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# Genetic (Co)variance Components for Body Weight and Body Measurements in Makooei Sheep

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**ABSTRACT :** The aim of this paper was to estimate genetic parameters for body weight and five body measurements for an experimental population of Iranian Makooei sheep maintained at the Makooei Sheep Breeding Station at Makoo, Iran. To do this, yearling live weight (YW), and five body measurements, i.e., body length (BL), heart girth (HG), height at withers (HW), height at back (HB) and scrotal circumference (SC), were analyzed in a multi-trait animal model using the DXMUX program of DFREML software package. Heritability estimates were 0.22±0.08, 0.11±0.06, 0.21±0.07, 0.17±0.06, 0.17±0.06 and 0.32±0.10 for YW, BL, HG, HW, HB and SC, respectively. These estimates indicate that selection in Makooei sheep would generate moderate genetic progress in body weight and body measurements. Scrotal circumference, as an indicator of reproductive potential, exhibited the highest heritability. This trait, therefore, could successfully be used to increase productivity of males and, indirectly, female fertility. Genetic correlations between traits studied were all positive and ranged from 0.15 (YW/HB) to 0.99 (HW/HB). Phenotypic correlations were also positive and ranged from moderate (0.32, HW/SC) to high (0.94, HW/HB). Positive genetic and phenotypic correlations indicate that improvement in body measurements both at the genetic and phenotypic levels is expected through selection on body weight and vice versa. (**Key Words :** Body Weight, Body Measurement, Sheep, Animal Model, REML, Heritability)

## INTRODUCTION

The Makooei sheep is one of the Iranian fat-tailed, medium-size breeds. They are distributed in the mountainous areas of the country, especially in west-Azerbaijan province. Also, they are found in Turkey and called White Karaman. They are valuable primarily for meat and also for their wool and milk. The wool produced is coarse and usually used for carpet weaving (Tavakkolian, 1999). Today, there are about 2,700,000 heads of Makooei sheep in west-Azerbaijan and due to the large population of this breed there is an increasing interest in the genetic improvement of this breed. In order to design effective selection programs to increase the efficiency of sheep production, knowledge of genetic parameters for economically important traits are needed. For this reason, information about growth traits, body measurements, and fleece traits has been recorded and stored at Makooei Sheep Breeding Station which provides an opportunity to evaluate productive performance of the breed, estimation of genetic parameters and development of an appropriate selection index for this breed.

In sheep breeding, it is well known that type traits have an important influence on sheep performance. Measures of size and body form are desired in many experiments with sheep, including studies of growth, inheritance and nutrition (Duguma et al., 2002; Fourie et al., 2002; Janssens and Vandepitte, 2004; Kunene et al., 2007; Mandal et al., 2008). In meat-producing species, body conformation and growth rate of animals are important selection criteria (Mandal et al., 2008). These measurements, in addition to weight measurements, describe more completely an individual or population than do the conventional methods of weighing and grading (Salako, 2006a) and are of value in predicting live body weight (Mohammed and Amin, 1996) and also in judging the quantitative characteristics of meat (Bose and Basu, 1984).

In young rams scrotal circumference is an indicator of reproductive potential, as it is highly correlated with total sperm production (Hahn et al., 1969) and quality of the produced semen (Bourdon and Brinks, 1986). Testicular

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size is best described in terms of testis weight. However, in the live ram, scrotal circumference (SC) is easily measured and is a reliable indicator of testes weight (Notter et al., 1981). It has been shown that scrotal circumference is highly repeatable (Hahn et al., 1969) and moderately to highly heritable (Matos et al., 1992; Fogarty, 1995; Al-shorpy and Notter, 1996; Duguma et al., 2002). The favorable relationship between testicular size of rams and relative fertility of females has been widely documented (Al-shorpy and Notter, 1996; Duguma et al., 2002). Nevertheless, the use of testicular size as a direct selection criterion for improvement of male fertility, and as an indirect selection criterion for improvement of female reproduction, is dependent to a large extent on how much testicular size is heritable.

The genetic improvement in a trait depends upon its additive genetic variation and its genetic correlation with other traits. Currently, the generally accepted strategy is to estimate necessary (co)variance using an animal model incorporating REML procedure and use these estimates for BLUP of breeding values. For Makooei sheep, the genetic information on body weight, body measurements and testicular size is scarce. The aim of this study, therefore, was to estimate genetic parameters for yearling weight, body length, heart girth, height at withers, height at back and scrotal circumference for an experimental flock of Iranian Makooei sheep. The relationships between traits were also studied.

## MATERIALS AND METHODS

### Data

Data were collected from 1995 to 2005 at the Makooei Sheep Breeding Station at Makoo (36°, 35′S and 48°, 22′E) in west-Azerbaijan province. In general, the flock is managed under a semi-migratory system. Ewes are raised in an annual breeding cycle starting in August. Young ewes are mated so as to lamb for the first time at approximately 1.5 years of age. There is one breeding season in August-October. Ewes in heat are exposed to pre-defined rams at morning. Lambing commences in mid-January and continues until April. Ewes are supplemented, depending upon the ewes’ requirements, for a few days after lambing. All lambs are identified at birth and birth weights, as well as sex, birth type and pedigree information are recorded. During the suckling period, lambs are fed with their mothers’ milk and also allowed dry alfalfa after 3 weeks of age. Lambs are weaned at approximately 100 days of age. Animals are kept on natural pasture during spring, summer and autumn seasons. Range conditions are poor during the winter months and, therefore, animals are kept indoors during the winter.

### Studied traits

The traits measured were yearling weight (YW) and five body dimensions measured at a year of age: body length (BL), heart girth (HG), height at withers (HW), height at back (HB) and scrotal circumference (SC). BL was considered as the distance between the point of the shoulder and pinbone, HG was measured behind the shoulder, HW was measured as the distance from the floor to between the shoulders, HB was taken on a flat surface and was the distance between the floor to the back of the animal, and SC was measured at the widest point of the scrotum.

### Statistical analyses

Preliminary yearling weight and body measurements were analyzed using the GLM (Generalized Linear Models) procedure of SAS software (2004) to identify non-genetic factors to be included in the final model. The fixed model for YW, BL, HG, HW and HB included effects for year of lambing (excluding 2000 for which no performance data were available on body measurements), month of lambing (January, February, March and April), sex (male and female), birth type (single and twin) and age of dam at lambing (2-7 years old). For SC, the effect of sex was excluded from the model. In addition, in order to account for the differences among animals with different ages, age was used as an auxiliary variable; i.e., the data were applied without age adjustment. For HW and HG, all the factors were significant ($p<0.05$), but for YW, BL, HB and SC age of dam was not significant ($p>0.05$) and was excluded from the final model. Preliminary analyses (not shown) carried out on our data showed that the influence of maternal effects was negligible and non-significant ($p>0.05$) for all variables. As a consequence, maternal effects were not included in the fitted model. A six-trait animal model combined with REML procedure, which allowed for unequal design matrices and missing observations, was used to estimate (co)variance components, heritability coefficients and correlations among the six traits simultaneously. DXMUX program of DFREML software package (Meyer, 2000) was used to analyze the data. The following model was fitted to the data:

$$y = X\beta+Za+e$$

where y is a vector of observations, β is a vector of fixed effects, a is a vector of random animal effects, e is a vector of random residual effects and X and Z are incidence matrices relating observations to fixed and random animal effects, respectively. It is assumed that additive genetic effects and residual effects are normally distributed with mean 0 and variance $A\sigma_a^2$ and $I_e\sigma_e^2$, respectively, where A is the additive numerator relationship matrix obtained from the pedigree structure, $I_e$ is an identity matrix with orders of

**Table 1.** Information on the datasets used in analyses

| Item | Trait[a] | | | | | |
|---|---|---|---|---|---|---|
| | YW | BL | HG | HW | HB | SC |
| No. of records | 617 | 1,000 | 997 | 1,001 | 999 | 530 |
| No. of sire | 61 | 67 | 66 | 66 | 66 | 64 |
| No. of dam | 405 | 531 | 530 | 536 | 530 | 374 |
| Phenotypic range | 20-52.70 | 37-64 | 61-99 | 49-78 | 50-76 | 10-20 |
| Mean[b] | 33.33 | 50.52 | 81.98 | 63.32 | 64.78 | 14.92 |
| SD | 6.24 | 4.18 | 6.09 | 4.32 | 4.51 | 1.19 |
| $CV_P$ (%) | 11.59 | 5.94 | 5.91 | 4.75 | 4.69 | 9.70 |

[a] YW = Body weight at a year of age; BL = Body length; HG = Heart girth; HW = Height at withers; HB = Height at back; SC = Scrotal circumference.

[b] YW in kg; BL, HG, HW, HB and SC in cm.

**Table 2.** Variance components and heritability estimates[a] for traits studied[b]

| Trait | YW | BL | HG | HW | HB | SC |
|---|---|---|---|---|---|---|
| $\sigma_a^2$ | 3.228 | 1.010 | 4.881 | 1.527 | 1.537 | 0.676 |
| $\sigma_e^2$ | 11.623 | 8.000 | 18.526 | 7.491 | 7.710 | 1.419 |
| $\sigma_p^2$ | 14.951 | 9.010 | 23.407 | 9.018 | 9.247 | 2.095 |
| $h^2$ | 0.22±0.08 | 0.11±0.06 | 0.21±0.07 | 0.17±0.06 | 0.17±0.06 | 0.32±0.10 |

[a] $\sigma_a^2$ = Direct additive genetic variance; $\sigma_e^2$ = Residual variance; $\sigma_p^2$ = Phenotypic variance; $h^2$ = Heritability.

[b] YW = Body weight at a year of age; BL = Body length; HG = Heart girth; HW = Height at withers; HB = Height at back; SC = Scrotal circumference.

N (number of records) and $\sigma_a^2$ and $\sigma_e^2$ are additive genetic variance and residual variance, respectively.

## RESULTS

Means, standard deviations, phenotypic range and phenotypic coefficient of variation for traits studied are summarized in Table 1. According to estimated values of phenotypic coefficients of variation ($CV_P$), YW and HW were the most and least variable traits and, among body measurements, SC exhibited highest $CV_P$ (9.70%).

Table 2 gives the estimates of variance components and heritability coefficients for traits studied. Estimates of heritability ranged from 0.11±0.06 (BL) to 0.32±0.10 (SC).

Different components of the correlation between traits studied are shown in Table 3. Genetic correlations between traits studied were low to high. The maximum genetic correlation was between HW and HB as 0.99±0.01 and the minimum genetic correlation was observed between YW and HB as 0.15±0.07. Phenotypic correlations were also positive and ranged from moderate (0.32, HW/SC) to high (0.94, HW/HB).

## DISCUSSION

Tavakkolian (1999) provided information about body weight and body measurements in Makooei sheep. His estimates of YW, BL, HW and HB were 31.30 kg, 48.38 cm, 59.55 cm and 59.82 cm, respectively. Apparently, these estimates in all cases are lower than our findings. This is probably caused by significant influences of husbandry system on certain body measurements. For this reason, single linear measurements are relevant for on-farm within herd use. Body weight was the most variable trait. The reason of greater $CV_P$ for YW was probably due to more variation and effect of outside environment on this trait. Similar to our findings, Janssen and Vandepitte (2004) found greater $CV_P$ for body weight compared to body measurements in three breeds of Belgian sheep: Blue du Main, Suffolk and Texel. Larger variation within certain measurements suggests absence of selection, or the parts respond more to environment than others (Salako, 2006b).

The estimated value of heritability for YW (0.22) was lower than those reported by Snyman et al. (1995) in Afrino breed (0.58), by Bathaei and Leroy (1998) in Mehraban breed (0.44) and by Gizaw et al. (2007) in Menz breed (0.56). On the other hand, our estimate is higher than those observed by Bahreini-Behzadi et al. (2007) in Kermani breed (0.14) and by Miraei-Ashtiani et al. (2007) in Sangsari breed (0.10). In general, due to increase in expression of genes with direct additive effects on body weight and also a gradual decrease in maternal effects with age, higher estimates of heritability are expected for body weights measured later in life.

The heritability estimates for BL, HG and HW were 0.11, 0.21 and 0.17, respectively, which are lower than those reported by Janssen and Vandepitte (2004) for three

**Table 3.** Correlations[a] between traits studied[b]

| Trait 1 | Trait 2 | $r_a$ | $r_e$ | $r_p$ |
|---|---|---|---|---|
| YW | BL | 0.39±0.18 | 0.54±0.05 | 0.53 |
| YW | HG | 0.74±0.15 | 0.58±0.05 | 0.61 |
| YW | HW | 0.17±0.07 | 0.59±0.05 | 0.50 |
| YW | HB | 0.15±0.07 | 0.63±0.05 | 0.53 |
| YW | SC | 0.30±0.14 | 0.53±0.09 | 0.46 |
| BL | HG | 0.82±0.18 | 0.36±0.04 | 0.43 |
| BL | HW | 0.20±0.10 | 0.55±0.04 | 0.50 |
| BL | HB | 0.24±0.09 | 0.58±0.04 | 0.53 |
| BL | SC | 0.68±0.21 | 0.36±0.06 | 0.41 |
| HG | HW | 0.50±0.20 | 0.37±0.05 | 0.40 |
| HG | HB | 0.51±0.20 | 0.40±0.05 | 0.42 |
| HG | SC | 0.63±0.18 | 0.26±0.07 | 0.35 |
| HW | HB | 0.99±0.01 | 0.93±0.01 | 0.94 |
| HW | SC | 0.56±0.21 | 0.26±0.07 | 0.32 |
| HB | SC | 0.58±0.20 | 0.30±0.07 | 0.36 |

[a] $r_a$, = Genetic correlation; $r_e$, = Residual correlation; $r_p$ = Phenotypic correlation.

[b] YW = Body weight at a year of age; BL = Body length; HG = Heart girth; HW = Height at withers; HB = Height at back; SC = Scrotal circumference.

breeds of adult Belgian sheep. Their estimates of heritability for BL, HG and HW were 0.30, 0.45 and 0.43 in Blue du Main, 0.35, 0.39 and 0.57 in Suffolk, and 0.28, 0.40 and 0.40 in Texel. In Germany, Horstick (2001) who worked on adult East Friesian and Black-Brown milk-sheep, found heritability estimates of 0.72, 0.70 and 0.56 for BL, HG and HW, respectively. In contrast, Mandal et al. (2008) studied body measurements at birth and weaning in Muzaffarnagari sheep and reported heritability estimates for BL, HG and HW of 0.14, 0.14 and 0.07 at birth and of 0.12, 0.16 and 0.15 at weaning, respectively. For HB, estimated value of heritability was 0.17. The general paucity of literature on the subject of estimates of heritability for HB makes comparison difficult. In general, our results show that selecting for improved body measurements in Makooei sheep would generate a relatively slow genetic progress because these traits are of relatively low heritability. In addition, the low heritability estimates imply that selection should be based on EBVs obtained by BLUP (Janssen and Vandepitte, 2004).

The heritability of scrotal circumference was relatively high (0.32). In Finnsheep, Fogarty et al. (1980) found heritability for SC at 140 days of age as 0.14. In a composite breed of sheep, Al-shorpy and Notter (1996) found heritability of SC at 60, 90 and 120 days of age as 0.15, 0.25 and 0.10, respectively. In addition, Duguma et al. (2002) who worked on South African Merino rams, reported heritability of 0.40 for SC at 16 months of age. Fogarty (1995) summarised $h^2$ estimates for SC in sheep which ranged from 0.08 to 0.50 with a mean value of 0.23. From a literature survey, Matos and Tomas (1992) reported that estimates of heritability for various measures of testis size ranged from 0.00 to 0.75. Significant effects of SC on ewe fertility have been studied by Duguma et al. (2002). They tested three categories of SC (24-30 cm, 31-35 cm and 36-40 cm) on ewe fertility and found that ewes served by rams of higher SC had higher fertility. Smith et al. (1989) found that Bulls with larger scrotal circumference can be expected to sire calves with moderate birth weight and above-average growth rates, sons with larger testicles and better milking daughters that reach puberty at an earlier age. All else being equal, SC as a highly heritable trait could be used as an effective selection criterion in order to increase flock fertility and reduce the number of breeding rams required.

Genetic correlations between traits of concern were positive and ranged from low to high (0.15-0.99), which indicated that traits were genetically linked. Heart girth had the highest genetic and phenotypic correlations with body weight (0.74 and 0.61, respectively). From a genetic analysis on Uda sheep, Salako (2006b) reported similar findings. Heart girth is a part of tissue measurements (Blackmore et al., 1958), while other measurements are related to skeletal measurements. It can explain, to some extent, the higher correlation between body weight and hearth girth. SC was positively correlated genetically and phenotypically with other traits and was most highly correlated with BL. In general, the genetic and phenotypic correlations of scrotal circumference with measures of growth reported in the literature are positive (Bourdon and Brinks, 1986; Duguma et al., 2002) which indicates that the chances are fairly small of selecting males with small testes for breeding purposes, when measures of growth are considered in the selection program. However, our estimate of genetic correlation between SC and YW (0.30) is lower than that reported by Duguma et al. (2002) for Merino rams as 0.70. On the other hand, Bourdon and Brinks (1986) reported a value of 0.39 for genetic correlation between YW and SC in Hereford bulls which is close to our findings. The low genetic correlation between scrotal circumference and body weight indicates that genes contributed in body weight have less influence on reproductive ability in young rams.

## CONCLUSIONS

Estimates of heritability indicated that improvement in body measurements and body weight of Makooei sheep is possible through selection procedures. The positive correlation between body weight and body measurements indicates that these traits share a genetic component; therefore, selection for body measurements could possibly lead to improve in body weight and vice versa. It may also lead to an increase in scrotal circumference, which might lead to improved fertility of the population and, consequently, reduce the number of breeding rams required.

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