Proc. Assoc. Advmt. Anim. Breed. Genet. 26: 256-259

GENETIC PARAMETERS FOR CAUSE OF DEATH TRAITS IN LAMBS AND INDICATORS TRAITS LINKED TO NEONATAL SURVIVAL

M. Hebart, R. McEwin and F.D. Brien

University of Adelaide, Roseworthy, SA, 5371 Australia

SUMMARY

Improving lamb survival has implications for production, economics and welfare. Direct selection for lamb survival is difficult given its low heritability. Selection based on cause of death could provide an alternative or supplementary strategy for improving lamb survival. This study estimated heritabilities for cause of death traits determined from necropsy, and genetic correlations between these and indicators of neonatal lamb survival. Our results support using lambing ease as an indicator trait to improve lamb survival. Although birth weight was positively genetically correlated with Dystocia A, it was negatively correlated with the starvation and mismothering and starvation, mismothering and exposure complexes, complicating its use as an indicator trait. However, the moderate genetic correlations between observed birth vigour and the starvation and mismothering complex (0.53) and between thorax circumference and Dystocia B (0.58) and a composite dystocia trait (0.47) indicate potential for indirect selection for improved lamb survival.

INTRODUCTION

Reproductive efficiency of the Australian sheep flock has remained unchanged for the past five decades. Hinch and Brien (2014) reported that on average 20-30% of lambs die before weaning, with 74% of those dying within three days of birth. Lamb survival is a complex trait that is influenced by many environmental and management factors, and heritability estimates of lamb survival are very low (Brien *et al.* 2010; Safari *et al.* 2005). McFarlane (1965) suggested that an alternative to selecting directly to improve lamb survival is to select against the cause of death, as determined by necropsy. Brown *et al.* (2014) estimated heritabilities for different causes of death and suggested little advantage to using these over direct selection for lamb survival. However, understanding the genetic relationships between different causes of death and other production and indicator traits will help understand and improve selection decisions for lamb survival. The aim of this study was to determine the genetic relationships between the cause of death traits and a suite of neonatal lamb metrics and behaviour characteristics that are potentially indicators of survival.

MATERIALS AND METHODS

Data from 27,240 lambs born between 2007 – 2011 from the Sheep CRC Information Nucleus Flock (IN) were used in this study. Detailed descriptions of the sites, design and management of the IN was provided by Geenty *et al.* (2014). Briefly, an average of 3,832 Merino ewes and 796 crossbred ewes were annually joined by AI to key industry sires at 8 sites across southern Australia. Lifetimewool guidelines (ewe body condition score of 3.0 at joining, mid-pregnancy, lambing and weaning; Young *et al.* 2011) were followed at all sites to manage the flocks. The average lamb survival was 79.8% (lambs from Merino ewes 79% and crossbred 85%; Refshauge *et al.* 2016).

Necropsies were performed on 3,198 neonatal lambs that died (Refshauge *et al.* 2016), and one of ten death categories were assigned; Dystocia A (DysA: oedema present, n = 282); Dystocia B (DysB: no oedema, significant cranial and central nervous system haemorrhage but no metabolised fat, n = 660); Dystocia C (DysC: as per DysB but with metabolised fat, n = 577), starvation mismothering complex (SM; no significant cranial and CNS haemorrhage, n = 796); Predation (n=214); deaths *in utero* pre-birth and in premature lambs (DIUPB, n = 328); Exposure (n=172); Infection (n=18); Misadventure (n = 21); and Undiagnosed (n = 130). Composite traits of Dystocia

(Dys; Dystocia A, B or C, n = 2315); and Starvation mismothering exposure (SME; n = 968) were also analysed. A pedigree was constructed with founder animals assigned a genetic group (Swan *et al*. 2016) to account for differences in breed, selection strategy, selection lines and flocks. The survival indicator traits, recorded at lamb tagging, included birth weight (BWT), metacarpal bone length (ML), crown-rump length (CRL), thorax circumference (THO), and rectal temperature (RT), and visually assessed lamb vigour (OBV), birth coat score (BCS), and lambing ease score (LE). Five timed behaviour traits were also analysed; time taken after release for the lamb to bleat (BLT), stand (STD), contact the ewe (CONT), contact the udder (UDD) and follow the ewe (FOLL). Data collection protocols for the IN are described by Brien *et al.* (2010). Descriptive statistics for the indicator traits can be found in McEwin *et al.* (2025).

Statistical analysis. Genetic correlations between the cause of death and timed behaviour traits and other survival indicator traits were estimated using the restricted maximum likelihood (REML) method within an animal model in ASREML-R 4.2 (Butler *et al.* 2023). All traits including necropsy traits were analysed as continuous variables. The main effects for the necropsy data included in the model were contemporary group (year x site; 41 levels), sire type (Maternal, Merino, Terminal), dam breed (Merino, Crossbred), type of birth (single, twin or multiple), age of dam (1-8 years), sex (male or female), and day of birth (nested within contemporary group). The random effects included in the model were direct additive genetic, maternal (comprising both maternal genetic and environmental effects), and genetic groups.

RESULTS AND DISCUSSION

The estimates of phenotypic variance were heritability estimates for the cause of death traits were generally low, ranging from 0.006 to 0.027 (Table 1), which were slightly lower than those of Brown *et al.* (2014), who included BWT and BWT^2 in their statistical model. In contrast, we did not fit BWT (or BWT^2) as covariates in analyses as the genetic relationship between BWT and cause of death traits were under investigation. The composite traits of Dys and SME had higher heritabilities than their components but were not higher than those for lamb survival itself (Brien *et al.* 2010).

Table 1. Estimates of phenotypic variance (V_P), direct heritability (h^2), combined maternal additive and environmental variance (mpe^2), and genetic group variance (gg^2)

Trait[a]	V_P	h^2	mpe^2	gg2
DysA	0.009	0.010 ± 0.006	0.007 ± 0.009	0.001 ± 0.002
DysB	0.022	0.008 ± 0.006	0.006 ± 0.007	0.007 ± 0.007
DysC	0.020	0.008 ± 0.006	0.022 ± 0.009	0.020 ± 0.011
Dys	0.049	0.014 ± 0.006	0.014 ± 0.008	0.038 ± 0.016
SM	0.026	0.006 ± 0.005	0.006 ± 0.009	0.001 ± 0.003
SME	0.031	0.014 ± 0.006	0.014 ± 0.011	0.000 ± 0.002
DIUPB	0.010	0.027 ± 0.007		0.008 ± 0.006

[a]DysA (Dystocia A: oedema present); DysB (Dystocia B: no oedema, significant cranial and central nervous system haemorrhage but no metabolised fat); DysC (Dystocia C: as per DysB but with metabolised fat), SM (starvation mismothering complex - no significant cranial and CNS haemorrhage); Dys (composite traits of Dystocia A, B or C); SME (Starvation mismothering exposure); and DIUPB (deaths *in utero* pre-birth and in premature lambs).

The cause of death traits DysA, DysB and Dys were positively genetically correlated with LE (Table 2). These estimates were slightly higher than those reported by Brown *et al.* (2014) and indicates that selection for improved LE may reduce cases of dystocia. SM and SME were not genetically correlated with LE. RT was negatively genetically related with DysA, DysB, Dys, SM, SME and DIUBP (range -0.18 to -0.54), indicating that selection for higher RT may genetically reduce losses generally from all these causes of death. BWT was positively genetically correlated with DysA (0.46) and Dys (0.23), but negatively genetically correlated with SM and SME (-0.32 and -0.28 respectively). This is consistent with the curvilinear relationship observed between BWT and lamb survival where lambs with lower BWT are more likely to die from SME while those with high BWT are more likely to die from dystocia.

Table 2. Estimates of genetic correlations ± s.e. between lamb survival indicator traits and cause of death traits

Trait[a]	DysA	DysB	DysC	Dys	SM	SME	DIUPB
LE	0.50 ±0.15	0.23 ±0.19	0.01 ±0.19	0.30 ±0.13	0.03 ±0.22	0.07 ±0.17	0.35 ±0.12
BWT	0.46 ±0.13	0.08 ±0.16	0.06 ±0.15	0.23 ±0.11	-0.32 ± 0.17	0.28 ±0.12	-0.06 ±0.10
RT	-0.35 ±0.17	-0.34 ±0.20	n.e.[b]	-0.18 ±0.16	-0.54 ±0.25	-0.42 ±0.18	-0.54 ±0.11
THO	0.23 ±0.21	0.58 ±0.22	0.37 ±0.22	0.47 ±0.16	0.07 ±0.01	0.01 ±0.18	-0.19 ±0.16
CRL	0.31 ±0.13	0.07 ±0.16	0.03 ±0.15	0.14 ±0.11	-0.12 ±0.18	-0.07 ±0.13	-0.01 ±0.10
ML	0.37 ±0.19	-0.16 ±0.20	0.16 ±0.20	0.09 ±0.15	-0.24 ±0.23	-0.13 ±0.17	-0.01 ±0.15
OBV	-0.11 ±0.15	0.29 ±0.17	0.13 ±0.16	0.15 ±0.12	0.53 ±0.22	-0.07 ±0.13	0.17 ±0.11
BCS	-0.01 ±0.12	-0.27 ±0.15	0.01 ±0.13	-0.12 ±0.10	-0.37 ±0.18	-0.29 ±0.12	0.14 ±0.09
BLT	-0.06 ±0.23	0.09 ±0.26	0.06 ±0.26	0.06 ±0.20	-0.20 ±0.30	-0.12 ±0.22	n.e.
STD	0.06 ±0.19	0.22 ±0.24	0.08 ±0.24	0.06 ±0.19	0.39 ±0.29	0.24 ±0.21	n.e.
CONT	-0.03 ±0.21	0.14 ±0.22	0.14 ±0.22	-0.01 ±0.17	0.21 ±0.25	0.11 ±0.19	n.e.
UDD	-0.25 ±0.36	-0.05 ±0.36	0.47 ±0.37	0.07 ±0.17	-0.27 ± 0.41	-0.20 ±0.30	n.e.
FOLL	-0.25 ±0.25	0.14 ±0.26	0.12 ±0.27	0.03 ±0.20	0.75 ±0.33	0.56 ±0.22	n.e.

[a]LE: lambing ease score; BWT: birth weight (kg); RT: rectal temperature (^{0}C); THO: thorax circumference (cm), CRL: crown-rump length (cm); ML: metacarpal bone length (cm); OBV: assessed lamb vigour, BCS: birth coat score; timed behaviour traits were recorded from time taken after release for the lamb to bleat (BLT), stand (STD), contact the ewe (CONT), contact the udder (UDD) and follow the ewe (FOLL). The cause of death traits are defined in the footnote to Table 1 and in the Materials and Methods
[b]n.e. not estimable

Moderate correlations between THO and DysB and Dys (and 0.37 with DysC) suggest that lambs with a large thorax circumference are more likely to die from dystocia causes, particularly from birth injury. However, THO appears unrelated to deaths caused by starvation, mismothering and exposure. Positive correlations between CRL and DysA, and between ML and DysA indicate that lambs with longer crown-rumps and metacarpals are more prone to die of classic dystocia. A moderate correlation (0.53) between OBV and SM indicates that more vigorous lambs are less likely to die from SM although this trend was not observed in the composite trait SME. The correlations between OBV and the dystocia traits were generally low indicating selection for OBV will not reduce deaths caused by birthing difficulties. High positive correlations between FOLL and SM and SME and moderate positive correlations between STD and SM and SME indicate that lambs that took longer to follow and stand are more likely to die from SM and SME. The correlations between the other timed behaviours and SM/SME, and dystocia traits were generally low.

CONCLUSION

Heritabilities for all cause of death traits were low which suggests little advantage in using these over selecting directly for lamb survival. Despite this, understanding the genetic relationships between causes of death and other survival indicator traits may allow more accurate selection decisions for improving lamb survival. Firstly, using LE in selection to improve lamb survival is supported by our results. Secondly, selection for OBV could reduce death from SM and thirdly, selection for reduced THO could reduce the incidence of all categories of dystocia.

ACKNOWLEDGEMENTS

The IN and associated research programs were supported by the Australian Government's CRC Program, MLA and AWI Ltd. Resources were provided by 5 partner organisations, NSW Department of Primary Industries and Regional Development (NSWDPIRD), the University of New England, the Victorian Department of Primary Industries, the South Australian Research and Development Institute, and the WA Department of Primary Industries and Regional Development. Supporting science and technical staff of these partner organisations are sincerely thanked. We acknowledge the key role of Gordon Refshauge of NSWDPIRD in coordinating the necropsy work and for data cleaning. We also acknowledge Daniel Brown of AGBU for providing data from the IN program. Finally, this study is part of the MDC project 'Fit to Lamb' P.PSH.1399, led by Murdoch University, administered by MLA, with funding provided by the Australian government, Murdoch University, the University of Adelaide, AWI Ltd, Animal Health Australia and CSIRO.

REFERENCES

Brien F.D., Hebart M.L., Smith D.H., Edwards J.E. Hocking, Greeff J.C., Hart K. W., Refshauge G., Bird-Gardiner T.L., Gaunt G., Behrendt R., Robertson M.W., Hinch G.N., Geenty K.G. and van der Werf J.H.J. (2010) *Anim. Prod. Sci.* **50**: 1017.

Brown D.J., Jones R.M. and Hinch G.N. (2014) *Anim. Prod. Sci.* **54**: 736.

Butler D.G., Cullis B.R., Gilmour A.R. Gogel, B.G. and Thompson, R. (2023) 'ASReml- R Reference Manual Version 4.2.' VSN International Ltd., UK.

Geenty G.N., Brien F.D., Hinch, G.N., Dobos R.C., Refshauge G., McCaskill M., Ball A.J., Behrendt R., Gore K.P., Savage D.B., Harden S., Hocking-Edwards J.E., Hart K. and van der Werf J.H.J. (2014) *Anim. Prod. Sci.* **54**: 715.

Hinch G.N. and Brien F. (2014) *Anim. Prod. Sci.* **54**: 656.

McEwin R.A. Hebart M.L. and Brien F.D. (2025). *Proc. Assoc. Advmt. Anim. Breed. Genet*. **26**: *These proceedings.*

McFarlane D. (1965) *New Zealand Vet. J.* **13**: 116.

Refshauge G., Brien F.D., Hinch G.N. and van de Ven R. (2016). *Anim. Prod. Sci.* **56**: 726.

Safari E., Fogarty N.M. and Gilmour A.R. (2005) *Livest. Prod. Sci.* **92**: 271.

Swan A.A., Brown D.J. and van der Werf J.H.J. (2016) *Anim. Prod. Sci.* **56**: 87.

Young J.M., Thompson A.N., Curnow M. and Oldham C.M. (2011) *Anim. Prod. Sci.* **51**: 821.