Use of Linear and Non-linear Growth Curves to Describe Body Weight Changes of Young Angus Bulls and Heifers

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Summary and Implications

The objectives of the current study were to describe bodyweight (BW) changes of purebred Angus bulls and heifer and to evaluate bias in the adjustment of weaning weight measures to a 205-d age. Linear and non-linear growth functions were used to evaluate changes in BW. Models used were a simple linear regression model fitting cubic polynomial of age at measurement (model I) and a Logistic model (model II) . Predicted mature weight for bulls was 763 kg (1,678.6 lbs.) as compared to 541.9 kg (1192.2 lbs.) for heifers. Bulls attained a maximum average daily weight gain (ADG) of 1.75 kg/d (3.85 lbs/d) at a mean age of 296 d. The maximum ADG attained by heifers was 1.24 lb/d (2.73 lb/d) at a mean age of 261 d. Beef Improvement Federation procedures underestimated 205 d BW of bull calves measured at relatively younger ages and overestimated those measured at later ages. However, the extent of this bias seems to vary depending on the rate of growth of individual calves. The current results suggest that producers should consider creating contemporary groups with a smaller spread in age.

Introduction

Body weight (BW) measures represent one of the most important economic traits in beef cattle. In addition, BW is strongly associated with other economic characters including production and reproduction traits. Therefore, selection programs designed to alter growth in cattle will ultimately cause permanent changes in the associated traits.

Currently National cattle evaluation programs for the American Angus Association use weaning weight measures taken between ages of 120 to 280 d. Data are then adjusted to 205 d based on Beef Improvement Federation (BIF) recommendations. This adjustment procedure may indeed be the best option considering that each calf at this stage has only two weight measures. However, allowing such a wide window of weaning ages is likely to introduce bias.

Any possible bias due to BIF adjustment procedure could be evaluated based on longitudinal BW measures from designed experiments. The objectives of this study were to describe body weight changes in young Angus bulls and heifers and to evaluate bias due to adjusting data to 205 d based on BIF procedures.

Materials and Methods

Source of Data

Bulls and heifers in the present study came from the Iowa State University Beef Cattle Breeding Project. The project is designed to develop two lines of beef cattle for use as a research base to answer questions that influence genetic improvement of beef cattle. The project was initiated in 1997 with the purchase of 285 spring1996-born, purebred registered Angus heifers. Detailed explanation of the project and herd management practices are provided in the last year's report (Hassen et al., 2003).

The current study included data from 927 purebred Angus bulls and heifers born during 1998-2001. Data included serial BW information of bulls and heifers measured from birth to harvest of unselected bulls, or to first breeding in case of selected bulls and all heifers.

Data Analysis

Linear and non-linear growth functions were used to evaluate changes in BW. Initially data were analyzed by sex group. In further analysis, the same models were used to develop individual animal growth curves.

Linear growth functions compared were simple linear regression models that included different levels of polynomial of age at measurement. Degree of fit was evaluated using model R^2, root mean square error (RMSE), Absolute difference between actual and predicted weight (ABS), and percent absolute difference (PABS). Non-linear growth models considered were special cases of Richard's family functions. These included Broody, Van Bertalanfy, Logistic, and Gomez growth functions. Non-linear models were compared based on degree of fit, ability to converge, and accuracy of parameter estimates.

Results and Discussions

Table 1 provides number of bulls and heifers used in the current study by year of birth. A total of 400 bulls and 527 heifers were included. Number of observations per animal ranged from 7 to 10.

Of the different linear regression equations compared, a model including cubic effect of age showed the best fit. Any additional polynomial beyond this level didn't show a substantial improvement in model R^2 and RMSE. In the analysis of data pooled within sex, all non-linear functions, with the exception of Broody's, did converge and showed similar R^2 values. However, only logistic regression model converged for more than 98% of the animals when used to compute individual animal growth curves. Therefore, a model fitting cubic polynomial of age at measurement (Model I) and logistic model (model II) were used to represent linear and non-linear functions in further description of changes in body weight.

For each sex, both models I and II showed a similar model R^2, RMSE, ABS, and PABS (Table 2). Data in the current study included very limited range of ages representing the "linear" part of the growth curve. Indeed, both model types could adequately describe body weight changes for the given range. Results from the pooled data showed an average mature weight of 682 Kg (1500.4 lbs.) for bulls and 492 kg (1,082.4 lbs.) for heifers. Although results are within literature reports, these estimates involve extrapolation, as range of ages in the current data did not include maturity.

For both model types, individual animal regressions showed a better fit to data than pooled regressions as evidenced by lower RMSE, ABS, PABS and higher R^2 values (Table 3). Comparing the two models based on individual animal data, model I seems to show a better fit than model II. This reinforces the fact that simple linear regression models could be used in such circumstances to describe changes in BW as well as to predict weight to a constant age.

Table 4 shows some calculated values of biological significance derived from parameter estimated in model II. Generally, bulls were older, heavier, and gained faster than heifers at point of inflection. The general change in ADG of bulls and heifers is shown in Figure 1. ADG at point of inflection for bulls was 1.75 kg/d (3.85 lb/d) as compared to 1.24 kg/d (2.73 lb/d) for heifers.

The BIF 205 d weight formula contains two variables including birth weight and ADG. Therefore, how well we adjust data to this age entirely rests on how accurate our ADG estimates are. Since Angus producers submit only two body weight measures by this age, accuracy of ADG estimates depends on how close the actual weaning age to 205 d is. Figure 2 shows the general trend in bias due to adjusting data based on BIF recommendations. BIF adjusted values were compared with 205 d WT computed based on all serial WT measures of each individual in a within animal regression procedure (model I). BIF procedures underestimated 205 d WT of calves measured at lower end of the window and over predicted for those measured at later ages. However, the extent of this bias seems to vary depending on the rate of growth of individual calves. Lack of such a clear bias in adjusting heifers could be due to the relatively low rate of gain for heifers.

Generally, the influence of such a bias could be minimized by placing cattle in contemporary groups (CG) with less age spread. Therefore, CG should be made to include information on range of weaning ages. Other option would be to use random regression models and thereby eliminate the need for adjusting data for age of calf.

References

Hassen, A. D. E. Wilson, G. H. Rouse. 2003. Estimating heritability of percentage of intramuscular fat and ribeye area measures by scan sessions in Angus bulls and heifers. Beef Research Report. Available: http://www.iowabeefcenter.org/pdfs/BRR/. Accessed December 2003.

Table 1. Number of bulls and heifers used in the current study.

Year	Sex: Bulls	Heifers	Obs. / head
1998	83	186	7
1999	83	72	7-8
2000	115	126	9-10
2001	119	142	8-9

Table 2. Linear and non-linear regression parameters for bulls and heifers based on pooled data[Z]

	Model I				Evaluation criteria			
	Int.	Age	Age^2	Age^3	RMSE	R^2	ABS	PABS
Bulls	41.98	0.192676	0.005140	-0.00000638	48.57	0.91	36.75	11.53
	(2.41)	(0.06943)	(0.000417)	(0.00000064)				
Heifers	37.65	0.70816	0.001132	-0.00000146	38.59	0.90	29.62	11.60
	(1.68)	(0.04912)	(0.00029)	(0.00000046)				
	Model II				Evaluation criteria			
	a	b	k		RMSE	R^2	ABS	PABS
Bulls	682.8	13.56550	0.00967		48.49	0.91	37.00	12.45
	(9.92)	(0.40480)	(0.00020)					
Heifers	492.0	9.24110	0.00941		39.18	0.90	30.84	14.38
	(5.596)	(0.23180)	(0.00017)					

[Z]Values in bracket refer to SE of estimates
ABS = Absolute difference between predicted and actual weight, kg; PABS = percent absolute difference (ABS as percentage of body weight); RMSE = root mean square error, kg; a =asymptotic (mature) weight, kg, b = integration constant, k = maturing rate, day^{-1}

Table 3. Linear and non-linear regression parameters for bulls and heifers based on individual animal regression[Z].

	Model I				Evaluation criteria			
	Int.	Age	Age^2	Age^3	RMSE	R^2	ABS	PABS
Bull	40.47	0.407367	0.0032925	-0.00000286	10.14	0.99	5.822	1.96
	(4.84)	(0.525551)	(0.003114)	(0.00000499)				
Heifer	37.80	0.76837	0.0005777	-0.0000003	9.09	0.99	4.86	1.75
	(4.91)	(0.5709)	(0.00377)	(0.000006)				
	Model II				**Evaluation criteria**			
	A	b	k		RMSE	R^2	ABS	PABS
Bulls	763.35	15.387	0.0092763		12.65	0.99	7.35	4.97
	(134.79)	(3.673)	(0.001145)					
Heifer	541.92	10.9362	0.0094433		14.67	0.99	8.22	6.27
	(115.12)	(2.8636)	(0.00190)					

[Z]Values in bracket refer to SE of estimates
ABS = Absolute difference between predicted and actual weight, kg; PABS = percent absolute difference (ABS as percentage of body weight); RMSE = root mean square error, kg; a =asymtotic (mature) weight, kg, b = integration constant, k = maturing rate, day^{-1}

Table 4. Mean estimated daily weight gain, age, and weight of calves at point of inflection.

SEX	r	t	BW
Bull	1.75	296	382
Heifer	1.24	261	271

r = max daily weight gain (kg /d), t = age, d; BW = body weight, kg
multiply by 2.2 to convert r and BW to pound equivalent.

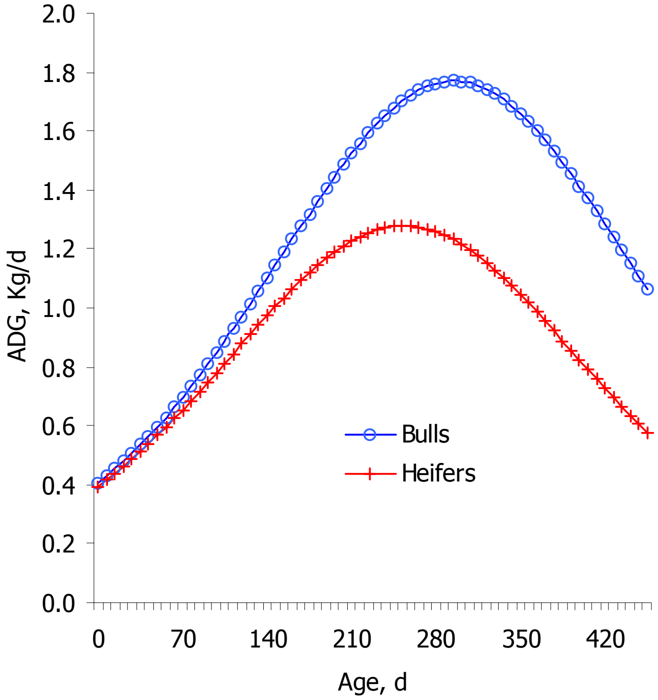

Figure 1. Predicted ADG of bulls and heifers based on means of individual animal linear regression models.

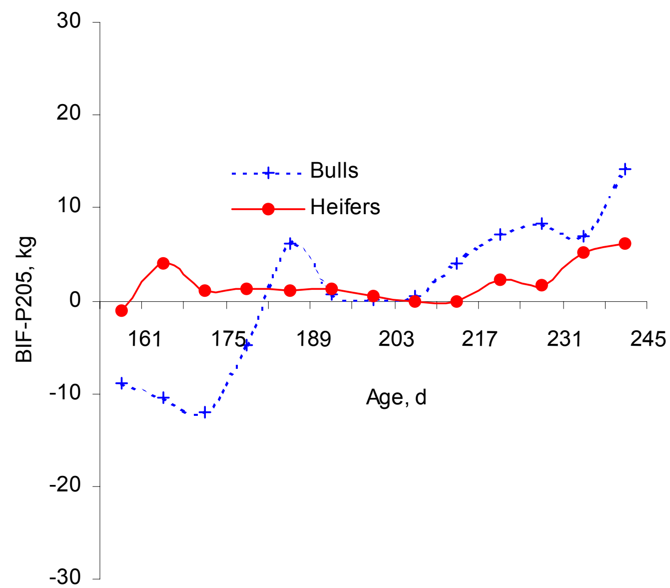

Figure 2. General trend in the amount of bias intdoduced by age of calf adjustment factors for bulls and heifers.