Adjustment Factors in NSIP[1]

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Summary

Multiplicative adjustment factors for effects of type of birth and rearing on weaning and postweaning lamb weights were systematically and inversely associated with flock means for these weights in NSIP Terminal breeds. Weights of twin and triplet lambs were correspondingly overadjusted in high-performance flocks and underadjusted in low-performance flocks. This apparent bias was reduced by use of additive adjustment factors. Alternatively, customized multiplicative adjustment factors (F_i) for the ith flock could be derived from population-wide factors (F) as $F_i = F(\overline{W}_i/\overline{W})^{\beta}$ where $\overline{W}_i$ and $\overline{W}$ are flock and population mean weights, respectively, for animals in the reference class and β is a power function with an average absolute value of approximately 0.2. A similar situation exists for adjusting weight records from yearling dams to an adult equivalent. This procedure works well for large flocks but adds a step to the genetic evaluation to estimate mean weights and generate the customized adjustment factors and creates operational issues for small flocks.

Background

Before merging operations with LAMBPLAN, NSIP estimated EBV separately for each participating sheep breed. However, in recent years, EBV for NSIP Terminal breeds (mainly Suffolk, Hampshire, Dorset, and Shropshire, plus a few Texel, Oxford, and Composite flocks) have been estimated in a single run. The NSIP Terminal data were initially dominated by Suffolk animals, though this has changed a bit in recent years. As a result, adjustment factors for common nongenetic effects such as the type of birth and rearing and age of the dam were mainly estimated from Suffolk records.

Two NSIP Terminal flocks had processed data in LAMBPLAN for a number of years but moved their data to NSIP to facilitate comparisons with other US flocks. We indicated at the time of the move that these breeders would likely see a few changes in EBV associated with differences in adjustment factors and genetic parameters. However, one of the flocks reported large differences in weaning weight EBV between single, twins, and triplets, with higher WW EBV for lambs from smaller litters. The apparent reason for this observation was under-adjustment of weaning weights for twin and triplet lambs.

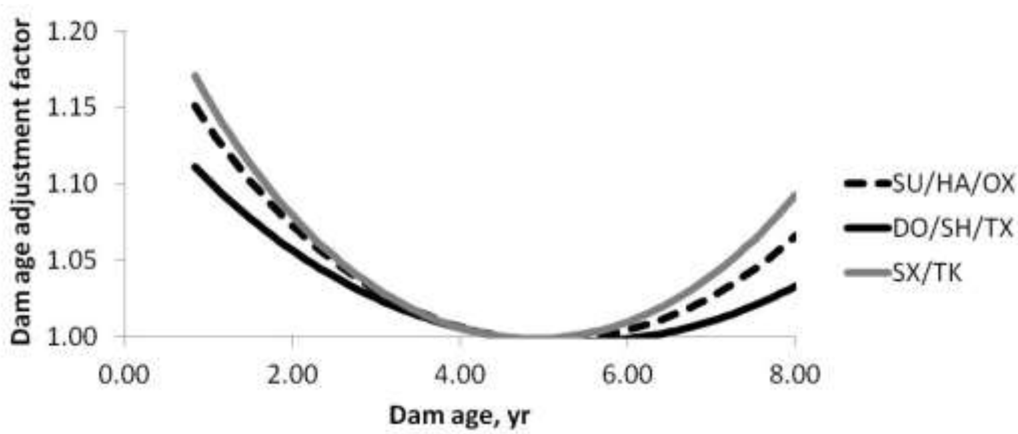
The possibility that adjustment factors for weaning weights might differ among breeds was not particularly surprising, so we calculated adjustment factors for each of the major breeds in the NSIP Terminal analysis. Some differences were observed among (Table 1). Effects of type of birth and rearing were smallest for the SU/HA/OX group, larger for the DO/SH/TX group, and much larger for the SX/TK Composites. Linear and quadratic curves to predict effects of dam age on lamb weaning weights (Figure 1) likewise indicated some differences in adjustment factors among breed groups, although differences were smaller than those for type of birth and rearing. With help from Daniel Brown, these breed differences in adjustment factors were implemented in the NSIP Terminal analysis.

[1] Sheep Genetics Technical Committee Meeting, 5 March 2015, ABRI Boardroom, UNE, Armidale.

Table 1. Adjustment factors for type of birth and rearing by breed group (SU/HA/OX = Suffolk, Hampshire, and Oxford; DO/SH/TX = Dorset, Shropshire, and Texel; SX/TK = two composite flocks).

Effect	Class	Adjustment factor		
		SU/HA/OX	DO/SH/TX	SX/TK
Type of birth	1	1.000	1.000	1.000
	2	1.093	1.095	1.104
	3	1.154	1.148	1.162
Type of rearing	1	1.000	1.000	1.000
	2	1.049	1.071	1.123
	3	1.108	1.131	1.215
Combined type of birth and rearing	11	1.000	1.000	1.000
	22	1.049	1.071	1.123
	33	1.108	1.131	1.215

Figure 1. Linear and quadratic effects of dam age on lamb birth weight for three groups of breeds.



Use of breed-specific adjustment factors seemed to be a reasonable approach. However, we also recognized that large differences existed among and within breed groups in flock mean weaning weights. Differences among breed groups (Table 2) in part reflected differences in adult size and these differences were anticipated to be accounted for by using multiplicative adjustment factors. However, flock differences in weaning weight means also reflected differences in levels of concentrate feeding within and among breed groups, and expected effects on adjustment factors of increasing body weights by increasing the feeding level were less clear. Suffolk lambs generally had the highest levels of concentrate feeding, whereas the two composite lines were managed to grow more slowly. The DO/SH/TX flocks were generally intermediate to the other breed groups in feeding level but also exhibited greater variation in feeding level among flocks.

Table 2. Breed group means for 60-d weaning weights of NSIP lambs born and reared as singles, twins, and triplets.

Type of birth and rearing	Breed group		
	SU/HA/OX	DO/SH/TX	SM/TK
11	34.3	29.8	26.6
22	30.2	25.5	21.6
33	27.0	22.9	18.8

With this background, we decided to investigate if there were systematic associations between the flock mean for 60-d weaning and 120-d postweaning weights and the magnitude of the adjustment factors required to correct those weights for effects of type of birth and rearing and dam age. We also studied associations between flock mean birth weights and adjustment factors for type of birth and dam age.

Materials and Methods

The strategy used for the analysis was to identify flocks with relatively large amounts of data, derive adjustment factors for effects of type of birth and rearing and dam age class for each flock, and investigate associations between flock performance levels and adjustment factors.

NSIP Terminal flocks used in this study were required to have at least 500 birth, weaning, or early postweaning weight records, yielding sets of 23, 28, and 10 flocks, respectively. Twenty nine different flocks were represented and included 20 Suffolk, five Dorset, one Hampshire, one Shropshire, and two composite flocks. Only lambs born as singles, twins, and triplets were included in the birth weight analysis, and only birth-rearing types (TBR) of 11, 22, and 33 were used for analysis of postnatal weights. Dam ages were categorized as 1, 2, 3 to 6 or >6 years; differences among dam age categories were easier to interpret than differences in linear and quadratic dam age curves. Final data sets for each body weight additionally required at least 50 observations per flock for each dam age class and birth-rearing type, but this minimum was reduced to 30 for the triplet lamb class. The final birth weight data sets contained records for 4,640 single, 15,718 twin, and 4,263 triplet lambs for analysis of effects of birth type and lambs with 2,952 yearling, 7,140 2-year-old, 17,481 adult, and 2,328 older dams for analysis of effects of dam age. The final weaning weight data sets contained records for 5,002 single, 14,474 twin, and 1,577 triplet lambs and lambs with 2,545 yearling, 6,166 2-year-old, 13,310 adult, and 1,230 older dams. The final postweaning weight data sets contained records for 2,557 single, 5,596 twin, and 635 triplet lambs and lambs with 1,085 yearling, 2,159 2-year-old, 4,909 adult, and 608 older dams.

Weaning and early postweaning weights were adjusted to 60 and 120 d of age using standard LAMBPLAN procedures. Adjusted body weights were then analyzed with a mixed linear model that included fixed effects of flock, birth year, dam age class, birth-rearing type, and interactions of dam age class × birth-rearing type, flock × dam age class, and flock × birth-rearing type. Random effects included management group effects (nested within flock and birth year); flock × dam age class × year and flock × birth-rearing class × year interactions; and residual error. The birth weight analysis also included fixed effects of lamb sex and flock × lamb sex interaction and random flock × lamb sex × year interaction. Management groups for birth weights were defined by the flock, year, and month of birth. Management groups for weaning and postweaning weights were defined using standard LAMBPLAN procedures. Flock × dam age class and flock × birth-rearing class interactions were tested using the flock × dam age class × year and flock × birth-rearing class × year interactions, respectively, to account for variation in flock-specific effect among years and assess repeatability of flock effects on dam age class and birth-rearing type effects among years.

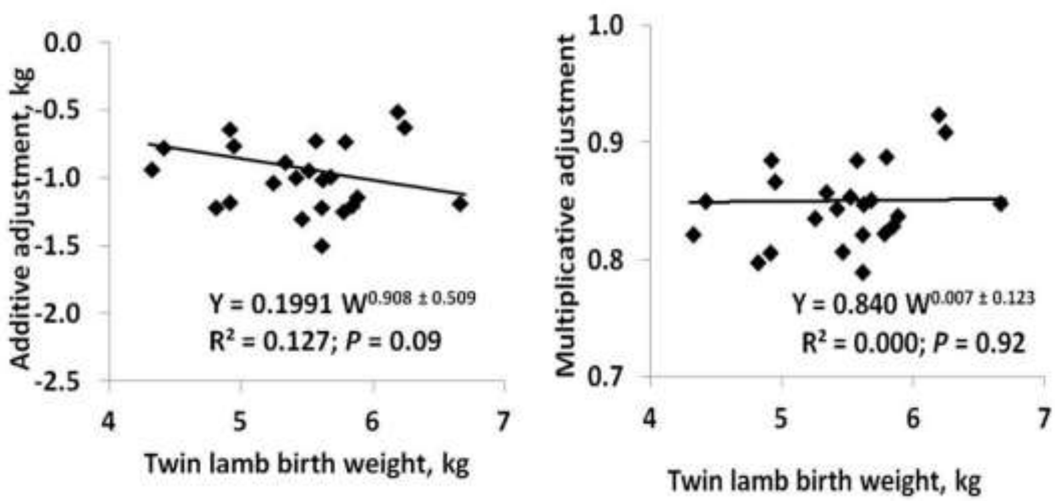
Flock × dam age class and flock × birth-rearing type least-squares means were then used to derive additive and multiplicative adjustment factors for each flock as differences from, and ratios to, respectively, reference classes (i.e., lambs from adult dams, and lambs born and reared as twins). Single lambs are commonly used as the reference class in sheep genetic evaluations, but twin lambs were more frequent and were used in this study. Flock-specific factors were then plotted against flock means for reference classes, and associations were determined.

Effects of alternative adjustment procedures were further evaluated by comparing differences in adjusted weaning weights between high- and low-performance flocks in the main data set and in an independent validation data set containing weaning weight records from 34 smaller flocks (minimum of 150 weaning weight records per flock) that were not used in the original analysis. The validation data contained 7,700 weaning weight records for lambs with TBR = 11 (n = 2,018), 22 (n = 5,012), or 33 (n = 670) and with yearling (n = 568), 2-year-old (n = 1,866), adult (n = 4,599), or aged dams (n = 667).

Results and Discussion

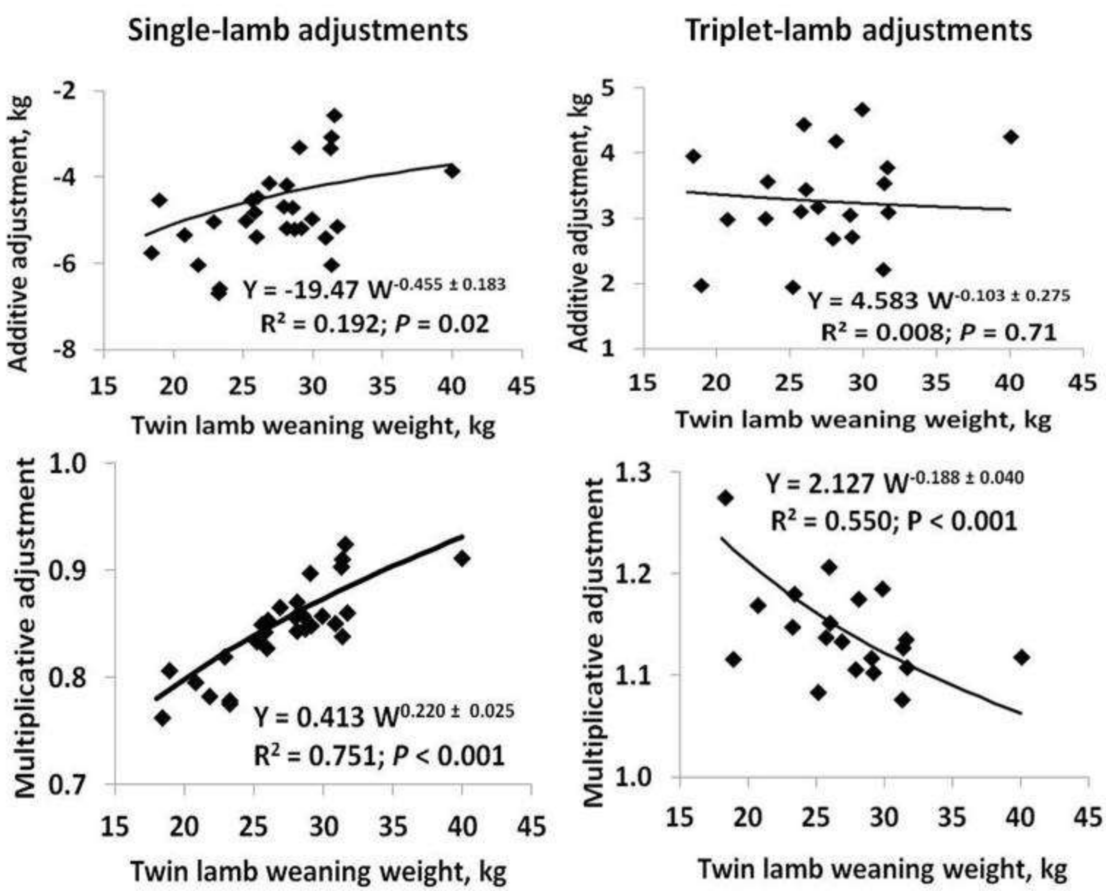
Birth weights. Differences among flocks in effects of birth type on lamb birth weights followed a classic multiplicative pattern (see Figure 2 for comparisons of twin and single lambs). Additive adjustment factors to correct birth weights of single lambs to a twin-lamb basis were proportional to the 0.91 power of the flock mean birth weights, indicating approximate proportionality between flock means and effects of birth type. By contrast, multiplicative adjustment factors to correct birth weights of single lambs to a twin-lamb basis were independent of flock means. Similar results were observed for differences between twin and triplet lambs and effects of dam age. We therefore concluded that simple multiplicative adjustment factors were appropriate to adjust lamb birth weights for effects of birth type and dam age.

Figure 2. Relationship between adjustment factors and flock means for birth weight. Additive or multiplicative factors (Y) required to adjust birth weights of single lambs to a twin-lamb basis were plotted against flock means for birth weights of twin lambs (W). Prediction equations were derived by weighting each observation by the number of single-born lambs in the flock.



Weaning weights. Effects of birth-rearing type on lamb weaning weights were significant (P < 0.001) and differed among flocks (P < 0.001). Differences between single and twin lambs became smaller as flock means for twin lambs increased (*P* = 0.02), with a corresponding positive relationship (*P* < 0.001) between multiplicative adjustment factors and flock means (Figure 3). This relationship was stronger for multiplicative factors than for additive factors, with R^2 of 0.75 and 0.19, respectively. For triplets, additive and multiplicative adjustment factors were both inversely related to flock means weaning weights of twin lambs (Figure 3), again indicating smaller effects on weaning weights for triplet lambs in high-performance flocks. The R^2 were again larger for multiplicative than for additive factors (0.55 and 0.01, respectively). Use of a single set of multiplicative factors to adjust weaning weights for effects of birth-rearing type across a wide range of flock performance levels thus resulted in biased adjustments in some flocks. Multiplicative factors for single and triplet weaning weights were proportional to the 0.22 ± 0.02 and -0.19 ± 0.04 powers, respectively, of flock means for weaning weights of twin lambs. As flock means for twin lambs from adult ewes increased from 18 to 40 kg, predicted multiplicative adjustment factors for single lambs increased from 0.78 to 0.93 and those for triplet lambs declined from 1.24 to 1.06.

Figure 3. Relationships between adjustment factors and flock means for weaning weight. Additive or multiplicative factors (Y) required adjust weaning weights of lambs born and reared as singles or triplets to a twin-born, twin-reared lamb basis are plotted against flock means for weaning weights of twin-born, twin-reared lambs.

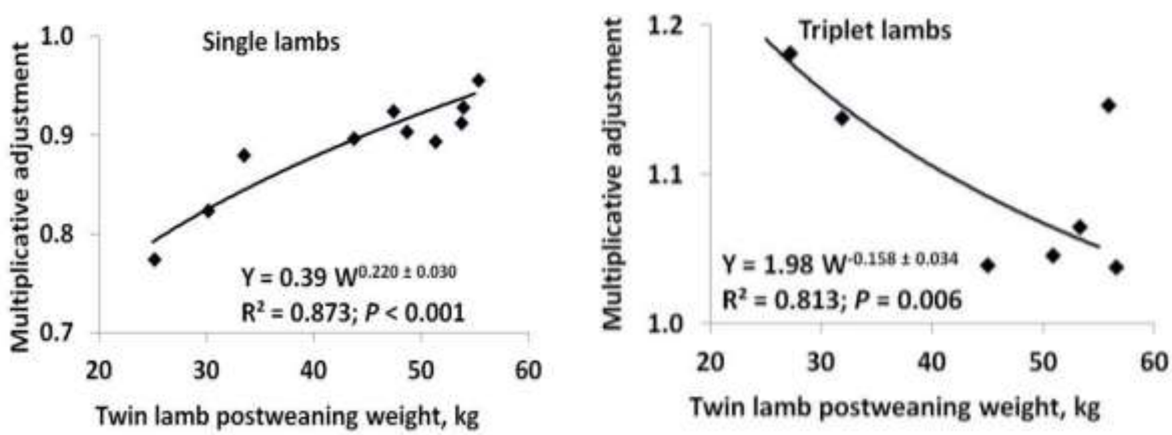


Many ewes that produced triplets did not suckle all their lambs, and selection of triplet-bearing ewes that were allowed to nurse all of their lambs may impact the realized performance of ewes nursing triplets. The percentage of triplet-born lambs that were reared as triplets (T) averaged 47% and varied from 17 to 81% for the 20 flocks in Figure 3. Addition of T to the model used to derive the power function for triplets in Figure 3 revealed a positive effect (P = 0.02) of T. The resulting prediction equation was $Y = 1.91W^{-0.171}e^{0.0010T}$ and predicted that the multiplicative adjustment factor for triplet weaning weights at the mean flock performance level would increase from 1.10 to 1.17 as the proportion of triplet-born lambs reared as triplets increased from 20 to 80%. The proportion of triplet-bearing ewes that actually nursed all of their lambs thus influenced the performance of those lambs relative to their twin-born contemporaries.

Flock x dam age class interaction was significant ($P \leq 0.02$) in all data sets and most significant (P = 0.001) in data that included yearling dams. Neither additive nor multiplicative factors to adjust lamb weaning weights to an adult-ewe basis were associated with flock means for weaning weight, although the multiplicative factor for yearling dams approached significance (P = 0.10 and R^2 = 0.19 with a proportionality constant of -0.11; not shown). Multiplicative adjustment factors for yearling dams were predicted to decline from 1.19 to 1.13 as flock mean weaning weights increased from 21 to 35 kg.

Postweaning weights. Effects of birth-rearing type (Figure 4) and dam age on postweaning weights were similar to those observed for weaning weights, again suggesting overcorrection of postweaning weights in high-performance flocks and undercorrection of postweaning weights in low-performance flocks.

Figure 4. Relationships between flock means for 120-d postweaning weights of lamb born and reared as twins (W) and multiplicative factors (Y) required to adjust postweaning weights of lambs born and reared as singles or born and reared as triplets to a twin-born, twin-reared lamb basis.



Development of adjustment protocols and comparison of adjusted weaning weights in original and validation data. Results in Figures 3 and 4 suggest that flock-specific multiplicative adjustment factors (F_i) could be derived from flock means for body weights of lambs in references classes as $F_i = F(\overline{W}_i/\overline{W})^{\beta}$ where F is the adjustment factor for the population, $\overline{W}_i$ and $\overline{W}$ are flock and population mean weights, respectively, for animals in the reference class, and β is a fitted power coefficient. Table 3 compares means for single versus twin or twin versus triplet lambs in high- or low-performance flocks after adjusting weaning weights using simple (i.e., population-wide) additive or multiplicative adjustment factors or the proposed flock-specific multiplicative adjustment.

The performance level of the flock significantly affected observed differences between birth-rearing types following application of simple multiplicative adjustment factors. Comparable levels of apparent bias were not, however, observed following application of simple additive adjustment factors. Effects of flock performance level on differences between twins and singles were minimized by use of flock-specific multiplicative adjustment factors, but this approach was not superior to use of a simple additive adjustment for triplet lambs. These results suggest that use of simple multiplicative adjustment factors across a wide range of flock performance levels is likely generating substantial bias in adjusted weaning and early postweaning body weights.

Effects of dam age class on weaning and early postweaning weights were small in ewes lambing at ≥ 2 yr of age, and effects of the adjustment strategy were correspondingly small. For yearling dams, use of a simple additive adjustment, or scaling of multiplicative adjustment factors for differences in flock means, were likely somewhat superior to a simple multiplicative adjustment, but effects were much smaller, and therefore less consequential, than those observed for effects of type of birth and rearing.

Table 3. Effect of adjustment protocol on differences between adjusted weaning weights of single and twin lambs (expressed as single – twin) in high- versus low-performance flocks from the original and validation data sets and between adjusted weaning weights of twin and triplet lambs (twin – triplet) in high- versus low-performance flocks from the original data set.

Data set and comparison	Adjustment protocol	Flock performance level		Difference (low – high)
		Low	High	
Original:	Simple additive	0.72 ± 0.48	-0.82 ± 0.55	1.54 ± 0.73†
single vs.	Simple multiplicative	1.26 ± 0.42**	-1.89 ± 0.48**	3.16 ± 0.64***
twin	Flock-specific multiplicative	0.19 ± 0.43	-0.32 ± 0.49	0.51 ± 0.65
Validation:	Simple additive	-0.55 ± 0.80	1.89 ± 0.54**	1.34 ± 0.97
single vs.	Simple multiplicative	-0.35 ± 0.68	-2.56 ± 0.46***	2.21 ± 0.82*
twin	Flock-specific multiplicative	-0.83 ± 0.69	-1.44 ± 0.47**	0.61± 0.84
Original:	Simple additive	0.18 ± 0.55	0.03 ± 0.58	0.15 ± 0.80
triplet vs	Simple multiplicative	0.97 ± 0.52†	-0.85 ± 0.55	1.82 ± 0.76*
twin	Flock-specific multiplicative	-0.03 ± 0.69	0.71 ± 0.73	-0.74 ± 1.00

For comparison of singles and twins, results are based on seven (of 28) flocks in the core data and nine (of 34) flocks in validation data with the highest and lowest flock means; for comparison of triplets and twins, results are based on 5 of 20 flocks in the core data set with the highest and lowest flock means; †, *, **, ***: P < 0.10, 0.05, 0.01, and 0.001, respectively.

Conclusions

Simple multiplicative adjustment factors work well to adjust lamb birth weights for effects of dam age and litter size across a wide range of flock mean birth weights. By contrast, if flock differences in weaning and postweaning weights arise mainly from differences in feeding level, effects of birth-rearing type and dam age are reduced, rather than accentuated, as growth rate increases, and use of simple multiplicative adjustment factors produces systematic bias in adjusted weights. In this situation, simple additive adjustments, or multiplicative adjustments that explicitly consider the flock performance level are preferred.