THE GENETICS OF SEXUAL DIMORPHISM IN SHEEP

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SUMMARY

This study estimated the magnitude of sexual dimorphism, i.e. sex specific heritabilities and correlations between ewes and rams for weaning, post weaning, yearling and hogget weights in 3 sheep breeds (Coopworth, Poll Dorset and White Suffolk). Rams were heavier than ewes at all ages, but higher heritability estimates were observed for ewes, although few of these differences were significant. Genetic correlations between ewes and rams varied from 0.97 to 0.59 and decreased with increasing age at measurement.

INTRODUCTION

While it is well known that rams are larger than ewes (sexual dimorphism), there has been little effort to quantify the genetic factors that contribute to this phenomenon and how sexual dimorphism may be utilised in breeding programs. Unequal heritabilities for traits measured on ewes and rams and/or correlations between the sexes of less than unity could have implications for the accurate estimation of breeding values and the optimal multiple trait selection response in each sex. Moreover, sexual dimorphism could potentially be exploited in breeding programs because it may be beneficial to divergent selection between sexes within breeds for growth and maternal traits.

MATERIALS AND METHODS

Data. Pedigree and performance data for the Coopworth, Poll Dorset and White Suffolk breeds were extracted from the Sheep Genetics database. This database consists of pedigree and performance records from Australian and New Zealand studs and is used for genetic evaluation purposes. Data for weaning (wwt - 40 to 120 days), post weaning (pwt - 80 to 340 days), yearling (ywt - 290 to 430 days) and hogget (hwt - 410 to 550 days) weights were extracted. Analysis of adult weights is not reported due to insufficient data. Only data that met the following criteria was used: 1) dates of birth and measurement were recorded, 2) both sire and dam were known, 3) the sex of the animal was known, 4) the animal resulted from natural conception (not artificial insemination or embryo transfer) and 5) the contemporary group (based on flock, birth year and trait management group) the animal belonged to had more than 10 records from the same sex recorded. The number of records used for analysis for each breed and trait is shown in table 1.

Table 1: Size of the Coopworth, Poll Dorset and White Suffolk datasets for each sex

	Coopworth		Poll Dorset		White Suffolk	
	ram	ewe	ram	ewe	ram	ewe
wwt	17271	18719	51956	48413	50935	51415
pwt	4409	4070	56326	38737	47495	38549
ywt	9959	9673	44379	30165	25053	19104
hwt	433	5357	19341	10164	7290	3924

Analysis. The mixed model analysis was carried out using the ASReml program (Gilmour *et al.* 2006). All models included the interaction between birth and rearing types, the age of the dam (years), the age of the animal at the time of measurement (days) and contemporary group as fixed factors. These fixed factors are the same as those used in the OVIS program used by Sheep Genetics for the genetic evaluation of industry studs (Brown *et al.* 2000). Random effects fitted in the model included additive genetic and, when significant, maternal additive genetic and maternal permanent environmental effects. The significance of additional random effects was established using Log Likelihood ratio tests. In the across sex multitrait analyses, the residual covariance was set to zero as the same animal could not be represented in both sexes.

The heritability (h^2), phenotypic standard deviation (σ_p) and genetic correlation between rams and ewes (rg) obtained from this analysis, along with selection intensities (i) for each breed and sex that were obtained from 10 year averages (1999-2008) in the Sheep Genetics Database (Sheep Genetics, *unpublished data*, 15/5/2009), were used to predict the response to mass selection in each sex (R) using the following equation from Cheverud *et al.* (1985):

$$R_{\text{Sex A}} = (0.5)\,(h^2_{\text{Sex A}}\ \sigma_{\text{pSex A}}\ i_{\text{Sex A}} + h_{\text{Sex A}}\ h_{\text{Sex B}}\ rg\ \ \sigma_{\text{p Sex A}}\ i_{\text{Sex B}})$$

Using this equation, the response of sexual dimorphism for a trait can be defined as the difference between the responses obtained for ewes and rams (Cheverud *et al.* 1985).

RESULTS AND DISCUSSION

The sex specific heritabilities for each of the 3 breeds and at each of the 4 ages are summarised in Table 2. Although there is a consistent trend in all analyses that ewes have larger heritability estimates than rams, the difference was only significant (95% confidence interval) in 2 out of 13 analyses. These findings are consistent with those found in literature (e.g. Pattie 1965, Baker *et al.* 1979). Comparison of variance components indicated that ewes had relatively lower residual and higher additive genetic variances than rams. Rams had significantly more phenotypic variation (Vp) than ewes, which was partly due to strong correlations between phenotypic variation and weight.

The genetic (r_g) correlations between the sexes for each of the 3 breeds and at each of the 4 ages are summarised in Table 3. The genetic correlation estimates between the sexes were high and varied between 0.97 at weaning in the Poll Dorset and White Suffolk breeds to 0.59 at 1 year of age in the White Suffolk breed. Estimates for the Coopworth breed were contained within this range. There was a noticeable decrease in the across sex genetic correlations between weaning and post weaning for the Poll Dorset and White Suffolk breeds and between post weaning and yearling for the Coopworth breed. This decrease could be possibly attributed to the fact that ram lambs reach sexual maturity before ewe lambs as reported in Taylor (1968).

Between sex genetic correlations of less than 1 allow response to selection for sexual dimorphism and examples of the sex specific responses are given in Table 2. Divergent selection objectives could be used to optimise selection for the sex specific roles present in a self replacing production system. An example of this would be to have a higher selection emphasis on growth in rams than ewes, thus producing male progeny that reach sale weight earlier and restrict or reducing mature ewe weight. Mature weight has a correlated influence on feed intake and the feed intake of the ewe can comprise over 80% of the total feed costs in a production system (Thompson, 1991). The responses shown in Table 2 are merely illustrative as they are based on single trait mass selection, whereas usually responses are optimized in a multiple trait objective. However, these results do suggest that a reasonable amount of response for sexual dimorphism is possible.

There was little variation in maternal heritability (m^2) between rams and ewes with estimates larger in rams in 7 out of the 9 analyses where this effect was estimated, but only on one occasion was this significant. No identifiable trend in maternal permanent environmental effects (pe) was found. The lack of variation in the maternal heritability and permanent environmental effects between the sexes is not surprising and indicate that the differences between dams affect ewe and ram lambs equally. For the analyses where the maternal additive genetic and maternal permanent environmental effects were estimable, the correlations between the sexes were high and positive.

Table 2: Phenotypic variance (Vp), heritability (h^2), maternal heritability (m^2), maternal permanent environmental effect (pe) and the predicted response to selection for each trait in ewes or rams.

Trait	Breed	Sex	Vp	h^2	m^2	pe	Response
wwt	Coopworth	ram	20.12^a	0.308^a	0.181^a	0.119^a	1.85
		ewe	15.94^b	0.394^a	0.134^a	0.122^a	1.67
	Poll Dorset	ram	30.94^a	0.280^a	0.138^a	0.131^a	3.57
		ewe	24.09^b	0.338^a	0.148^a	0.128^a	2.72
	White Suffolk	ram	31.71^a	0.506^a	0.265^a	0.130^a	2.35
		ewe	23.83^b	0.517^a	0.191^b	0.131^a	1.99
pwt	Coopworth	ram	22.25^a	0.272^a	0.220^a		1.72
		ewe	17.06^b	0.284^a	0.104^a		1.47
	Poll Dorset	ram	52.36^a	0.298^a	0.189^a	0.092^a	2.13
		ewe	30.98^b	0.447^b	0.160^a	0.086^a	1.71
	White Suffolk	ram	43.97^a	0.416^a	0.185^a	0.121^a	2.60
		ewe	27.62^b	0.482^a	0.210^a	0.105^a	1.75
ywt	Coopworth	ram	26.99^a	0.323^a	0.198^a		2.00
		ewe	22.89^b	0.364^a	0.113^a		1.92
	Poll Dorset	ram	62.68^a	0.295^a	0.236^a		2.68
		ewe	31.17^b	0.350^a	0.220^a		1.74
	White Suffolk	ram	49.31^a	0.285^a	0.195^a	0.072^a	2.25
		ewe	32.87^b	0.444^b	0.133^a	0.125^b	1.79
hwt	Coopworth	ram	60.75^a	0.120^a			2.57
		ewe	31.15^b	0.411^a			2.44
	Poll Dorset	ram	76.14^a	0.324^a			3.42
		ewe	30.38^b	0.368^a			2.23
	White Suffolk	ram	56.16^a	0.249^a			2.08
		ewe	33.37^b	0.344^a			1.69

Identical superscripts indicate that the sexes are not significantly different within trait (95% confidence interval) from each other.

Table 3: Genotypic correlations between ewes and rams

	Coopworth		Poll Dorset		White Suffolk	
wwt	0.93	±0.03	0.97	±0.01	0.97	±0.01
pwt	0.94	±0.09	0.82	±0.03	0.80	±0.03
ywt	0.84	±0.06	0.74	±0.04	0.59	±0.06
hwt	0.78	±0.52	0.80	±0.06	0.75	±0.16

Corrected weights for each sex at each of the 4 ages were obtained from the ASReml program (Gilmour *et al.* 2006) and are shown in figure 1. In each of the 3 breeds and at each of the 4 ages, rams were significantly (95% confidence interval) heavier than ewes and the degree of sexual dimorphism (ram weight/ewe weight) increased with age, from around 1.10 at weaning in all 3 breeds to 1.26 in the Coopworth breed, 1.27 in the White Suffolk breed and 1.30 in the Poll Dorset breed in the hogget age group. Based on this evidence, it appears that not only do rams grow faster than ewes up to puberty but they continue to do so until hogget age.

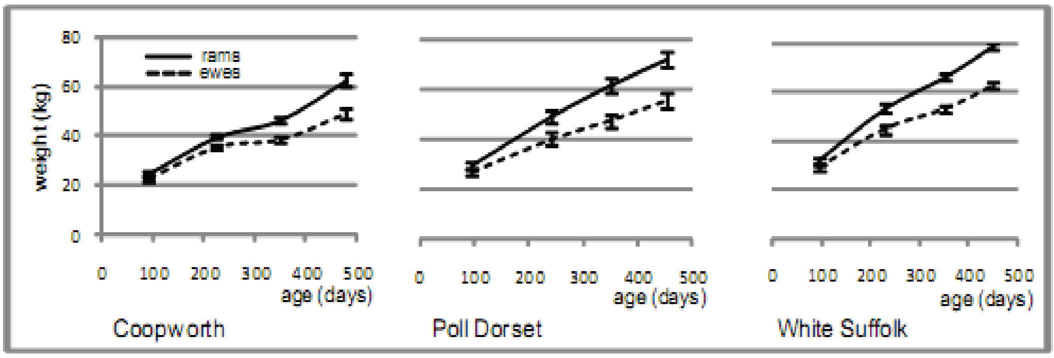

Figure 1: Growth curves for ewes and rams. Error bars represent a 95% confidence interval for each value.

CONCLUSIONS

Sexual dimorphism (rams larger than ewes) clearly exists in sheep and could be increased by selection. Weight traits measured on ewes had slightly higher heritability estimates compared with rams, but lower phenotypic variation, and the genetic correlations between the sexes were significantly less than 1. The combination of these results potentially have implications for determining the optimal models required for the accurate estimation of breeding values and in determining the optimal selection response in each sex, particularly in a scenario where one sex is recorded preferentially. Sexual dimorphism could also be combined with the sex specific roles found in self replacing lamb production systems to reduce the total feed requirements of the production system.

ACKNOWLEDGMENTS

This research was supported by Meat and Wool New Zealand (MWNZ), Meat and Livestock Australia (MLA) and the University of New England (UNE). The assistance of Arthur Gilmour is also gratefully acknowledged.

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