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Longitudinal changes in ultrasonic measurements of body composition during growth in Suffolk ram lambs and evaluation of alternative adjustment strategies for ultrasonic scan data

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ABSTRACT: Four equations were used to compare alternative procedures to adjust ultrasonic estimates (y) of backfat thickness (BF) and LM area (LMA) for BW using data from a series of 7 scans on 24 Suffolk ram lambs born in 2007. Equations were linear, linear + quadratic, allometric ($y = \alpha BW^{\beta}$), and allometric + BW (ABW; $y = \alpha BW^{\beta}e^{\gamma W}$). Goodness of fit was very similar between equations over the range of the data. Resulting adjustment equations were tested using 3 serial scans on winter-born Suffolk (n = 150), Hampshire (n = 36), and Dorset (n = 43) rams and 52 fall-born Dorset rams tested at the Virginia Ram Test in 1999 through 2002. Partial correlations (accounting for the effect of year) between predicted and actual measures ranged from 0.78 to 0.87 for BF and 0.66 to 0.93 for LMA in winter-born rams and from 0.70 to 0.71 for BF and 0.72 to 0.78 for LMA in fall-born rams. No significant differences in predictive ability existed between equations for BF or LMA ($P > 0.05$), and there was no indication that the allometric equation was a better predictor than linear within the range of the data. Adjustment equations were also tested using serial scan data from 37 Suffolk ewe lambs born in the same contemporary group as the rams used to derive the prediction equations but fed for a substantially slower rate of BW gain. Correlations between predicted and actual values of BF and LMA indicated lambs were too young and small at the first scan (77 d, 32.4 kg) to reliably predict carcass measures at typical slaughter weights. For prediction using data from the 2 subsequent scans, at mean ages >96 d and mean BW >39 kg, correlations between predicted and actual values were 0.72 to 0.74 for BF and 0.54 to 0.76 for LMA. Little difference existed between equations for predicting BF. For LMA, the ABW form was a weaker predictor than the others, and the linear equation was slightly superior to allometric. Therefore, it appears the linear and allometric forms are both suitable for use in central ram test and performance-tested farm flocks.

Key words: body composition, growth, sheep, ultrasound

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INTRODUCTION

Ultrasonic estimates of backfat thickness (**BF**) and LM area (**LMA**) in swine, cattle, and sheep predict analogous carcass measurements with acceptable accuracy if scanning is performed by experienced technicians and images are traced by trained interpreters (Simm, 1983; McLaren et al., 1989, 1991; Leeds et al., 2008). Technologies such as CT scanning allow carcass traits to be measured in vivo with greater precision and accuracy (Macfarlane et al., 2006), but ultrasound is advantageous in terms of cost and portability. Carcass indicator traits measured in carcasses or estimated in vivo using ultrasound are also correlated to carcass lean yield (Berg et al., 1997; Leeds et al., 2008). Thus, selection based on ultrasonic measurements in live animals is anticipated to improve composition in slaughter lambs.

Genetic improvement in lean content resulting from use of ultrasonic measurements in selection has been documented in swine, cattle, and, in some countries, sheep (Simm and Dingwall, 1989). However, the US sheep industry has yet to adopt large-scale genetic evaluation of carcass traits, and estimates of breeding values for carcass trait are currently not provided by the US National Sheep Improvement Program (**NSIP**). Use of scanning data in selection requires that measurements be adjusted to a constant endpoint, generally based on age or BW, yet few studies have reported longitudinal changes in ultrasound traits in lambs. The most substantial research involving repeated ultrasonic

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measures (Fischer et al., 2006) focused on patterns of variation but did not compare descriptive models.

This study compared alternative procedures to adjust ultrasonic estimates of BF and LMA in growing lambs for differences in BW. The broader objective was to provide information on optimal adjustment procedures to flock owners, central test stations, and NSIP for use in developing procedures for across-flock genetic evaluation of lamb carcass composition.

MATERIALS AND METHODS

All measurements were made in accordance with approved protocols of the Virginia Tech Animal Care and Use Committee.

Seven serial ultrasonic measurements of BF and LMA were taken on 26 Suffolk ram lambs from the Virginia Tech flock between April 27 and August 10, 2007. Lambs were transferred to the Virginia Ram Testing Station, Steeles Tavern, on May 1 and were officially on test from May 15 to July 17. The feeding program emphasized rapid growth and development and was thought to be representative of the feeding regimen in Suffolk farm flocks contributing data to NSIP. During the test period, rams were fed a corn-based pelleted ration (available for ad libitum consumption; 16.4% CP and 71.1% TDN on DM basis) and had continuous access to native fescue pastures. After completion of the test, intake of concentrates was reduced from ad libitum to approximately 1.5% of BW until August 25 to prepare rams for breeding in a pasture environment. Rams were scanned at approximately 21-d intervals on April 27, May 18, June 8, June 29, July 24, and August 10. Scans on June 8 were repeated June 11, to have a greater number of scans available when rams were near 120 d in age, the point to which postweaning weights are currently adjusted by NSIP.

Body weights on the day of scanning were recorded on April 27, June 11, and August 10; linear interpolations using these BW and official test weights from May 15, June 5, June 19, July 3, and July 17 were used to estimate BW on the other scanning dates. Body weight per day of age (**BWDA**) was used to identify growth outlier suspects; lambs with BWDA that were consistently more than 2.5 SD from the mean BWDA (calculated after suspects were removed) were excluded from analysis.

The same technician scanned all lambs in the study. Scans were performed on the right side of the lambs between the 12th and 13th ribs using an Aloka 500 ultrasound machine (Corometrics Medical Systems, Wallingford, CT) set at 2× magnification and equipped with an 11-cm, 3.5-mHz transducer. The transducer was fitted with a Superflab standoff guide (Mick Radio-Nuclear Instruments Inc., Mt. Vernon, NY) to ensure proper contact with the animals and minimize tissue distortion in the images. Lambs were held in a relaxed position by an assistant, wool was shorn from the scan site, and vegetable oil was applied as a couplant to obtain adequate acoustic contact.

An image deemed suitable by the technician was captured and recorded to a laptop computer. Images were interpreted by the scan technician using Rib-O-Matic Version 2.0 software (Critical Visions Inc., Atlanta, GA). The perimeter of the LM was traced to determine LMA, and BF was measured at the midpoint of the LM. Two independent interpretations were made for each image, and resulting values were averaged before analysis.

Data were analyzed using the GLM procedure (SAS Inst. Inc., Cary, NC). Four different functions were used to describe relationships of BF and LMA (y) to BW:

$$\text{linear: } y = \alpha + \beta BW;$$

$$\text{linear + quadratic (LQ): } y = \alpha + \beta BW + \gamma BW^2;$$

$$\text{allometric: } y = \alpha BW^{\beta}; \text{ and}$$

$$\text{allometric + BW (ABW): } y = \alpha BW^{\beta} e^{\gamma W}.$$

Log-transformations were used to linearize allometric equations as $\ln(y) = \ln\alpha + \beta\ln(BW)$ and $\ln(y) = \ln\alpha + \beta\ln(BW) + \gamma BW$.

Adjustment equations were compared and validated by prediction of BF and LMA in 2 other data sets. The first data set included 281 ram lambs of 4 groups scanned 3 times by a different operator but using the same equipment at the Virginia Ram Test between 1999 and 2002. Groups included 150 Suffolk, 36 Hampshire, and 43 Dorset rams born in winter (January and February) of their respective test year, and 52 fall-born Dorsets born in September, October, or November of the previous year. Rams were fed in the same facility as the 2007 rams, with a similar diet and time on test. In each year, 3 ultrasonic scans of BF and LMA were collected at intervals of approximately 30 d. The ultrasonic BF and LMA at the second scan were predicted from BW and ultrasonic measurements at the first or third scan and compared with actual values using partial correlation coefficients (accounting for effects of year) for each breed and birth season and each functional form.

Similar comparisons were made between predicted and actual measurements of BF and LMA using 9 serial scans taken between 77 and 181 d of age on 40 Suffolk ewe lambs from the same flock and birth year as the ram lambs used to develop adjustment equations and scanned by the same operator using the same procedures. The postweaning diet of the ewe lambs consisted of a corn-soybean meal concentrate (approximately 14% CP and 87% TDN) fed daily at 2% of BW, along with continuous access to native fescue/white clover pastures. These ewe lambs remained at the Virginia Tech Sheep Center and had a mean ADG over the scanning period of 220 g/d. The first, second, third, and seventh ewe-lamb scans were used for this study. The mean BW of ewe lambs at the seventh scan corresponded most

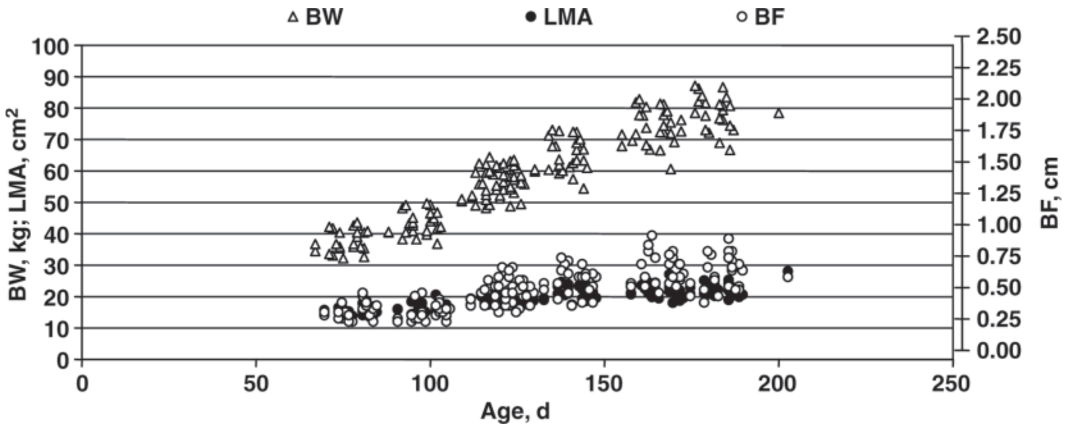

Figure 1. Relationship of BW, LM area (LMA), and backfat thickness (BF) with age in 24 growing Suffolk ram lambs.

closely to the 120 d BW of approximately 56 kg for the ram lambs and was chosen as the reference point. In addition, BW were not available at some intermediate scan periods, and not all lambs were present for the last 2 scans. Thus, measurements from the third, second, and first scans were used to predict ultrasonic measures in the seventh, and correlation coefficients between predicted and actual variables were reported.

Correlation coefficients (r) were normalized as $z = 1/2[\ln(1 + r) - \ln(1 - r)]$ with SD of z equal to $(n - 3)^{-0.5}$ where n is the number of pairs of observations (Snedecor and Cochran, 1967). Confidence limits for z were then assigned and back-transformed to set confidence limits on r.

RESULTS AND DISCUSSION

Development of Descriptive Equations and Adjustment Strategies

Means for age, BW, BF, and LMA on each scan date for Suffolk ram lambs measured in 2007 are reported in Table 1. Age at scanning ranged from 67 to 200 d and averaged 76 d at the first scan and 181 d at the last scan. Body weights ranged from 32 to 87 kg and averaged 38 kg on April 27 and 78 kg on August 10. Growth was essentially linear during the test period with mean ADG of 410 g/d through July 17, but ADG declined to 240 g/d between July 17 and August 10. One ram lamb with BWDA more than 2.5 SD below the mean on 5 of the 7 scan dates was identified as an outlier and excluded from analysis. Another ram lamb was missing data for one of the scan periods and was also excluded, leaving 24 ram lambs with complete records for all 7 scanning dates.

Scatter diagrams of BW, BF, and LMA are shown in Figure 1. Prediction equations for BF and LMA were developed using age or BW as the independent variable. Goodness of fit was superior for BW-based predictions ($R^2 = 0.69$ vs. 0.56 for BF and $R^2 = 0.73$ vs. 0.58 for LMA), and only BW-dependent predictors will be considered further.

Scatter diagrams of LMA and BF with BW and plots of descriptive equations (Figure 2) show that goodness of fit was very similar for the 4 equations over the range of the data. Particularly during the test period, we found no evidence that the assumption of linear change in scanning traits was not acceptable. For BF, the 4 equations gave essentially identical results, even when extrapolated beyond the range of the data. Higher-order predictors of BF (LQ vs. linear and ABW vs.

Table 1. Means and SD of recorded variables for Suffolk ram lambs at each of 7 serial ultrasound scanning dates[1]

	Age, d		BW, kg		Backfat thickness,[2] cm		LM area, cm^2	
Scan date	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Apr. 27	77	6	38.0	3.7	0.32	0.07	12.5	1.6
May 18	98	6	43.5	3.8	0.31	0.06	14.1	1.8
Jun. 8	119	6	55.3	4.2	0.47	0.11	16.1	1.6
Jun. 11	122	6	57.4	4.4	0.47	0.08	17.2	1.9
Jun. 29	140	6	65.3	5.3	0.55	0.11	18.3	2.0
Jul. 24	165	6	74.1	5.8	0.65	0.13	19.4	2.3
Aug. 10	182	6	78.2	5.5	0.60	0.13	19.1	2.0

[1]n = 24. Scans were performed on the right side of the lambs between the 12th and 13th ribs using an Aloka 500 (Corometrics Medical Systems, Wallingford, CT) ultrasound machine set at 2× magnification, equipped with an 11-cm, 3.5-mHz transducer, and fitted with a Superflab standoff guide (Mick Radio-Nuclear Instruments Inc., Mt. Vernon, NY) to minimize tissue distortion in the images.

[2]Backfat thickness was measured at the midpoint of the LM.

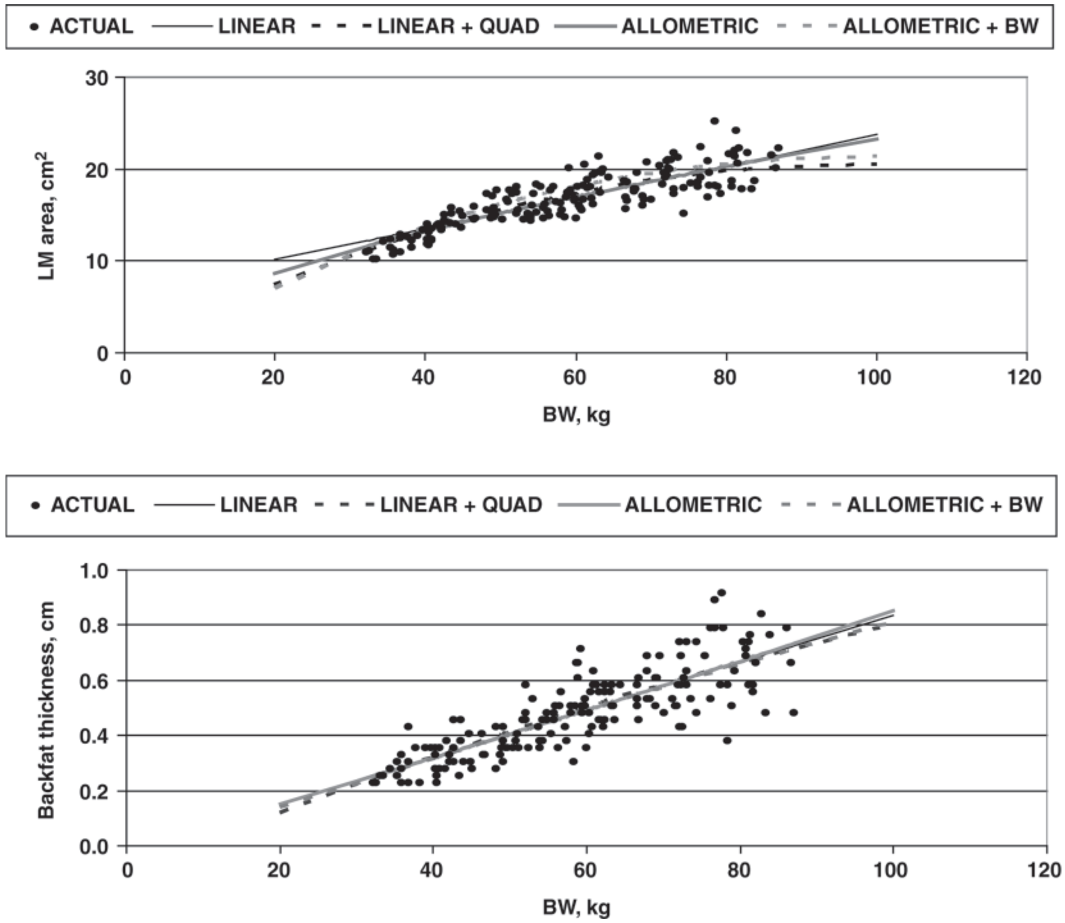

Figure 2. Relationship of ultrasonic LM area and backfat thickness to BW in 24 growing Suffolk ram lambs. QUAD = quadratic.

allometric) did not significantly improve goodness of fit. The observed allometric coefficient of 1.06 ± 0.04 (Table 2) did not differ from unity ($P > 0.10$), but was larger ($P < 0.001$) than the value of 0.33 anticipated between BW and a linear body measurement increasing at an equivalent rate to body size. That finding indicates that BF was, as expected, increasing relatively more rapidly than BW. Direct comparison of prediction equations with the same numbers of parameters fitted to transformed vs. untransformed data (i.e., linear vs. allometric and LQ vs. ABW) is not straightforward, especially when effects of animal appear in the model. For BF, R^2 values were greater for allometric than for polynomial models (Table 2). Residual SD of log-transformed data (for BF, 0.127 for allometric and ABW) are approximately comparable to residual CV in actual units (0.134 for linear and LQ), again suggesting some superiority for allometric models. Allometric forms involving logarithmic transformation of the data may also better account for the positive relationship between mean and variance in BF shown in Figure 2.

Significant nonlinearity was observed for the relationship between LMA and BW in polynomial and allometric equations, and the LQ and ABW forms diverged from the simpler linear and allometric equations at, or just beyond, the limits of the data (Figure 2). For LMA, R^2 were greater for allometric than for polynomial models, with residual SD for models A (0.067) and ABW (0.062) smaller than residual CV for models linear (0.072) and LQ (0.066), suggesting some superiority for allometric models.

Although changes in real-time ultrasound measurements of fat and muscle in growing Australian lambs were best explained by linear models (Hopkins et al., 1996), and linear adjustments are presently used for scan traits in the beef industry (Rumph et al., 2007), the possibility of nonlinear allometric growth patterns for ultrasound traits exists as has been described for direct measures of body tissue components (Notter et al., 1983; Jenkins and Leymaster, 1993).

The observed allometric coefficient of 0.61 ± 0.02 for LMA differed from unity ($P < 0.001$) and was somewhat smaller ($P < 0.01$) than the value of $\beta = 0.67$ anticipated for the relationship between BW and a 2-dimensional cross-sectional measurement associated with body size. Changes in this allometric coefficient during growth are accommodated by equation ABW, which predicted that the allometric coefficient would change from 0.80 at 40 kg to 0.36 at 75 kg [see Notter et al. (1983) for additional discussion of the ABW predictor] and was consistent with the observed negative second-order polynomial coefficient (Table 2).

Table 2. Coefficients for 4 equations used to describe changes in ultrasonic measurements of LM area (LMA) and backfat thickness (BF) during growth in Suffolk ram lambs[1]

		Parameter estimate			
Measurement	Equation[2]	α	β	γ	R^2
LMA	Linear	6.71	0.169		0.867
	Linear + quadratic (LQ)	−0.257	0.422	−0.00215	0.889***
	Allometric	1.38	0.611		0.892
	Allometric + BW (ABW)	0.171	1.31	−0.0127	0.906***
BF	Linear	−0.0218	0.00854		0.855
	Linear + quadratic (LQ)	−0.0973	0.0113	−0.0000234	0.856
	Allometric	0.00615	1.06		0.878
	Allometric + BW (ABW)	0.00352	1.25	−0.00338	0.879

[1]Prediction equations were based on 7 serial measurements taken on 24 Suffolk rams at intervals of approximately 21 d beginning at an average of 77 d of age.

[2]Linear, linear + quadratic, allometric, and allometric + BW equations are $y = \alpha + \beta BW$; $y = \alpha + \beta BW + \gamma BW^2$; $y = \alpha BW^{\beta}$; and $y = \alpha BW^{\beta} e^{\gamma W}$, respectively.

***Models linear and LQ or models allometric and ABW differ ($P < 0.001$).

Equations to derive adjusted (**Adj**) ultrasound measurements of LMA and BF at a target BW ($\widetilde{BW}$) using each functional form and measured values of LMA, BF, and BW were thus:

$$\text{linear: Adj}(\text{LMA}) = \text{LMA} + 0.169\,(\widetilde{BW} - BW);$$

$$\text{Adj}(\text{BF}) = \text{BF} - 0.00854\,(\widetilde{BW} - BW);$$

$$\text{LQ: Adj}(\text{LMA}) = \text{LMA} + 0.422\,(\widetilde{BW} - BW) - 0.00215\,(\widetilde{BW}^2 - BW^2);$$

$$\text{Adj}(\text{BF}) = \text{BF} + 0.0113\,(\widetilde{BW} - BW) - 0.0000234\,(\widetilde{BW}^2 - BW^2);$$

$$\text{allometric: Adj}(\text{LMA}) = \text{LMA}\,(\widetilde{BW}/BW)^{0.61};$$

$$\text{Adj}(\text{BF}) = \text{BF}\,(\widetilde{BW}/BW)^{1.06};$$

$$\text{ABW: Adj}(\text{LMA}) = \text{LMA}\,(\widetilde{BW}/BW)^{1.31} e^{-0.0127(\widetilde{BW}/BW)};\text{ and}$$

$$\text{Adj}(\text{BF}) = \text{BF}\,(\widetilde{BW}/BW)^{1.25} e^{-0.00338(\widetilde{BW}/BW)}.$$

Linear regression coefficients of 0.169 ± 0.007 cm^2/kg for LMA and 0.00854 ± 0.00035 cm/kg for BF were similar to equivalent metric coefficients of 0.179 cm^2/kg for LMA and 0.0106 cm/kg for BF derived from Suffolk rams tested in 1999 through 2002 (S. P. Greiner, unpublished data). Slightly smaller linear coefficients for LMA ($P < 0.20$) and BF ($P < 0.001$) in our study may reflect the fact that 2007 Suffolks were older at their final scan than Suffolks measured in 1999 through 2002.

Backfat was more variable than LMA (CV = 17.4 to 23.4% vs. 9.8 to 12.7%), particularly in heavier lambs. Relative growth of BF in this study, particularly at heavier BW, was somewhat different from that expected in growing lambs unrestricted by diet. The rate of fattening is expected to increase at heavier BW, but quadratic components for BF in the LQ and ABW equations were negative, though not significant (P = 0.35 and 0.54, respectively). This result could be a reflection of the period of restricted growth that began after conclusion of test on July 17 when rams weighed approximately 70 kg. This BW is slightly before the point in Figure 2 where rams appear to become more variable in ultrasonic BF and a portion appear to plateau for BF. An interesting dilemma thus arises; reducing energy intake at the end of the test period is considered desirable to facilitate pasture mating, but may mask anticipated increases in fatness in lambs of earlier physiological maturity or other unanticipated sources of variation in fatness at later BW. From a selection perspective, one is therefore faced with the conundrum of whether to keep ram lambs on full feed to a point of more advanced physiological maturity to accurately assess fattening patterns or to direct the feeding regimen toward preparation of ram lambs (which should be genetically superior to older rams for lean gain) to breed larger numbers of ewes.

To consider the impact of reduced growth rates before the final scan, prediction equations were derived using only the 4 scans taken when rams were on full feed; however, results did not differ from those obtained using all 7 scans.

The choice of BW or age as the dependent variable to describe changes in ultrasonic measurements has been discussed in the literature (Rumph et al., 2007), and most studies have chosen BW as the basis for adjustment. Body weights are more variable in sheep than carcass composition traits (Simm and Dingwall, 1989). Selection on age- or BW-adjusted scans will potentially

Table 3. Means and SD of recorded variables for lambs used for validation

Breed	Scan	Age, d		BW, kg		Backfat thickness, cm		LM area, cm^2	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD
Virginia ram-test rams									
Suffolk (n = 150)	1	103	15	51.2	7.0	0.37	0.13	16.5	2.5
	2	135	15	64.6	7.2	0.50	0.13	18.9	2.5
	3	167	15	78.8	7.5	0.66	0.17	21.4	2.8
Hampshire (n = 36)	1	100	21	50.1	10.5	0.35	0.16	15.1	2.9
	2	133	24	65.7	10.7	0.53	0.18	18.3	2.5
	3	164	22	78.4	12.9	0.65	0.19	20.2	3.2
Winter Dorset (n = 43)	1	118	23	49.2	11.1	0.32	0.12	15.9	3.7
	2	150	23	62.4	11.7	0.49	0.16	18.6	4.0
	3	182	23	73.8	12.4	0.62	0.17	21.5	4.7
Fall Dorset (n = 52)	1	222	24	72.8	11.4	0.52	0.14	20.9	3.8
	2	256	25	84.7	10.9	0.63	0.16	23.9	3.7
	3	287	25	94.7	11.2	0.72	0.19	26.1	4.0
Virginia Tech ewe lambs									
Suffolk (n = 37)	1	77	6	32.4	3.8	0.35	0.08	12.6	1.6
	2	97	6	39.2	4.1	0.41	0.09	14.4	2.0
	3	118	6	40.7	4.0	0.44	0.11	15.1	1.8
	7	181	6	55.7	5.1	0.66	0.16	18.5	2.1

change composition by altering the growth curve so that lambs that are leaner at a constant age or BW are also less mature relative to larger adult size. An advantage for BW-constant adjustment of carcass traits is that lambs are more typically marketed at constant BW rather than constant ages. Thus, if an increase in slaughter weight is not a goal, BW-constant scans provide a more directly informative assessment of composition and are anticipated to be less confounded with growth traits. However, regardless of the adjustment protocol that is chosen, attention to both BW and ultrasonic measures of composition will likely be required to develop a comprehensive breeding objective.

Evaluation of different endpoints for adjustment of carcass data are a common theme in beef literature. Most beef carcass trait adjustments are made on an age-constant basis, but alternative endpoints including constant BW, BF, or marbling score have been considered (Rumph et al., 2007). Although many of the genetic implications are outside the scope of this paper, the particular challenge with carcass traits is that their inter-relationship may cause traits of interest to represent something different if adjusted to an endpoint that is a component trait (e.g., adjusting percentage retails cuts to a constant BF endpoint; Rumph et al., 2007).

Validation of Predictive Equations

Ram Lambs Tested in Different Years. Means and SD for age, BW, and ultrasound BF and LMA for these rams tested in 1999 through 2002 are shown in Table 3. Suffolk and Hampshire rams used for validation had mean ages and BW at each scanning time that were similar to those of Suffolks used to develop prediction equations. Winter-born Dorset rams were, on average, older than Suffolks and Hampshires ($P < 0.01$), but did not differ in BW ($P > 0.20$) at similar measurement times. Means for BF in Suffolks, Hampshires, and winter-born Dorsets were nearly identical at similar BW to those of 2007 rams. Means for LMA for these rams were likewise similar to those for 2007 rams at the first and second scan but were an average of 1.8 ± 0.7 cm^2 larger at the third scan ($P < 0.02$). Scan technician bias (the consistent over- or underestimation of actual carcass measurements with ultrasound) is known to exist (Tait et al., 2005; Leeds et al., 2008; Emenheiser et al., 2009) and may contribute to this difference.

Fall Dorsets were older ($P < 0.0001$) and larger ($P < 0.001$) than rams used to develop prediction equations (Table 3). In addition, fall-born rams consigned to ram tests are often not fed for maximum growth until the onset of the test period and are thus typically considerably lighter, and expected to be leaner, than winter-born tested rams at similar ages. The capacity of the different prediction equations to accommodate differences in age, BW, and prior growth pattern in fall-born rams was thus of particular interest.

The SD for traits in rams tested in 1999 through 2002 were commonly larger than those for rams used to develop prediction equations, as might have been expected for a larger number of rams, originating from multiple flocks and representing multiple years within each breed group.

When ultrasound traits at the second scan were predicted using analogous BW and ultrasound measurements from the first scan (forward prediction) or the third scan (backward prediction) using each of the 4 adjustment equations, residual correlations (after accounting for differences in year) between predicted and actual values for BF and LMA at the second scan (Table 4) indicated that adjustment equations differed little in predictive ability. Residual correlations ranged from 0.78 to 0.87 for BF and 0.66 to 0.93 for LMA in winter-born rams, and from 0.70 to 0.71 for BF and 0.72 to 0.78 for LMA in fall-born rams. Differences

Table 4. Residual correlation coefficients between observed and predicted ultrasound measurements for 4 groups of tested rams and 4 alternative prediction equations[1]

		Backfat thickness		LM area	
Breed and season	Equation[2]	Forward	Backward	Forward	Backward
Winter Suffolk	Linear	0.79	0.80	0.81	0.81
	LQ	0.79	0.80	0.80	0.82
	Allometric	0.78	0.81	0.80	0.82
	ABW	0.78	0.81	0.78	0.82
	95% CI[3]	0.71–0.84	0.75–0.86	0.73–0.85	0.76–0.87
Winter Hampshire	Linear	0.86	0.78	0.74	0.69
	LQ	0.85	0.78	0.70	0.70
	Allometric	0.86	0.77	0.71	0.72
	ABW	0.86	0.77	0.66	0.71
	95% CI[3]	0.74–0.93	0.59–0.88	0.50–0.84	0.51–0.85
Winter Dorset	Linear	0.81	0.86	0.93	0.90
	LQ	0.81	0.86	0.92	0.91
	Allometric	0.81	0.87	0.92	0.91
	ABW	0.80	0.87	0.89	0.91
	95% CI[3]	0.67–0.89	0.77–0.93	0.86–0.96	0.84–0.95
Fall Dorset	Linear	0.70	0.70	0.77	0.75
	LQ	0.70	0.71	0.72	0.78
	Allometric	0.70	0.70	0.75	0.76
	ABW	0.70	0.71	0.72	0.78
	95% CI[3]	0.53–0.82	0.53–0.82	0.60–0.85	0.62–0.86

[1]Each ram was scanned 3 times with approximately 30 d between each scanning. Measurements at the second scanning were then predicted from measurements taken at the first (forward) or third (backward) time and compared with the actual values at second scanning.

[2]Linear + quadratic (LQ); allometric + BW (ABW).

[3]Approximate 95% confidence intervals (95% CI) for correlations for each ram group and measurement were specifically derived for the allometric prediction equation and, within a column, breed, and season, were similar for other equations.

among equations were generally larger for LMA, but all correlations still fell within a common 95% confidence interval; almost no differences among equations existed for BF. Correlations for LMA were more variable for forward than backward prediction. Compared with the other forms, the ABW equation was somewhat less accurate for LMA prediction, especially for forward prediction. This result suggests that quadratic equations may be somewhat unique to specific groups and not extend well to other populations. We had hypothesized that allometric predictions would be more robust than polynomial predictors when applied to other sets of animals, but that was not the case for these tested rams.

The relative prediction accuracy for fall-born rams was particularly encouraging. Prediction accuracies for LMA and BF were less for fall-born Dorsets than for both winter-born Dorsets ($P < 0.05$) and Suffolks ($P < 0.10$), but were greater than or equal to 0.70 in absolute values, which is similar to the repeatabilities of 0.66 for LMA and 0.79 for BF reported by Emenheiser et al. (2009) for lambs scanned twice on the same day. Predicted values were thus not much more variable than repeated scans.

Ewe Lambs. Of the 40 ewe lambs that were scanned, 2 lambs that were deemed to be growth outliers based on BWDA and 1 lamb that did not have a record in 1 of the 4 scan periods were removed before analysis. The second, third, and seventh scans of the ewe lambs were used for this study (Table 3). Mean ages at scans 2 and 3 (97 and 118 d, respectively) approximate the smaller limit (90 d) and target age (120 d), respectively, for measurement of postweaning weights in NSIP, and mean BW at scan 7 (55.7 kg) corresponded to the approximate BW of male siblings to these ewe lambs at approximately 120 d of age. The first scan was taken shortly after weaning and represents a substantial extrapolation. However, sale of a proportion of lambs after weaning sometimes occurs, and the value of scans taken at early ages is an issue in genetic evaluation.

Ram and ewe lambs were scanned at similar ages, but ewe lambs were approximately 5 kg lighter than rams at similar ages for the first 2 scans. This difference increased to over 20 kg by the seventh scan, reflecting different goals for daily BW gain between feeding regimens. Means for BF were similar ($P > 0.50$) for males and females at similar ages and thus were expected to be greater in ewes at similar BW. Mean LMA averaged 0.3 ± 0.2 cm^2 less ($P < 0.20$) for ewe lambs than for rams at the same age.

When ultrasound traits for Suffolk ewe lambs at the seventh scan were predicted from measurements at the third, second and first scan, simple correlations between predicted and actual variables (Table 5) were less than those for other groups of ram lambs but, based on the striking difference in management and corresponding rate of BW gain, were greater than might have been expected. Ultrasonic measurements of BF and LMA at the third scan and of BF at the second scan were acceptable predictors of analogous measures at the seventh scan. The latter result is somewhat surprising due to the relative differences in magnitude and variability in BF compared with LMA at these ages and BW.

Table 5. Residual correlation coefficients in Suffolk ewe lambs between ultrasound measurements at an average of 181 d of age and predicted measurements derived from measurements taken at averages of 118, 97, or 77 d of age (scan 3, 2, or 1, respectively) using 4 alternative prediction equations

Prediction equation[1]	Backfat thickness			LM area		
	Scan 3	Scan 2	Scan 1	Scan 3	Scan 2	Scan 1
Linear	0.72	0.74	0.53	0.76	0.65	0.63
LQ	0.73	0.74	0.53	0.73	0.60	0.58
Allometric	0.72	0.73	0.47	0.73	0.60	0.56
ABW	0.73	0.73	0.46	0.67	0.54	0.43
95% CI[2]	0.52–0.85	0.53–0.85	0.17–0.69	0.53–0.85	0.34–0.77	0.29–0.75

[1]Linear + quadratic (LQ); allometric + BW (ABW).

[2]Confidence intervals (CI) were specifically derived for the allometric prediction equation. Widths of 95% intervals within a column were similar for other equations.

However, prediction accuracies at the first scan were inferior to those at the second or third scan for BF ($P < 0.05$) and those at the third scan for LMA ($P < 0.10$). Use of scans similar to the first scan in these ewe lamb data (77 d, 32.4 kg) to predict carcass measures at typical slaughter weights in ewe lambs fed for similar rates of BW gain is thus not recommended.

Differences among prediction equations were very small for BF. In contrast to our expectation, the linear equation was slightly more robust for prediction of LMA than the allometric form. The ABW form was inferior to other forms, supporting our inference from ram lambs that this equation may generalize more poorly to different populations.

Conclusions

We believe that our data sufficiently covered the age range relevant for evaluation of postweaning growth and that scans performed within the age range specified for genetic evaluation of postweaning growth by NSIP (120 ± 30 d) can confidently be adjusted to a standard BW using our prediction equations. Adjustment strategies developed using serial scans on Suffolk ram lambs accurately predicted values for ultrasonic BF and LMA in similarly tested rams of 4 breeds, 2 birth seasons, and 4 yr, and in Suffolk ewe lambs managed to achieve slower rates of BW gain and with correspondingly different body BW. Future studies should focus on validation of these adjustment strategies across a wider range of breeds and management conditions and on derivation of alternative prediction equations if necessary. We believe that 4 or more serial scans covering the postweaning growth period would be adequate to derive and compare allometric or linear prediction equations for different breeds, management systems, and production environments.

LITERATURE CITED

Berg, E. P., M. K. Neary, J. C. Forrest, D. L. Thomas, and R. G. Kauffman. 1997. Evaluation of electronic technology to assess lamb carcass composition. J. Anim. Sci. 75:2433–2444.

Emenheiser, J. C., S. P. Greiner, R. M. Lewis, and D. R. Notter. 2009. Validation of live animal ultrasonic measurements of body composition in market lambs. J. Anim. Sci. doi:doi:10.2527/jas.2009-2378

Fischer, T. M., J. H. J. van der Werf, R. G. Banks, A. J. Ball, and A. R. Gilmour. 2006. Genetic analysis of weight, fat and muscle depth in growing lambs using random regression models. Anim. Sci. 82:13–22.

Hopkins, D. L., D. G. Hall, and A. F. Luff. 1996. Lamb carcass characteristics 3. Describing changes in carcasses of growing lambs using real-time ultrasound and the use of these measurements for estimating the yield of saleable meat. Aust. J. Exp. Agric. 36:37–43.

Jenkins, T. G., and K. A. Leymaster. 1993. Estimates of maturing rates and masses at maturity for body components of sheep. J. Anim. Sci. 71:2952–2957.

Leeds, T. D., M. R. Mousel, D. R. Notter, H. N. Zerby, C. A. Moffet, and G. S. Lewis. 2008. B-mode, real-time ultrasound for estimating carcass composition in live sheep: Accuracy of ultrasound measures and their relationships with carcass composition. J. Anim. Sci. 86:3203–3214.

Macfarlane, J. M., R. M. Lewis, G. C. Emmans, M. L. Young, and G. Simm. 2006. Predicting carcass composition of terminal sire sheep using x-ray computed tomography. Anim. Sci. 82:289–300.

McLaren, D. G., F. K. McKeith, and J. Novakofski. 1989. Prediction of carcass characteristics at market weight from serial real-time ultrasound measures of backfat and loin eye area in the growing pig. J. Anim. Sci. 67:1657–1667.

McLaren, D. G., J. Novakofski, D. F. Parrett, L. L. Lo, S. D. Singh, K. R. Neumann, and F. K. McKeith. 1991. A study of the operator effects on ultrasonic measures of fat depth and longissimus muscle area in cattle, sheep and pigs. J. Anim. Sci. 69:54–66.

Notter, D. R., C. L. Ferrell, and R. A. Field. 1983. Effects of breed and intake level on allometric growth patterns in ram lambs. J. Anim. Sci. 56:380–395.

Rumph, J. M., W. R. Shafer, D. H. Crews Jr., R. M. Enns, R. J. Lipsey, R. L. Quaas, and E. J. Pollak. 2007. Genetic evaluation of beef carcass data using different endpoints. J. Anim. Sci. 85:1120–1125.

Simm, G. 1983. The use of ultrasound to predict the carcass composition of live cattle—A review. Anim. Breed. Abstr. 51:853–875.

Simm, G., and W. S. Dingwall. 1989. Selection indices for lean meat production in sheep. Livest. Prod. Sci. 21:223–233.

Snedecor, G. W., and W. G. Cochran. 1967. Statistical Methods. 6th ed. The Iowa State Univ. Press, Ames.

Tait, J. R., Jr., B. Kimm, and D. Morrical. 2005. Accuracy of ultrasound measures relative to carcass measures of body composition in sheep. Iowa State University Animal Industry Report 2005. A. S. Leaflet R2046. http://www.ans.iastate.edu/report/air/2005pdf/2046.pdf Accessed Jun. 23, 2007.