Impact of birth and rearing type, as well as inaccuracy of recording, on pre-weaning lamb phenotypic and genetic merit for live weight[1]

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ABSTRACT: The objective of the present study was to quantify the impact of the systematic environmental effects of both birth and rearing type on pre-weaning lamb live weight, and to evaluate the repercussions of inaccurate recording of birth and rearing type on subsequent genetic evaluations. A total of 32,548 birth weight records, 35,770 forty-day weight records and 32,548 records for average daily gain (ADG) between birth and 40-day weight from the Irish national sheep database were used. For each lamb, a new variable, birth-rearing type, reflecting both the birth and rearing type of a lamb was generated by concatenating both parameters. The association between birth-rearing type and birth weight, 40-day weight, and ADG was estimated using linear mixed models. The repercussions of inaccurate recording of birth type were determined by quantifying the impact on sire estimated breeding value (EBV; with an accuracy of ≥ 35%), where one of the lambs born in a selection of twin litter births was assumed to have died at birth but the farmer recorded the birth and rearing type as a singleton. The heaviest mean birth weight was associated with lambs born and subsequently reared as singles (5.47 kg); the lightest mean birth weight was associated with lambs born and reared as triplets (4.10 kg). The association between birth-rearing type and 40-day weight differed by dam parity ($P < 0.001$). Lambs reared by first parity dams as singles, irrespective of birth type were, on average, heavier at 40-day weighing than lambs reared as multiples, but as parity number increased, single-born lambs reared as twins outperformed triplet-born lambs reared as singles. Irrespective of the trait evaluated, the correlation between sire EBV estimated from the accurately recorded data and sire EBV estimated from the data with recording errors was strong ranging from 0.93 (birth weight) to 0.97 (ADG). The EBV for sires with progeny data manipulated were 0.14 kg, 0.34 kg and 5.56 g/d less for birth weight, 40-day weight and ADG, respectively, compared to their equivalent EBV calculated using accurately recorded data. Results from this study highlight the importance of precise recording of birth-rearing type by producers for the generation of accurate genetic evaluations.

Key words: birth type, live weight, rearing type, sheep

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INTRODUCTION

Quantification of the mean (pre-weaning) performance of lambs from different birth and rearing types has multiple uses including providing informative biological parameters for the development of bioeconomic models but also in farm-based real-time decision support tools. In breeding objectives, for example, which do not include a goal trait associated with weaning weight, the economic impact of birth type on pre-weaning performance may be encapsulated within the economic value of birth type. For decision support tools, the actual performance of individual lambs should be compared to the expected performance taking cognizance of the effect of birth and rearing type on expected live weight (gain).

Accurate genetic evaluations are predicated on accurate recording. Thus, proper recording of both birth and rearing type of the lamb, as well as the respective

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appropriate adjustment in the genetic evaluation model, is required to achieve accurate genetic evaluations for growth. The appropriate adjustment is necessary because the pre-weaning growth potential of a lamb is affected by whether the lamb was born or reared as a singleton or multiple (Safari et al., 2007; David et al., 2011; Notter and Brown, 2015), and birth type can account for up to 31% of the phenotypic variance in pre-weaning growth (Hagger, 1998). Nonetheless, lambs born into a multiple litter are at greater risk of mortality (McHugh et al., 2016) and, where mortality may have occurred, a reduced litter size may not actually be recorded by the producers. Similarly, cross-fostering events may not always be recorded thus introducing errors into the recorded rearing type of a given animal.

The objective of the present study was first to quantify the association between birth and rearing type on pre-weaning lamb live weight and second to evaluate the impact of inaccurate recording of birth and rearing type on subsequent genetic evaluations. Results from the present study will provide information on the importance of proper recording of birth and rearing type in achieving accurate genetic evaluations.

MATERIALS AND METHODS

Data

A total of 112,572 live weight records from 58,567 lambs collected from 436 flocks between the years 2010 and 2015, inclusive were extracted from the Irish national database hosted by Sheep Ireland (http://www.sheep.ie). Lamb live weight is recorded at birth and again at approximately 40 days of age by Irish producers using weigh-scales. Lambs with a recorded weight at birth between 2 and 9 kg were retained and lamb birth weight was rounded to the nearest half kilogram (McHugh et al., 2016). Based on the editing criteria used in the national genetic evaluations, 40-day weight was defined in the present study as the live weight taken between 20 and 65 d of age; only records of lambs weighing between 12 and 32 kg were retained. Average daily gain between birth and 40-day weight was also calculated for each lamb with a known birth and 40-day weight. Average daily gain was calculated as 40-day weight less birth weight divided by the actual age of lamb at the assumed 40-day weight; 369 lambs with an average daily gain (ADG) > 560 g/d were discarded. Live weight records were discarded if flock of birth, sire, or dam were unknown. Only lambs with ≥ 50% of their breed fraction known were retained. Lambs were subsequently grouped into 5 broad breed classifications based on their dominant breed composition: terminal, dual purpose, hill, maternal and other breed class. Birth and 40-day weight records more than four SD from the mean, within breed class, were discarded.

Dams with no information on parity number were discarded, as were records from parities > 10; dam parity was subsequently categorized as 1, 2, 3, 4, or ≥ 5. Age of the dam at first lambing was categorized as lambing either: 1) between 8 and 18 mo of age, or 2) between ≥ 18 and 28 mo of age. Dams that lambed for the first time at less than eight mo of age were excluded from the analysis. Birth type was defined as the recorded number of lambs born (alive or dead) per lambing event; only birth types between 1 (singles) and 3 (triplets) were retained for analysis. Rearing type per lamb was defined as the number of lambs reared in the litter (including the lamb itself); only rearing types between 1 and 3 were retained. Lambs recorded as artificially fed were not considered for further analysis.

A new variable reflecting both the birth and rearing type of a lamb was generated by concatenating both parameters; for example 3 possible birth-rearing types existed for triplet born lambs - born as a triplet and reared, as either, a triplet (Triplet-Triplet), a twin (Triplet-Twin), or a single (Triplet-Single). Heterosis and recombination loss were calculated for each lamb as:

$$1-\sum_{i-1}^{n} sire_i \times dam_i \text{ and } 1-\sum_{i-1}^{n} \frac{sire_i^2 + dam_i^2}{2},$$

respectively where $sire_i$ and dam_i are the proportion of breed i in the sire and dam, respectively. Heterosis and recombination loss were subsequently grouped into distinct classes based on the frequency distribution of the respective coefficients; for heterosis 5 distinct classes were formed: less than 10%, 10% to 49%, 50% to 89%, 90% to 99%, and 100%. For recombination loss 2 classes were formed: less than 10% and 10% to 50%.

For 40-day weight and ADG, each lamb was allocated to a contemporary group of flock-date of 40-day weighing. For birth weight, the contemporary group was defined as flock-year-calendar week of birth. Only records from contemporary groups with at least 5 records were retained. Following all edits, 32,548 birth weight records, 35,770 forty-day live weight records and 32,548 ADG records remained.

Phenotypic Analysis

The association between birth-rearing type and birth weight, 40-day weight, and ADG was estimated separately using linear mixed models in PROC HPMIXED (SAS Inst. Inc., Cary, NC); dam was included in all models as a random effect. Potential fixed effects considered in the models included birth-rearing type (single-single, single-twin, twin-single, twin-twin, triplet-single, triplet-twin, or triplet-triplet), contemporary group, sex (male or female), lamb breed class (terminal, dual purpose, hill, maternal, and other), parity of dam (1, 2, 3, 4, ≥ 5), age at first lambing of dam (8 and 18 mo of age or ≥ 18 and 28 mo of age), and both the heterosis (< 10%, ≥ 10% and < 50%, ≥ 50% and < 90%, ≥ 90% and < 100%, 100%), and recombination loss (< 10%, ≥ 10% and < 50%) coefficients of each lamb; heterosis and recombination loss coefficients of the dam were not associated with either trait and were therefore not considered further. The age of the lamb on the day of measurement at 40-day weight was also included as a covariate when the dependent variable was 40-day weight. Two-way interactions of biological interest were also tested.

Genetic Analysis

For the genetic analysis, only sires with at least 1 generation of descendants with records, and an estimated breeding value (EBV) accuracy ≥ 35% from the national genetic evaluations for direct genetic merit for both 40-day and birth weight, were retained. Records from sires with < 40 progeny, and that appeared in less than 3 contemporary groups, were discarded. In addition, live weight records in contemporary groups that contained progeny from only one sire were not considered further. Following edits, a total of 14,711 birth weight records across 347 contemporary groups and 177 sires, and 12,166 forty-day weight records as well as 12,166 records for ADG across 214 contemporary groups and 126 sires, remained. The genetic analysis using these data will be referred to as the Accurate Scenario.

To quantify the impact of inaccurate recording of birth type, a second scenario (referred to as the Inaccurate Scenario), which mimicked inaccurate recording of birth and rearing type, was also undertaken. Such a scenario was implemented to mimic a scenario where the death of 1 twin lamb in a litter was not recorded but instead the remaining twin lamb was recorded as a singleton. For this scenario, the data were manipulated for a random selection of 20% of the sires. The manipulation undertaken discarded the data from one of the lambs in 20% of the twin-litters per sire selected; these data manipulation were restricted to just 20% of each sire's contemporary groups. The remaining twin lamb was reclassified as being a singleton birth and as being reared as a singleton. Estimated breeding values for birth weight, 40-day weight and ADG were generated for all sires both in the Accurate and Inaccurate scenarios using an animal linear mixed model in MIX99 (Lidauer et al., 2015).

For all 3 traits analyzed, birth type, rearing type, dam parity, dam age at first lambing, heterosis and recombination loss coefficients of each lamb and contemporary group were included as fixed effects. When birth weight and ADG were the dependent variable, sex was also included as a fixed effect. When 40-day weight was the dependent variable, age at weighing and the interaction between age at weighing and sex were also included as a fixed effect. An additive direct animal effect and a maternal genetic effect, as well as a dam permanent environmental effect were included as random effects for all models. The genetic, dam permanent environmental and residual variance for each trait and scenario were estimated using ASReml (Gilmour et al., 2009); estimated variance components were subsequently used in the genetic evaluations in MIX99.

The impact of birth and rearing type mis-recording on the EBV for number of lambs born were estimated for all ewes mated to sires with or without birth and rearing type manipulation. For the estimation of EBV for number of lambs born, ewe parity, ewe age at first lambing, heterosis and recombination loss coefficients of each ewe and contemporary group based on flock and week of lambing were also included as fixed effects; an additive genetic direct effect and a permanent environmental effect of the dam were included as random effects.

RESULTS

The proportion of lambs born as singles, twins and triplets was 23%, 67% and 10%, respectively; the corresponding proportion of lambs reared as a singles, twins or triplets was 26%, 67% and 7%, respectively. A total of 8.23% of lambs were recorded to have been reared in a different class to their birth type, which is due to a combination of cross-fostering or mortality at birth; artificially reared lambs were not accounted for in this statistic as artificially reared lambs were omitted from the analysis. There was no bias in the sex ratio of lambs that were reared in a different class to their birth type. Mean recorded birth weight of the population was 4.82 kg (SD = 1.03 kg), while mean recorded 40-day weight and mean ADG was 19.85 kg (SD = 4.17 kg) and 319 g/d (SD = 75.40 g/d), respectively. Male lambs were 0.24 kg heavier at birth and 1.03 kg heavier at 40-day weight and grew 21 g/d faster between birth and 40-day weight compared to females ($P < 0.001$; Table 1).

Least Squares Means for Birth-Rearing Type

Birth weight, 40-day weight, and ADG all differed by lamb birth-rearing type (Table 2). The heaviest birth weight was associated with lambs both born and reared as singles (5.47 kg); the lightest birth weight was associated with triplet-born lambs reared as triplets (4.10 kg). Birth weights of twin-born lambs reared as either singles or twins did not differ from each other (Table 2).

Table 1. Least square means (SE in parenthesis) for birth weight (kg), 40-day weight (kg), and average daily gain (ADG) between birth and 40 days of age (g/d) of female and male lambs

Trait	Female	Male	*P*-value
Birth weight	4.38 (0.07)	4.62 (0.07)	$P < 0.001$
40-day weight	19.22 (0.29)	20.25 (0.29)	$P < 0.001$
ADG	245 (2.72)	266 (2.75)	$P < 0.001$

Lambs born and reared as singles were, on average, heaviest at 40 days (22.42 kg), while lambs born and reared as triplets were, on average, lightest at 40 days (18.04 kg). Forty-day weight recorded for single born (20.18 kg) or twin-born (19.34 kg) lambs both reared as twins, or triplet-born lambs reared as singles (19.96 kg) did not differ from each other (Table 2).

The association between birth-rearing type and 40-day weight differed by dam parity ($P < 0.001$; Fig. 1). Irrespective of birth type, lambs born from first parity dams and reared as singles were, on average, heavier at 40-day weight than lambs from first parity dams reared as multiples; in older parity dams, however, single-born lambs reared as twins were heavier than twin-born lambs reared as singles (Fig. 1).

The association between birth-rearing type and 40-day weight also differed by lamb breed. For most breed classes, heavier 40-day weight was recorded for twin-born lambs reared as singles compared to single-born lambs reared as twins; however, single-born du-

Table 2. Number of records (N), least square means (LSmeans; SE in parenthesis) of each birth and rearing type for birth weight (kg), 40-day weight (kg), and ADG between birth and 40-day (g/d)

		Birth Weight		40-day weight		ADG	
Birth type	Rearing type	N	LSmeans	N	LSmeans	N	LSmeans
Single	Single	6637	5.47 (0.05)[a]	7679	22.42 (0.22)[a]	7679	363 (4.30)[a]
	Twin	422	5.36 (0.06)[b]	435	20.18 (0.26)[b]	435	318 (5.10)[b]
Twin	Single	1129	4.67 (0.05)[c]	1348	20.74 (0.23)[c]	1348	345 (4.50)[c]
	Twin	20,767	4.68 (0.05)[c]	22,508	19.34 (0.21)[b]	22,508	315 (4.20)[b]
Triplet	Single	122	4.34 (0.08)[d]	143	19.96 (0.32)[b]	143	333 (6.40)[c]
	Twin	938	4.16 (0.06)[e]	1015	18.51 (0.23)[d]	1015	308 (4.60)[d]
	Triplet	2533	4.10 (0.05)[f]	2642	18.04 (0.22)[e]	2642	299 (4.40)[e]

[a–f]Within columns, least square means with different superscripts differ ($P < 0.05$) from each other.

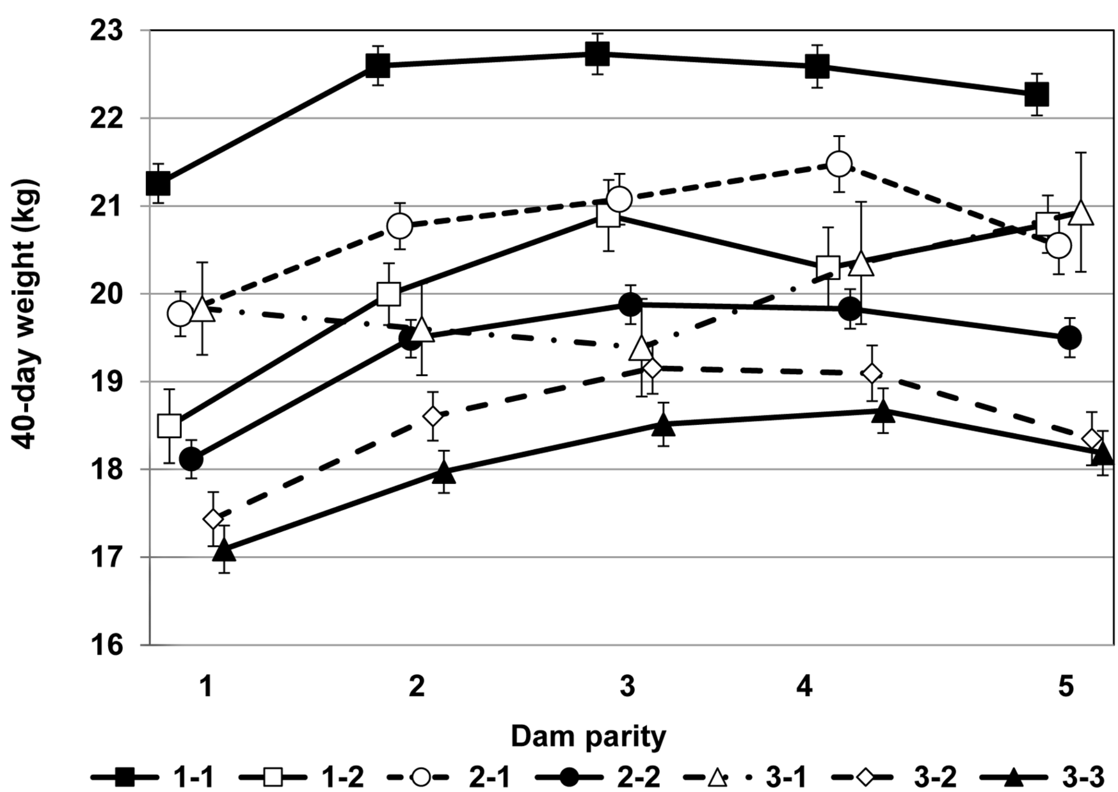

Figure 1. Least squares mean 40-day weight for each dam parity (SE included in error bars) estimated for each birth-rearing type, where 1–1 is a single-born lamb reared as a single, 1–2 is a single-born lamb reared as a twin, etc.

al-purpose lambs reared as twins were 4.08 kg heavier ($P < 0.001$) at 40-day weight than dual-purpose twin-born lambs reared as singles.

The association between birth-rearing type and ADG followed a similar trend to the observed associations for 40-day weight; lambs born and reared as singles achieved an ADG of 363 g/d, whereas lambs born and reared as triplets grew slower ($P < 0.001$) at a rate of 299 g/d (Table 2). Average daily gain of single- and twin-born lambs both reared as twins did not differ from each other; likewise ADG did not differ between twin- or triplet-born lambs both reared as singles.

The association between birth-rearing type and ADG differed by dam parity and also by the breed of the lamb ($P < 0.001$). For younger (i.e., parity one) and older parity (i.e., parity > 4) dams, lambs reared as singles, irrespective of birth type, expressed faster growth rates from birth to 40-day weight than all other birth-rearing types. However for third parity dams, greater weight gains were associated with twin or triplet-born lambs both reared as twins compared to triplet-born lambs reared as singles ($P < 0.01$). With the exception of dual-purpose lambs, twin-born lambs, irrespective of breed, reared as singles grew faster from birth to 40-day weight than singleton lambs reared as twins.

Genetic Evaluations

Genetic and residual SD, as well as, direct heritability, maternal heritability and maternal repeatability estimates for both the Accurate and Inaccurate scenarios are in Table 3. Irrespective of the trait investigated, the genetic, permanent environmental or residual variances or their ratios did not differ between the Accurate and Inaccurate Scenarios.

The number (proportion in parenthesis) of twins recorded as singles with the second twin discarded in the Inaccurate Scenario was 326 records (0.02) for birth weight, 265 (0.02) for 40-day weight, and 265 (0.02) for ADG. The number (proportion in parenthesis) of sires with twin data manipulated in the Inaccurate Scenario ranged from 23 (0.18; forty-day weight) to 30 (0.19; birth weight). Irrespective of the trait evaluated, the correlation between sire EBV for all sires with or without progeny data manipulation estimated across the Accurate Scenario and the Inaccurate Scenario were strong ranging from 0.97 (birth weight) to 0.98 (ADG). For only sires with progeny data manipulation, the genetic correlation between sire EBV for the Accurate and Inaccurate Scenario ranged from 0.93 (birth weight) to 0.97 (ADG). The mean EBV for sires with data manipulated in the Inaccurate Scenario was 0.14 kg, 0.34 kg and 5.56 g/d less for birth weight, 40-day weight and ADG, respectively, compared to their respective EBV calculated in the Accurate Scenario (Fig. 2). Moreover, the discarding of data in the Inaccurate Scenario also impacted the EBV for number of lambs born of the ewes mated to sires with progeny data manipulated (Fig. 3); EBV for number of lambs born for ewes mated to sires with data manipulation in the Inaccurate Scenario were, on average, 0.22 lambs lower than their respective EBV calculated in the Accurate Scenario.

DISCUSSION

The accuracy of genetic evaluations, like in any prediction or statistical model, is a function of the accuracy and completeness of data used to calibrate the predictions. Collection of accurate phenotypes under practical agricultural conditions may not, however, always be achievable especially during periods of high resource demand such as during concentrated seasonal lambing periods. Moreover, some breeders may be wary of any potential stigma associated with reported high flock mortality rates but also the impact that high mortality rates could have on the genetic evaluations of their sheep and thus their market value at sale. Because genetic evaluations are based on contemporary comparisons, high within-contemporary group mortality rate does not necessarily affect animal genetic merit assuming the mortality is equally spread across the germplasm represented in the contemporary group. Nonetheless, the objective of the present study was to quantify the impact mis-

Table 3. Genetic (s_g) and residual (s_e) SD, direct heritability (h^2_d; SE in parentheses), maternal heritability (h^2_m; SE in parentheses) and the maternal repeatability (R_m; SE in parentheses) for birth weight, 40-day weight and ADG between birth and 40-day estimated for the Accurate and Inaccurate scenario

Trait	Scenario	σ_g	σ_e	h^2_d (SE)	h^2_m (SE)	R_m (SE)
Birth weight (kg)	Accurate	0.34	0.54	0.18 (0.03)	0.31 (0.01)	0.31 (0.01)
	Inaccurate	0.34	0.56	0.18 (0.03)	0.30 (0.01)	0.30 (0.01)
40-day weight (kg)	Accurate	0.87	2.34	0.09 (0.02)	0.25 (0.01)	0.25 (0.01)
	Inaccurate	0.99	2.36	0.11 (0.02)	0.24 (0.01)	0.24 (0.01)
ADG (g/d)	Accurate	0.01	0.05	0.07 (0.02)	0.24 (0.01)	0.24 (0.01)
	Inaccurate	0.02	0.05	0.09 (0.02)	0.23 (0.01)	0.23 (0.01)

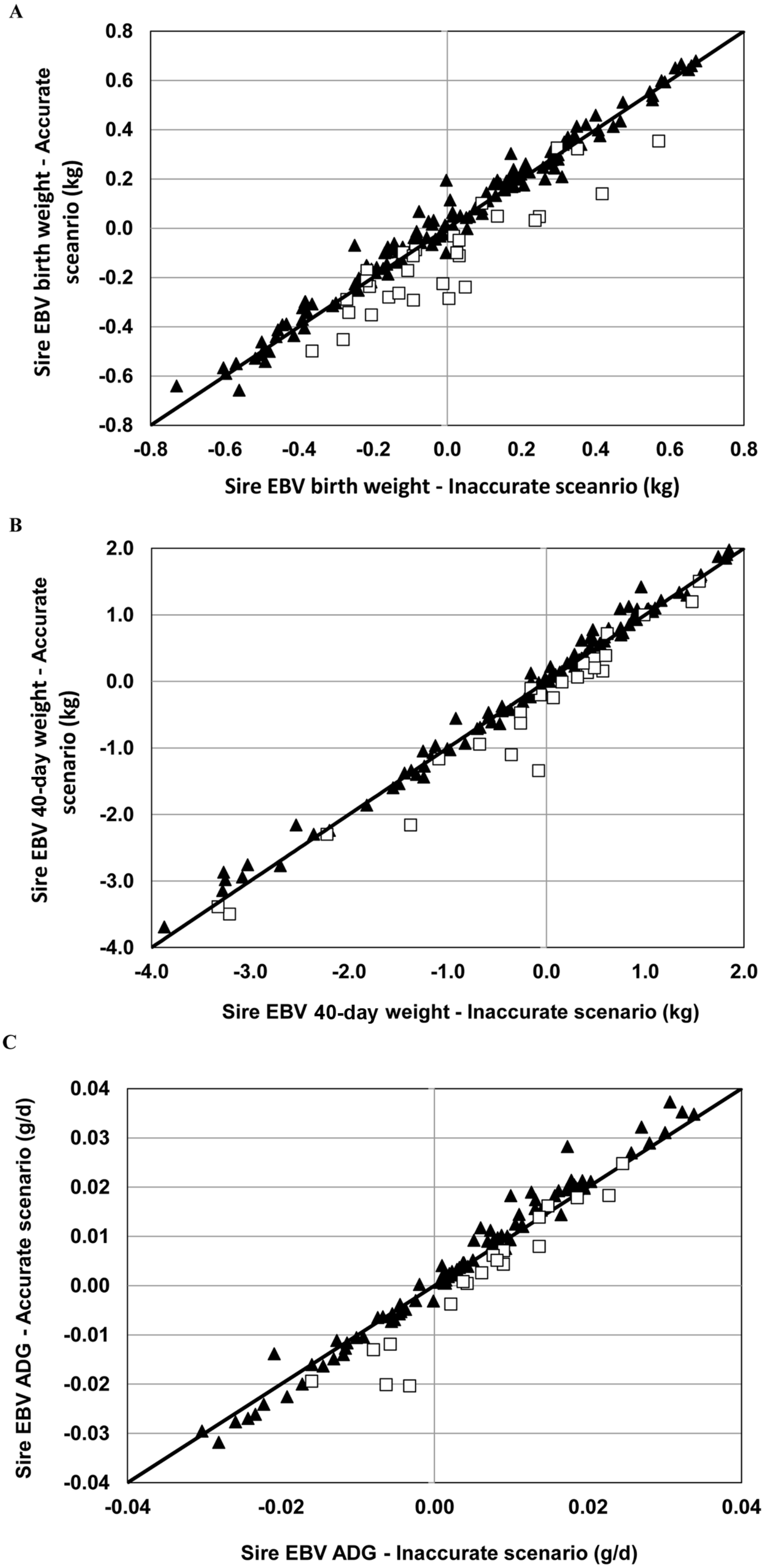

Figure 2. Scatter plot of sire EBV from the Accurate Scenario and the Inaccurate Scenario, with the black triangles representing sires without data manipulation and the white squares representing sires with data manipulation, for: A) birth weight, B) 40-day weight, and C) ADG from birth to 40-day weight.

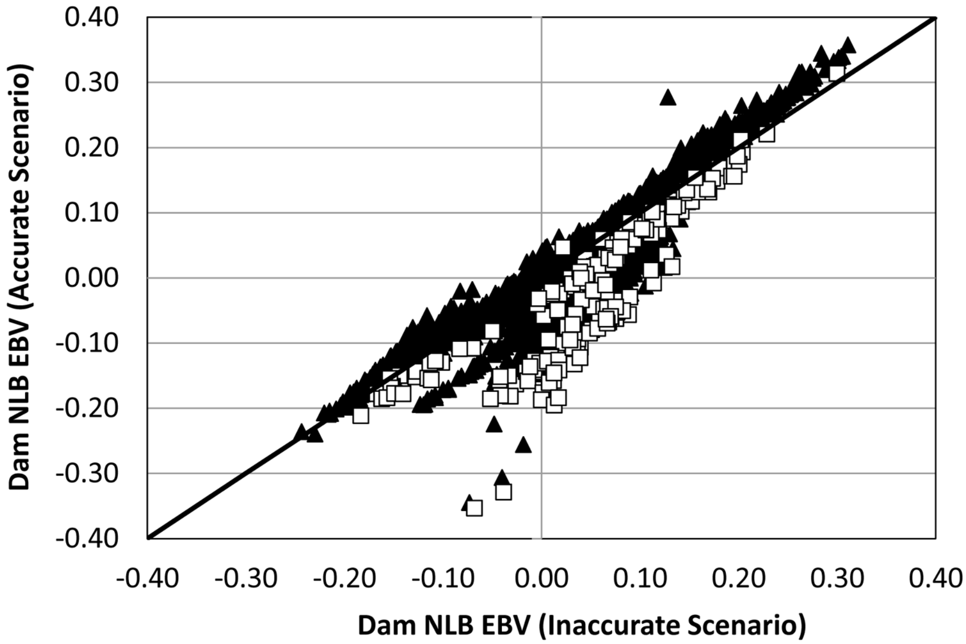

Figure 3. Scatter plot between ewe EBV for number of lambs (NLB) for ewes mated to sires in the Accurate Scenario and in the Inaccurate Scenario, with the black triangles representing ewes mated to sires without data manipulation in the Accurate Scenario and the white squares representing ewes mated to sires with data manipulation in the Inaccurate Scenario.

recording of litter size can have on biasing genetic evaluations. Results suggest inaccurate birth-rearing type does indeed impact individual sire EBV.

Least Squares Means

The main causes for lamb rearing type to differ from the respective birth type are lamb mortality, cross-fostering or artificial rearing. The incidence and causes of lamb mortality vary by litter size and have been well documented (Sawalha et al., 2007; Geenty et al., 2014; McHugh et al., 2016). Cross-fostering is a common management practice undertaken worldwide (Australia– Alexander et al., 1985; New Zealand– Pollard and Littlejohn, 1999; US– Snowder and Knight, 1995), with reports of over 93% of producers adopting this management tool (Ward et al., 2011). Although the overall within-flock incidence of cross-fostering or artificially rearing has been reported to vary from 1.5 to 50% (María et al., 1993; Tosh and Kemp, 1994), the impact of birth type on these cross-fostering practices is unreported. Given that the proportion of lambs reared in a different class from their birth type is not consistent for singles (1.18%), twins (3.75%) and triplets (3.30%) it is likely that the causes of the dis-concordance between birth and rearing type differ by birth type; results from this study facilitated each birth type to be characterized separately.

For singleton-born lambs, the heavier birth weight is not unexpected and corroborates previous studies in both sheep (Christley et al., 2003) and cattle (Gregory et al., 1990). Where single bearing ewes are selected to become foster dams, producers, on average, selected ewes with lighter-single born lambs, indicating that when cross-fostering, producers aim to minimize the weight (and size) differential between the ewe's natural lamb and the cross-fostered lamb. This ensures that the competition for the ewe's resources does not favor one lamb over the other (Van Welie et al., 2016). Rearing type did not directly influence the growth potential of single-reared lambs, as lambs born and reared as singles had greater growth rates from birth to 40 d and were thereby heavier at 40 d than multiple-born lambs reared as singles. This suggests that the superior morphological development of singleton-born lambs at birth could not be overcome by multiple-born lambs at least during the pre-weaning phase. Results from beef cattle suggest birth type does not affect growth rate during the post-weanling period (Gregory et al., 1990).

Interestingly, however, no difference was detected in either 40-day weight or ADG in twin-reared lambs born as either singles or twins, corroborating previous sheep research that shows that the rearing type can influence the milk yield of the ewe (Cardellino and Benson, 2002) and the suckling behavior of the lamb(s) (Hess et al., 1974). For triplet-born lambs reared as a single, the heaviest triplet lamb was likely to be reared by the natural dam; the lighter littermates were likely to be less vigorous at birth (Moore et al., 1986; Macfarlane et al., 2010) and therefore more likely to be cross-fostered or artificially reared, or even die at birth or soon thereafter (Sawalha et al., 2007; Geenty et al., 2014; McHugh et al., 2016). As heavier triplet lambs tend to be reared as singles or twins, one might therefore expect a bias toward male lambs, but the proportion of males and females triplet-born lambs reared as singles or twins were equal, indicating that producers had no preference toward the sex of triplet lambs destined for cross-fostering.

The quadratic relationship between lamb pre-weaning weight and dam parity is not unexpected (Lewis et al., 1989) since lesser milk yield is associated with first and older parity ewes (Gosling et al., 1997). This reduced milk production, coupled with the poorer mothering ability (Dwyer, 2014) in younger ewes, may help to explain the interaction between ewe parity and rearing type in the present study. This therefore contributed to rearing type having a greater influence on live weight at 40 d in younger parity ewes compared to older ewes.

Genetic Evaluations

To our knowledge, no previous sheep study has investigated the impact of mis-recording of phenotypic data on genetic evaluations for lambing traits. The impact of pedigree errors on genetic evaluations has, however, been studied extensively in dairy cattle and results suggest that parentage misidentification will result in downward biased heritability estimates (Van Vleck, 1970; Parlato and Van Vleck, 2012) and reduced rates of genetic gain (Israel and Weller, 2000; Banos et al., 2001). In contrast, the direct and maternal heritability estimates reported in the current study did not differ between the Accurate and Inaccurate Scenario (Table 3) but the proportion of data manipulated in the Inaccurate Scenarios was low (~0.02). The direct and maternal heritability estimates for the growth traits in the present study are, nonetheless, within the ranges previously reported across a variety of breeds and international populations (Safari and Fogarty, 2003). Although the maternal repeatability remained relatively consistent across age in the present study, similar to previous studies, the maternal heritability halved from birth to 40 d weighing (Näsholm and Danell, 1996; Larsgard and Olesen, 1998).

Breeding objectives globally generally adopt a holistic approach whereby animals are ranked based on estimated genetic merit for a multitude of traits (Santos et al., 2015). There is a common misconception among producers that recording lamb mortality will have a deleterious effect on the sire's or animal's individual lambing EBV but also on their overall multi-trait breeding objectives. However, results from this study suggests that the opposite is true and manipulation of birth-rearing data will first result in the recording of lower litter sizes to individual animals thereby reducing the animals EBV for prolificacy. In addition, the manipulation of birth-rearing type clearly impacted sire EBV for pre-weaning growth traits (Fig. 2); given the strong genetic relationship for growth measured across an animal's life (Safari and Fogarty, 2003), this is likely to have a repercussions on post-weaning growth and slaughter EBV. Internationally, animal growth represents a large proportion of the weighing in sheep breeding objectives; for example the Irish (43 to 87%) and New Zealand (55 to 88%; Santos et al., 2015) breeding objectives are heavily weighted toward growth traits. Therefore birth-rearing type data can have a large impact on an animal's ranking not just on individual growth traits but also on the overall breeding objectives.

The majority of breeding rams are sold in many countries as young, relatively unproven, ram lambs. This, coupled with the relatively low direct heritability recorded for pre-weaning growth traits, will result in breeding ram being sold with low accuracy levels; therefore inaccurate recording of birth-rearing data can have large repercussions. For example the manipulation of only 20% of a sire's birth-rearing type data in the present study could result in the sire ranking in the bottom 20% for weight EBV, whereas the recording of accurate data results in the sire ranking in the top 50% of sires. The subsequent generation of phenotypic data on progeny of the sire will result in the true genetic potential of the sire being expressed but this may also lead to large re-ranking of individual sires thereby eroding producers' confidence in genetic evaluations. Interestingly the manipulation of birth-rearing type data also had an unfavorable impact on the fertility EBV of ewes mated to sires subjected to the data manipulation (Fig. 3), thereby contributing to poorer maternal EBV for number of lambs born for these (unrelated) ewes.

In conclusion, results from the present study clearly show the birth-rearing type and other animal-level factors impact pre-weaning lamb growth rate. Although producers may believe that the omission of lamb mortality records will increase the value and the EBV of their breeding animals, results from this study suggest that mis-recording of birth-rearing type can have unfavorable consequences on genetic evaluations for both lamb performance and number of lambs born, even with a little as 20% of data mis-recorded. The present study therefore highlights the importance of precise recording of birth-rearing type to producers for the generation of accurate genetic evaluations.

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