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Research Article

Relative contribution of effects included in contemporary groups for adjusted and actual 120-day and 210-day weights in Nelore cattle in Brazil

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Abstract

The objective of this research was to estimate the relative magnitude of effects included in contemporary groups (CG) and their interactions with adjusted and actual 120 d and 210 d weights in 72,731 male and female Nelore calves born from 1985 to 2005 in 40 herds from PMGRN (Genetic Improvement Program of Nelore). Ten models with different CG structures were compared. The analyses were done using the general linear models (GLM) procedure run in *SAS* software. All of the effects included in the CG for each model were significant ($p < 0.001$) for the four traits analyzed. Inclusion of semester or trimester of birth as part of a CG was more appropriate than its use as an independent effect in the model because it accounted for interactions with the other effects in the CG. Calf sex (CS) and dam age at calving (DAC) had similar effects across the models, which suggested independence from other effects in these models. The corresponding age deviation effect had a larger impact on actual weight at 120 d than any other effect in all of the models tested. The use of actual weights in models with no CS effect in CG provides an alternative that would allow better genetic connectedness among CGs and greater accuracy in genetic evaluations.

Key words: beef cattle, models, preweaning growth.

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Introduction

Contemporary groups (CGs) are used in genetic evaluations to eliminate bias caused by systematic environmental effects such as differences in management, feeding and seasons (Van Vleck, 1987; Van Bebber *et al.*, 1997; Carabaño *et al.*, 2004; Cantet *et al.*, 2005). However, a large number of CG can result in a small number of records per subclass, resulting in an increase in the variance of prediction errors and a reduction in the accuracy of genetic evaluations (Van Vleck, 1987; Van Bebber *et al.*, 1997).

The length of time to identify animals belonging to the same CG within a herd is controversial. A balance between maximum accuracy and reduced bias must be achieved to optimize the definition of CG. The problem with the usual definition of CG is its arbitrary definition of periods of time that do not correspond to criteria for maximum accuracy and minimum bias (Schmitz et *al.*, 1991; Carabaño *et al.*, 2004). In an attempt to resolve this problem several criteria to compare different definitions of CG that consider the estimated intra-CG variance, residual variance and accuracy of genetic evaluations have been proposed (Schmitz *et al.*, 1991; Sivarajasingam, 1993; Van Bebber *et al.*, 1997; Carabaño *et al.*, 2004).

Brazil is known for its environmental diversity, with strong seasonal effects and fluctuations in pasture production that should be considered in the construction of CGs for genetic evaluation models (Fries and Ferraz, 2006). A significant influence in non-genetic effects and their interactions on growth in beef cattle has been widely proven in Brazil (Cardellino and Cardellino, 1984; Pons *et al.*, 1989; Mascioli *et al.*, 1996; Reyes *et al.*, 1998, 2006; Paz *et al.*, 1999; Cardoso *et al.*, 2001; Bocchi *et al.*, 2004).

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Several studies have shown that a linear adjustment of weight to a constant age at weaning in beef cattle does not completely remove the effect of age (Rossi *et al.*, 1992; Villalba *et al.*, 2000; Lobo and Martins Filho, 2002; Teixeira and Albuquerque, 2003; Reyes *et al.*, 2004; Torres Júnior and Toral, 2006) because the age of the animal at weighing time influences its average daily gain and consequently its adjusted weight (Toral *et al.*, 2007).

A model for genetic analysis should be preceded by careful study of systematic environmental effects and their interactions. The objective of this study was therefore to estimate and compare the relative magnitudes of effects included in CGs and their interactions on adjusted and actual calf weights at 120 d and 210 d of age in Nelore cattle in Brazil.

Material and Methods

The dataset consisted of adjusted and actual (real) weights at 120 d (AW120, RW120) and 210 d (AW210, RW210) of age from 72,731 male and female Nelore calves born from 1985 to 2005 in 40 herds belonging to PMGRN (Genetic Improvement Program of Nelore). Actual weights were those within 120 ± 60 d of age for RW120 and within 210 ± 60 d of age for RW210, and the corresponding ages were expressed as deviations (CAD – corresponding age deviations) for 120 d and 210 d, respectively. Standardized weights were obtained by interpolation using a weight before and another after the standard age (120 d or 210 d), with a maximum interval of 195 d between them (± 90 d with a tolerance of 15 days because of possible changes in management). If there was no previous weight for AW120, then birth (either measured or the average of the breed: males = 33 kg and females = 31 kg) was used as the first weight for the interpolation. Computations were done in a manner similar to that used by PMGRN (Lôbo, 1996):

$$AW = W + [(W-Wp)/I] \times (A - Aw)$$

where AW = adjusted weight at a standardized age (AW120 or AW210), W = nearest actual weight to a standardized age, Wp = previous weight, I = days between W and Wp, A = standardized age (120 d or 210 d) and Aw = age at measurement of W.

The effect of dam age at calving (DAC) was classified into six classes: 1 = 2 yr, 2 = 3 yr, 3 = 4 yr, 4 = 5 yr, 5 = 6-9 yr and 6 = ≥ 10 yr old. Five CG structures, with a minimum of five records per subclass, were defined as follows:

CG_1: herd - year of birth - management group at each age.
CG_2: CG_1 - semester of birth.
CG_3: CG_1 - trimester of birth.
CG_4: CG_2 - calf sex.
CG_5: CG_3 - calf sex.

The GLM procedure of SAS was used to estimate the relative importance of effects included in CGs and their interactions in 10 linear models. The structure of these models (M) was as follows:

M_1: Weight = $\alpha + CG_1 + SB + CS + DAC + \varepsilon$
M_{1A}: Weight = $\alpha + CG_1 + TB + CS + DAC + \varepsilon$
M_{1B}: Weight = $\alpha + CG_1 + CS + DAC + JDB + \varepsilon$
M_{1C}: Weight = $\alpha + CG_1 + CS + DAC + JDB(CS) + \varepsilon$
M_2: Weight = $\alpha + CG_2 + CS + DAC + \varepsilon$
M_3: Weight = $\alpha + CG_3 + CS + DAC + \varepsilon$
M_{3A}: Weight = $\alpha + CG_3 + CS + DAC(CS) + \varepsilon$
M_{3B}: Weight = $\alpha + CG_3 + CS + DAC + CAD(CS) + \varepsilon$
M_4: Weight = $\alpha + CG_4 + DAC + \varepsilon$
M_5: Weight = $\alpha + CG_5 + DAC + \varepsilon$

where Weight = adjusted or actual weight at 120 d or 210 d of age, α = a constant, CG = contemporary group, SB = semester of calf birth, TB = trimester of calf birth, CS = calf sex, DAC = class of dam age at calving (one of the six classes defined above), JDB = Julian date of calf birth, CAD = calf age deviation (deviation from 120 d or 210 d) and ε = a residual. The CAD effect was modeled as a cubic polynomial in all analyses using actual weights (RW120 and RW210).

The adjustability of the models was evaluated using an adjusted coefficient of determination (R^2_A = 1 - [residual mean square / total mean square]) and an estimate of the residual variance. The contribution of each effect to the R^2 coefficient for each model was computed as the ratio of the sum of squares due to each effect (Type I) and the total sum of squares.

Models for adjusted weights (AW120 and AW210) were defined as follows. Models M_1 to M_{1C} included the effects of CG_1, calf sex (CS), dam age at calving (DAC), and season of birth defined as semester of birth (SB, M_1), trimester of birth (TB, M_{1A}) and Julian date of calf birth (cubic polynomial; JDB, M_{1B}), and Julian date of calf birth date nested within calf sex (cubic polynomial; JDB(CS), M_{1C}). Model M_2 included $CG_2 = CG_1$ - SB, whereas models M_3 and M_{3A} contained $CG_3 = CG_1$ - TB, and these three models included the effects of CS and DAC; DAC was nested within CS in M_{3A}. Model M_4 tested $CG_4 = CG_2$ - CS, model M_5 had $CG_5 = CG_3$ - CS, and both models included DAC. Models for actual weights (RW120 and RW210) contained the same effects as models for adjusted weights plus the effect of calf age at weight expressed as a deviation from 120 d or 210 d of age (CAD) as a cubic polynomial. This model was tested using M_{3B}, where a cubic polynomial CAD effect was nested within CS.

Results and Discussion

Table 1 shows descriptive statistics for adjusted and actual weights at 120 d and 210 d of age. Larger ranges and greater standard deviations were observed for actual weights compared to standardized weights at both ages because of the effect of calf age on weight measurements.

Table 1 - Number of observations and mean, minimum, maximum and standard deviations of adjusted weights (AW) and actual weights (RW) in Nelore cattle at 120 d and 210 d of age.

Trait	N	Mean (kg)	Min (kg)	Max (kg)	Std (kg)
AW120	70,543	124.8	54	218	18.9
RW120	70,677	128.3	34	276	29.5
AW210	65,607	181.2	73	307	27.7
RW210	69,978	182.7	57	327	32.9

Max = maximum, Min = minimum, N = number of observations, Std = standard deviation.

Table 2 - Number of contemporary groups (1st line) and mean number of animals per contemporary group (2nd line) for adjusted weights (AW) and actual weights (RW) in Nelore cattle at 120 d and 210 d of age.

Trait	CG_1	CG_2	CG_3	CG_4	CG_5
AW120	456	688	1,077	1,093	1,670
	154.7	102.5	65.5	64.5	42.2
RW120	456	688	1,077	1,093	1,670
	155.0	102.7	65.6	64.7	42.3
AW210	459	674	1,042	1,057	1,609
	142.9	97.3	63.0	62.1	40.8
RW210	472	699	1,081	1,098	1,667
	148.3	100.1	64.7	63.7	42.0

CG_1: herd – year of birth – management group at each age; CG_2: CG_1 - semester of birth; CG_3: CG_1 - trimester of birth; CG_4: CG_2 - calf sex; CG_5: CG_3 - calf sex.

Table 2 shows the number of CGs and the mean number of records per CG for the five CG structures defined here. For weight at 120 d the number of subclasses remained constant between the actual and standardized weights and the average size of the five CG structures was similar. On the other hand, for weight at 210 d, CG number and size were slightly larger for actual weights than for standardized weights in all five CG structures, possibly because of management conditions in the herds where the animals were located. A large proportion of animals was weighed before the standard age of 210 d and subsequently at ages beyond the maximum interval of 195 d (maximum interval allowed for standardization), thus explaining the difference between the actual weights and weights standardized to 210 d.

The relative contributions of each effect to the coefficient of determination (R^2) in each model are summarized in Table 3. All effects were significant ($p < 0.001$) for the four traits analyzed (AW120, AW210, RW120 and RW210).

The smallest contribution of seasonal effects was for SB (M_1), the largest was for JDB (M_{1B}), and the effect of TB (M_{1A}) was intermediate between SB (M_1) and JDB (M_{1B}). Maximum R^2_A (%) differences for AW120, AW210, RW120 and RW210 were between those for M_{1B} and M_1 (0.4, 3.2, 0.2 and 2.5, respectively), and the corresponding maximum reductions in V_R (%) were 0.6, 5.4, 0.5 and 5.2. These results clearly indicate that seasonal effects were more important for weight at 210 d of age than at 120 d of age, in agreement with the findings of Reyes *et al.* (1998) for adjusted weights at 120 d and 240 d of age in Nelore cattle.

The differences in R^2_A (%) between models M_5 and M_1 showed increases of 3.2, 5.03, 1.5 and 3.9, accompanied by reductions in V_R (%) of 5.0, 8.9, 4.9 and 8.0 for AW120, AW210, RW120 and RW210, respectively. The differences in R^2_A (%) between models M_2 and M_1 (1.4, 1.7, 0.6 and 1.3 for AW120, AW210, RW120 and RW210, respectively) reflected the contribution of interactions between SB and the other effects in CG. The contribution of interactions between TB and the rest of the effects contained in CG_3 were 2.5, 2.7, 1.2, and 2.1 for the same four traits (M_3 - M_{1A}). These values showed that interactions involving SB (M_1) and TB (M_{1A}) were of similar importance and that inclusion of some seasonal class effects within a CG would be more effective than their inclusion as an independent main effect (including as JDB) or the application of a correction factor for these effects. Similar results were found by Reyes *et al.* (1998) for adjusted weights at 120 d and 240 d of age in Nelore cattle, and by Reyes *et al.* (2006) for preweaning growth in a multibreed Nelore x Hereford population.

As shown in Table 2, CG_2 had only 62.9% of CG, but a mean CG size 58.9% larger than CG_4 for AW120; the corresponding values for AW210, RW120 and RW210 were 63.8% and 56.7%, 62.9% and 58.7%, and 63.7% and 57.1%, respectively. Table 2 also shows that GC_3 had 64.5% of CG and a mean CG size 55.2% larger than GC_5 for AW120; the corresponding values for AW210, RW120 and RW210 were 64.8% and 54.4%, 64.5% and 55.1%, and 64.8% and 54.0%, respectively. Significant differences among the CG structures were accompanied by increases in R^2_A (%) between 0.26 (RW120) and 0.84 (AW210), and reductions in V_R (%) between 0.83 (RW120) and 1.46 (AW210). These results identified models M_2 (GC_2 with SB) and M_3 (GC_3 with TB), both without CS in their CG but with R^2_A (%) differences between 0.61 (RW120) and 1.98 (RW210), as viable alternatives for use in genetic evaluations of preweaning growth traits.

Estimates of the effects of CS and DAC and their contributions to R^2 were similar for all traits in all models. The estimates for CS(%) were 3.9, 4.7, 1.8 and 3.3 for AW120, AW210, RW120 and RW210, respectively, and for DAC (%) they were 4.1, 1.9, 1.7 and 1.6, respectively. Similar estimates for CS and DAC were obtained for preweaning growth in Nelore x Hereford crosses (Reyes *et al.*, 2006). These results indicated that CS and DAC were independent of the other effects in the models considered here for all four traits, and that, for both adjusted and actual weights, CS was more important than DAC at 210 d of age, whereas the opposite was true at 120 d of age. These results agreed with the expectation of an increase in the importance of the sex effect and a decrease in maternal influence as the animals grow older; they also support the current practice of including maternal effects when evaluating growth in young calves.

Table 3 - Relative contribution of each effect to fitting of the models, expressed as a fraction of the coefficient of determination (R^2) for adjusted weights (AW120 and AW210) and actual weights (RW120 and RW210) in Nelore cattle at 120 d and 210 d of age.

Model terms^{a}	M_1	M_{1A}	M_{1B}	M_{1C}	M_2	M_3	M_{3A}	M_{3B}	M_4	M_5
Adjusted weight (AW120-1$^{st.}$row) and actual weight (RW120-2$^{nd.}$row) at 120 days of age										
CG	0.2848	0.2848	0.2848	0.2848	0.3163	0.3320	0.3320	-	0.3659	0.3832
	0.1753	0.1753	0.1753	0.1753	0.2052	0.2520	0.2520	0.2520	0.2326	0.2805
SB	0.0139	0.0149	-	-	-	-	-	-	-	-
	0.0098	0.0101	-	-	-	-	-	-	-	-
CS	0.0390	0.0389	0.0394	0.0394	0.0387	0.0383	0.0383	-	-	-
	0.0181	0.0181	0.0183	0.0183	0.0179	0.0176	0.0176	0.0176	-	-
CAD	-	-	-	-	-	-	-	-	-	-
	0.4680	0.4676	0.4617	0.4613	0.4555	0.4172	0.4173	^{c}0.4186	0.4311	0.4125
DAC	0.0421	0.0421	0.0411	0.0411	0.0406	0.0406	^{c}0.0410	-	0.0386	0.0383
	0.0178	0.0183	0.0172	0.0172	0.0178	0.0173	^{c}0.0174	0.0173	0.0169	0.0163
JDB	-	-	0.0181	^{c}0.0184	-	-	-	-	-	-
	-	-	0.0180	^{c}0.0185	-	-	-	-	-	-
V_R ^{b}	**223.62**	**223.29**	**222.33**	**222.26**	**218.64**	**214.31**	**214.16**	**-**	**216.67**	**212.25**
	273.06	**272.65**	**271.68**	**271.57**	**267.43**	**262.15**	**261.99**	**260.96**	**265.20**	**259.73**
$R^{2\ b}$	0.3798	0.3807	0.3834	0.3836	0.3956	0.4109	0.4113	-	0.4045	0.4215
	0.6889	0.6894	0.6905	0.6907	0.6964	0.7040	0.7042	0.7054	0.7006	0.7092
R^2_A ^{b}	***0.3757***	***0.3766***	***0.3793***	***0.3795***	***0.3896***	***0.4017***	***0.4021***	***-***	***0.3951***	***0.4075***
	0.6869	***0.6874***	***0.6885***	***0.6886***	***0.6933***	***0.6994***	***0.6996***	***0.7008***	***0.6959***	***0.7022***
Adjusted weight (AW210-1$^{st.}$row) and actual weight (RW210-2$^{nd.}$row) at 210 days of age										
CG	0.3212	0.3212	0.3212	0.3212	0.3668	0.3926	0.3926	-	0.4259	0.4541
	0.2553	0.2553	0.2553	0.2553	0.3038	0.3358	0.3358	0.3358	0.3479	0.3821
SB	0.0264	0.0391	-	-	-	-	-	-	-	-
	0.0276	0.0348	-	-	-	-	-	-	-	-
CS	0.0469	0.0480	0.0478	0.0478	0.0463	0.0471	0.0471	-	-	-
	0.0326	0.0334	0.0333	0.0333	0.0326	0.0333	0.0333	0.0333	-	-
CAD	-	-	-	-	-	-	-	-	-	-
	0.1874	0.1882	0.1895	0.1890	0.1807	0.1677	0.1678	^{c}0.1685	0.1792	0.1658
DAC	0.0174	0.0211	0.0168	0.0168	0.0171	0.0212	^{c}0.0213	-	0.0160	0.0197
	0.0152	0.0176	0.0145	0.0145	0.0153	0.0177	^{c}0.0178	0.0177	0.0142	0.0164
JDB	-	-	0.0579	^{c}0.0581	-	-	-	-	-	-
	-	-	0.0506	^{c}0.0513	-	-	-	-	-	-
V_R ^{b}	**454.99**	**441.56**	**430.43**	**430.25**	**442.29**	**420.93**	**420.83**	**-**	**435.84**	**414.41**
	525.15	**513.15**	**498.06**	**497.84**	**511.47**	**489.99**	**489.88**	**489.17**	**504.61**	**483.19**
$R^{2\ b}$	0.4120	0.4293	0.4437	0.4440	0.4303	0.4608	0.4610	-	0.4419	0.4738
	0.5183	0.5293	0.5431	0.5433	0.5323	0.5544	0.5546	0.5552	0.5412	0.5643
R^2_A ^{b}	***0.4078***	***0.4252***	***0.4397***	***0.4400***	***0.4243***	***0.4521***	***0.4522***	***-***	***0.4327***	***0.4606***
	0.5149	***0.5260***	***0.5399***	***0.5401***	***0.5276***	***0.5474***	***0.5475***	***0.5482***	***0.5339***	***0.5537***

[a] For each term: Adjusted weights (1$^{st.}$ row) and actual weights (2$^{nd.}$ row). CG = Contemporary group; (CG_1 M_1 to M_{1C}) = concatenation of herd – year of birth – management groups at 120 and 210 days of age; (CG_2 M_2) = concatenation of CG_1 - semester of birth; (CG_3 M_3 to M_{3B}) = concatenation of CG_1 - trimester of birth. CS = calf sex. (CG_4 M_4) = concatenation of CG_2 - CS; (CG_5 M_5) = concatenation of CG_3 - CS. SB = season of birth, semester (M_1), trimester (M_{1A}), JDB = Julian date of calf birth (1 to 366 days, M_{1B}); JDB(CS) M_{1C}; CAD = calf age at weighing as deviation from 120 or 210 days; DAC = dam age at calving class (one of six classes as defined in the text); DAC(CS) M_{3A}; CAD(CS) M_{3B}.

[b] V_R = residual variance. R^2 = coefficient of determination of the model. R^2_A = adjusted R^2 = 1- (residual mean square / total mean square).

[c] Effects of DAC(CS) M_{3A}, and of cubic polynomial regressions of AW120 or AW210 on JDB(CS) M_{1C}, and of RW120 or RW210 on CAD(CS) M_{3B} and JDB(CS) M_{1C}.

Differences of 0.6, 0.8, 0.3, and 0.6 in R^2_A (%) between models M_4 and M_2 and reductions in V_R (%) of 0.9, 1.5, 0.8 and 1.4, for AW120, AW210, RW120 and RW210, respectively, represented the contribution of interactions between CS and the remaining effects in *CG_2*. Similarly, R^2_A (%) differences between models M_5 and M_3 and reductions in V_R (%) were attributable to the combined effect of interactions between CS and the other components of CG_3. The corresponding values were 0.6, 0.9, 0.3 and 0.6 for differences in R^2_A (%) and 1.0, 1.6, 0.9 and 1.4 for reductions in V_R (%) for AW120, AW210, RW120 and RW210, respectively. The low interaction between CS and other CG components in CG_2 and CG_3 relative to the main CS effect suggested that CS can be included as a class effect separately from CG, and that this will have a very small impact on the adjustment of records. In addition, an independent CS effect will decrease the number of CGs and increase their size, thereby increasing connectedness and the accuracy of genetic evaluations. These results showed that estimates of CS were similar across models and reconfirmed the results for Nelore x Hereford cattle (Reyes *et al.*, 2006).

Although significant, within sex estimates of DAC (M_{3A}) and JDB (M_{1C}) for all four traits, and of CAD (M_{3B}) for actual weights did not show appreciable contributions to the increase in R^2_A (< 0.1%) or to the reduction in V_R (< 1 unit), suggesting that these effects would not need to be included in the usual models for genetic evaluation of preweaning growth traits where simple models are required. Reyes *et al.* (2006) reached a similar conclusion for Nelore x Hereford cattle.

The contribution of the CAD effect was large relative to other effects in the CGs tested here. The CAD contributed most to the increase in R^2_A and the reduction in V_R, and was one of the most important effects for weight at 210 d. Figure 1 shows the cubic polynomial regressions of calf actual weights on days of age expressed as deviations from 120 d and 210 d, estimated using models M_2, M_3, M_4 and M_5. The quadratic and cubic terms were significant ($p < 0.05$) for both traits in all models, reconfirming that the relationship between weight and age is not linear, in agreement with previous findings (Rossi *et al.*, 1992; Lobo and Martins Filho, 2002; Reyes *et al.*, 2004; Torres Júnior and Toral, 2006). Hence, the use of actual weights measured within an interval centered on a pre-established standard age, and inclusion of the effect of calf age in the analysis model provides an advantageous alternative for genetic evaluations.

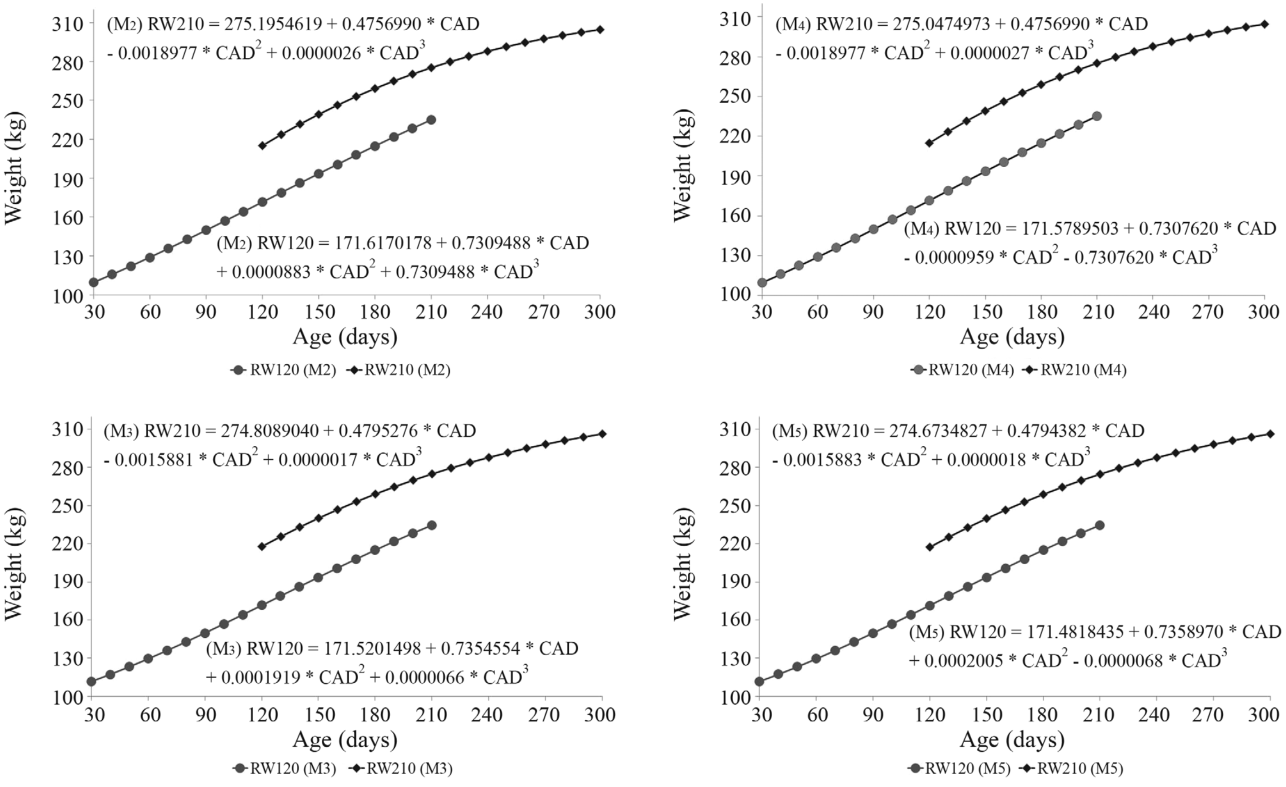

Figure 1 - Cubic polynomial regressions of actual weights at 120 d (RW120) and 210 d (RW210) on age expressed as deviations (CAD), estimated with models M_2, M_3, M_4 and M_5. RW120: actual weight at 120 d; RW210: actual weight at 210 d; CAD = calf age at weighing as deviation from 120 or 210 days; M_2: weight = $\alpha + CG_2 + CS + DAC + \varepsilon$; M_3: weight = $\alpha + CG_3 + CS + DAC + \varepsilon$; M_4: weight = $\alpha + CG_4 + DAC + \varepsilon$; M_5: weight = $\alpha + CG_5 + DAC + \varepsilon$; CG = contemporary group; (CG_2 M_2) = concatenation of herd - year of birth - management groups at 120 and 210 days of age - semester of birth; (CG_3 M_3) = concatenation of herd - year of birth - management groups at 120 and 210 days of age - trimester of birth. (CG_4 M_4) = concatenation of CG_2 - CS (CG_5 M_5) = concatenation of CG_3 - CS. CS = calf sex. DAC = dam age at calving class (one of six classes as defined in the text).

In conclusion, the independence of calf sex effects from other effects in the CGs tested here suggests that this effect could be modeled separately from CG effects. This independence creates a promising alternative for modeling genetic analyses of preweaning growth traits that would increase the size of CGs and the accuracy of genetic predictions. The inclusion of semester or trimester of birth as part of a CG was more appropriate than independent estimates of these effects because it accounted for interactions with all other components of a CG. Estimates of Julian date of calf birth, dam age at calving, and calf age at weighing within calf sex suggested that genetic evaluation models for preweaning growth traits need not include these effects, which means that simpler models for these traits can be used. The use of actual weights in models that include a season of birth effect within CGs and model calf sex separately constitute alternatives that could improve genetic connectedness among CGs and help increase the accuracy of genetic evaluations.

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Errata: Due an error, Table 3 in Ahead of Print version was replaced by Table 3 in this article.