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INHERITANCE OF TAIL LENGTH IN MERINO SHEEP

J.C. Greeff, L.J.E. Karlsson and A.C. Schlink

Department of Agriculture and Food Western Australia, 3 Baron Hay Court Perth, WA, 6051

SUMMARY

The inheritance of tail length and spine length was estimated using data of 2667 Merino lambs assessed at approximately 6 weeks of age on the marking cradle. Maternal permanent environmental effects affected spine length and marking weight but not tail length. The heritability of tail length and spine length was both 0.58 ± 0.05, while the genetic correlation between the two traits amounted to 0.58 ± 0.05. However, adjusting the data for marking weight or spine length removed the genetic correlation between spine and tail length. The heritability of a subjective score for tail length was 0.38 ± 0.05. The results indicate that selection for short tails is possible and that it will not have a negative impact on spine length provided adjustment is made for body weight or spine length.

INTRODUCTION

Breech and tail strike are the most common types of blowfly strike suffered by Merino sheep. Mulesing and tail docking are therefore used to reduce the impact of the main predisposing factors such as wrinkles, dags and breech cover that contributes to breech strike. Mulesing removes the skin around the anus, and docking the tail at the 3 or 4th joint, makes animals less susceptible to breech and tail strikes because it reduces the accumulation of faecal material and urine in the breech and on the tail (James, 2005).

Recent trends in animal welfare and ethical sheep production systems, question these surgical techniques. This has resulted in alternative methods being investigated to remove or reduce the impact of the predisposing factors to breech strike. Greeff *et al.* (2013) and Smith *et al.* (2009) have shown that dags, wrinkles, urine stain and high breech cover scores are the most important indicator traits and selecting against these traits will reduce breech strike. Watts *et al*. (1977) showed that tail length played an important role in determining the susceptibility of sheep with diarrhoea to breech strike. Sheep with very short tails are more susceptible to breech strike than longer tails because they cannot lift their tail to hold the wool out of the way when defaecating and urinating. James (2005) therefore suggested that breeding for shorter tails should be considered in un-mulesed sheep to make sheep less susceptibility to breech strike.

However, breeding for short tails may result in skeletal abnormalities as was found by James *et al.* (1990; 1991) in Merino sheep where single dominant genes were the mode of inheritance. Shelton (1977) showed that tail length adjusted for body length had a heritability of 0.38 in Rambouillet sheep. Scobie and O'Connell (2002) showed that the mode of inheritance of tail length in different sheep breeds was additive. However, no study has estimated the genetic correlation between tail length and spinal length. This study was carried out to determine whether it would be possible to breed for short tails, and whether there is any negative relationship between tail length, spinal length and body weight in Merino sheep.

MATERIAL AND METHODS

Animals. Body weight, tail length, spinal length and a visual score for tail length were recorded on 2667 lambs that were the progeny of 62 sires mated to 1294 ewes and born from 2012 to 2014 in the Australian Wool Innovation Breech strike flock at Mt Barker research station in Western Australia. Lambs were born over approximately 6 weeks from mid July to end of August every year. Full pedigrees, sex of the lamb, birth status and age of the dam were recorded on all lambs.

Measurements. Tail length was measured at marking at approximately 6 weeks after birth. A tape measure was permanently fixed length-wise in the marking cradle. The lamb was placed in the cradle with its spine lying lengthwise on the tape. A measurement was taken at the joint between the skull and the first neck vertebrae of the lamb, at the root of the tail, and at the tip of the tail. Spinal length and tail length for each lamb were calculated through subtraction. Tail length was also scored by holding the lamb's leg perpendicular to its body and laying the tail along the anterior side of the backleg over the hock. Lambs were scored from 1 (short) to 5 (long) depending on the length of the tail relative to the hock. Tails that touched the hock were given a score of 3, while shorter tails were given scores of 1 or 2, and longer tails 4 or 5 depending on length. Any lamb with evidence of their tails being bitten off, were not recorded.

Body weight of each lamb was recorded at marking in 2013 and 2014. As marking weight was not recorded in 2012, a body weight at marking was estimated for the 2012 drop by multiplying the average daily gain from birth to weaning at 85 days of age, with the average age of the 2012 drop at marking and adding birth weight. This method assumes that growth was linear which may not have been the case. However, it was deemed acceptable in a preliminary study such as this until more data are recorded.

Data analysis. The data were analysed with ASREML (Gilmour *et al.* 2009). An animal model with and without maternal permanent maternal environmental effects was fitted with year of birth (3 years), sex (male or female), age of the dam (2 to 6 years) and birth status (single or multiples) as fixed factors and all 2 way interactions. Day of birth was fitted as a covariate within year of birth. Maternal pedigrees were not fitted because of shallow pedigrees. Different univariate analyses were first carried out with and without body weight at marking as a covariate to identify significant fixed effects. The following combinations of direct additive and maternal permanent environmental effects were fitted.

$$y = Xb + Za + e \qquad (1)$$

$$y = Xb + Za + Wpe_{+} e \qquad (2)$$

where y, b, a, pe and e are the vectors of observed traits of animals, fixed effects, direct additive genetic effects, permanent maternal environmental effect and residual effects, respectively. X, Z and W are incidence matrixes for fixed, direct additive genetic and permanent maternal environmental effects of y, respectively. Marking weight was also fitted as a covariate to tail and spine length, while tail length was also adjusted for spine length to determine its impact on the inheritance of tail length. Log likelihood ratio tests were carried out amongst the models to determine the most appropriate model for each trait. This was followed by bivariate analyses between tail length, spinal length and body weight to obtain variances and covariances for genetic parameter estimation, by fitting the most appropriate model as determined by the previous analysis. Tail score was only analysed to estimate the correlations with tail length.

RESULTS AND DISCUSSION

Table 1 shows the average spine length, tail length, tail score and marking weight at marking at approximately 6 weeks of age.

Year of birth, sex of the lamb, birth status, day of birth and age of the dam affected tail length, tail score, spine length and marking weight significantly ($P<0.001$). No significant interaction effects were found between these fixed effects. Log likelihood ratio tests shows that model 2 which included both direct additive genetic and permanent maternal environment effects, fitted the spine and marking weight data best while model 1 with only direct additive genetic effects fitted the tail length and tail score data best.

Table 1. Average spine length, tail length and body weight at marking (approximately 6 weeks of age).

Trait	n	Mean	SD	CV	Min	Max
Spine length (cm)	2665	73.4	6.02	8,2	46	98
Tail length (cm)	2665	23.2	3.62	15.6	11	40
Tail score	2661	3.7	0.67	18.1	1	5
Marking weight* (kg)	2665	13.0	3.09	23.8	4.2	25.4

* Include some estimates

Fitting marking weight as a covariate to spine length removed all the permanent maternal environmental effects and resulted in model 1 fitting the data best. The variance components are shown in Table 2.

Table 2. Phenotypic variation, heritability and permanent maternal environmental effects of tail length, spine length, body weight at marking, and tail score, and fitting marking weight or spine length as covariate to tail length and tail score.

Parameter	Tail length	SE	Spine length	SE	Marking weight	SE	Tail score	SE
Vp	9.5		31.5		7.7		0.40	
h^2	0.58	0.05	0.58	0.05	0.44	0.06	0.38	0.05
h^2	0.48[a]	0.05[a]	0.51[a]	0.04[a]	---	---	0.36[a]	0.05[a]
h^2	0.54[b]	0.05[b]	---	---	---	---	0.35[b]	0.05[b]
m^2_{pe}	---	---	0.06	0.02	0.17	0.03	---	---

Vp = Total phenotypic variation with model 1; h^2 = direct additive heritability; m^2_{pe} = maternal environmental effect, [a] Marking weight fitted as covariate; [b] spine length fitted as covariate

Heritability estimates. Tail and spine length and tail score were all heritable traits with tail and spine length having the highest heritability of 0.58 followed by an estimate of 0.44 for marking weight and 0.38 for tail score. Maternal permanent environmental effects were not significant for tail length but it made a significant contribution ($P<0.01$) to marking weight and for spine length. The heritability estimate of 0.58 for Merinos is higher than the heritability of 0.39 in Rambouillet sheep (Shelton, 1977). However, it is not clear whether Shelton (1977) used the measured tail length, or a tail length adjusted for body length in his analysis. Fitting marking weight as covariate in this study decreased the heritability of tail length from 0.58 to 0.48 and decreased the heritability of spine length from 0.58 to 0.51. When tail length was adjusted for spine length, the heritability of tail length decreased slightly to 0.54. Scobie (2002) reported a very high heritability of 0.82 for tail length which is of the same magnitude as the estimate of 0.77 reported by Branford Oltenacu and Boylan (1974). However, both these studies worked with crossbred sheep in which the short-tail Finnish Landrace featured prominently. In the more common type of sheep breeds, Branford Oltenacu and Boylan (1974) reported an estimate of 0.50 which is slightly lower than the estimates derived in this study.

Correlations. Table 3 shows the phenotypic and genetic correlations between tail length, spine length, body weight at marking and tail score. Tail length was phenotypically positively correlated with spine length (0.44) and with body weight (0.53) at marking. Similarly, moderately strong genetic correlations were found between tail length and spine length (0.58) and between tail length and marking weight (0.67). However, fitting marking weight as covariate removed the strong correlation between tail and spine length. This indicates that tail and spine length are independent traits and that the genetic correlation is induced through body weight. Tail score was genetically moderately strongly correlated with tail length. Although the heritability of tail score is less than that of tail length, and has a correlation with tail length that is lower than expected, it may still be a useful trait to select indirectly for short tails without resorting to direct measurements.

Table 3. Phenotypic (above diagonal) and genetic (below diagonal) correlations between tail length, spine length and marking weight and their standard errors in brackets.

	Tail length	Spine length	Spine length [a]	Marking weight	Tail score
Tail length		0.44 (0.02)	0.05 (0.02)	0.53 (0.02)	0.61 (0.02)
Spine length	0.58 (0.05)		----	0.81 (0.01)	----
Spine length [a]	-0.01 (0.08)	----		----	----
Marking weight	0.67 (0.02)	0.80 (0.03)	----		----
Tail score	0.77 (0.05)	----	----	----	

[a] Fitting marking weight as covariate

CONCLUSIONS

This study shows that tail length is a heritable trait and that it would respond to selection. It has a moderately strongly genetic correlation with body weight at marking but adjustment for body weight or spine length at marking removed the genetic relationship between tail length and spine length. This indicates that Merino breeders can breed for shorter tails without having any negative impact on spine length provided adjustment is made for body weight or body size.

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