement, muscularity scores and early pregnancy presented a moderate correlation. These results can be attributed to a possible influence of increased muscularity at the onset of puberty and in reducing age at first calving.

The depth score also presented significant potential to precocious conception discrimination, being associated with higher muscular mass volume and higher subcutaneous fat deposition. The animals with growth curves for short cycle tend to present higher muscular deposition at earlier ages, and, therefore, they have higher depth score in relation to the limbs (Koury Filho et al. 2009, de Melo & Moura 2012). The association of depth score and muscularity score with sexual precocity can be attributed to the influence of these body traits on ovarian activity and, consequently, on age at first conception (Morris 1980, Olson 1994). The results in this study corroborated with those observed by Souza (2003), whom evaluated the prediction of sexual precocity with the use of visual scores, and observed that muscularity and depth score turn up were efficient indicators of precocity in Nellore heifers. Indeed, the phenotypic correlation between depth score with early pregnancy was moderate, demonstrating that heifers that have higher depth score also present early sexual maturity. Thus, depth score is an appropriate phenotypic indicator for sexual precocity in Nellore heifers.

Tail insertion score was also identified as a discriminant trait for early heifer pregnancy, where the highest scores for tail insertion were related to younger females at first conception. Accordingly, the phenotypic correlation between tail insertion score with early pregnancy was moderate and this trait would be used as an appropriate phenotypic indicator for sexual precocity in Nellore heifers. This result can be attributed to the association between tail insertion score and muscularity score, where this trait was also used to discriminate precocious females. The tail insertion is a point to visualize the muscularity score of the animal body score (Koury Filho et al. 2009, de Melo & Moura 2012, Qualitas 2016). Muscularity is associated with the hormonal trigger of puberty, and it can be attributed to higher tail insertion.

Rump angle score was effective in precocious female discrimination, where animals with median scores (3), represented by large rumps and soft inclination are desired. Animals with lower scores represent excessively inclined rumps, while high scores indicate excessively flat rumps, both of which are associated with difficulty at calving. It is inferred, that the larger size of the rump is also associated with the higher growth of the animals and, like the higher bone structure, it can be used as indicative of later females and higher size at maturity (Pereira et al. 2010). In this way, to reduce the age at puberty it should be used females with median rumps.

The growth, carcass and visual scores traits can be used as indicator traits to improve the female sexual precocity in Nellore cattle. The birth weight, fat thickness, bone structure score, muscularity score, depth score, tail insertion score and rump score showed the highest discrimination power between early and late pregnancy heifers. These results and phenotypic traits indicated that producers can manage heifers to particular birth weight, fat deposition, and body conditions to improve heifer conception rates and early puberty.

The fetal development influenced the manifestation of precocious puberty, thus early life effects are crucial. Age at puberty can be significantly delayed in late born calves and also in environments that limit growth rates, particularly during the dry season and nutritional status of dams. Thus, the dam supplementation in late gestation and early lactation could reduce time to the calving of heifer progeny by 1 year. Therefore, nutrition and management can be used to reduce the age at puberty by proper synchronization of the mating station, and the nutrition management of the dams. The management to obtain higher body condition in heifers can also be used to reduce the age at puberty.

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Brunes LC, Baldi FS, Magnabosco CU and Oliveira e Costa MF contributed to the design and performance of the study, the statistical analysis and interpretation of data, and writing of the manuscript. Quintans G and Banchero G contributed to reviewing the manuscript. Lôbo RB contributed to data set and to reviewing the manuscript.