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Phenotypic and Genetic Analysis of Lori-Bakhtiari Lamb's Weight at Different Ages for Autosomal and Sex-Linked Genetic Effects

Research Article

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ABSTRACT

The data set used in this study contained 8793 records of lamb's weight (kg) from 320 sires and 2349 dams collected during 1989 to 2014 from the Lori-Bakhtiari flock at Shooli station in Shahrekord, Iran. Non-genetic factors and genetic parameters (partitioned into autosomal, sex-linked and maternal) of lamb's weight at different ages were estimated using without and with sex-linked genetic effects models. The results showed that the overall mean of lamb's weight were 5.01, 28.93, 41.42, 51.33 and 56.52 kg at birth, weaning, 6, 9 and 12 months of age, respectively. The effect of fixed factors; year and month of birth, age of dam, sex of lamb, type of birth; dam body weight and age of lamb (days) as linear covariate were significant (P<0.01 or 0.05) on lamb's weight at different ages. The heritability estimates of lamb's weight obtained by most favorable model (without and with sex-linked genetic effects for pre and post-weaning weight, respectively) were low to medium and ranged from 0.08 to 0.22 for autosomal, 0.01 to 0.14 for sex-linked and 0.04 to 0.20 for maternal additive genetic effects. The estimates of autosomal, sex-linked and maternal genetic correlations of lamb's weight at different ages were medium to high. In conclusion, lamb's weight at different ages can be improved by farm management practices and improving environmental factors. Genetic analysis using linear models which able to estimate breeding values in autosomal, sex-linked and maternal separately, could make a more effective genetic selection to improve growth traits in lambs.

KEY WORDS autosomal and sex-linked, Lori-Bakhtiari lambs, non-genetic factor, weight.

INTRODUCTION

Genetic and environmental improvements offer an opportunity to increase production from existing animal resources. The genetic characterization of local breeds is of paramount importance, not only for conservation purposes but also for the definition of breeding objectives and breeding schemes. Any genetic improvement programs applied for livestock are conducted on the basis of a selection and mating system (Ceyhan *et al.* 2011). Development of effective genetic evaluation and selection requires knowledge of the genetic parameters for economically important production traits. Growth potential of the lambs is one of the most important traits in a genetic improvement scheme for meat sheep. A number of non-genetic and genetic factors affect the growth traits. Non-genetic factors should be determined to ensure proper adjustment of such effects in order to obtain reliable estimates of breeding values for these traits. Reliable breeding values are needed to increase accuracy of selection of breeding animals. Up to now, the genetic evaluation of growth traits in sheep breeding programs has been carried out using animal models with autosomal inheritance, included non-genetic factors, and direct genetic and maternal (genetic and common environment) effects.

The weighted means of heritability reviewed from estimates published for growth traits were generally moderate in magnitude and ranged from 0.15 to 0.41 (Safari *et al*. 2005). In this review, the maternal heritability for live weight were shown to decline with increasing age, and ranged from 0.04 to 0.24. In another study the heritability estimates of growth traits in different breeds of sheep were reported as moderate to high ranging from 0.22 to 0.65 (Lalit *et al*. 2016).

There is evidence that sex-linked inheritance may make a contribution that should not be ignored in evaluating individuals genetically for economically important traits (Fernando and Grossman, 1990). Van Raden (1987) suggested about 5% of genetic variation for milk and fat production in Holstein cattle is located on the X-chromosome. A study on beef calves showed that Y-chromosome accounted for 2% and 6% of the total phenotypic variance for weight at birth and weaning, respectively (Fina *et al*. 2012). Vatankhah *et al*. (2016) reported that the estimates of heritability sex linked effects on lamb's survival rate were equal to maternal heritability (0.01 to 0.02) in Lori-Bakhtiari sheep.

The Lori-Bakhtiari sheep is one of the most common native breeds in the southwestern part of Iran (the Zagros mountains), with a population of more than 1.7 million head, having the fattest tail among all of the breeds in Iran. The animals of this breed are usually kept in villages under semi intensive systems.

The Ministry of Jihad-Agriculture in Iran has found it important to increase the efficiency of sheep production. An effective breeding plan can only be devised after thorough knowledge has been obtained about the inheritance of economically important traits. The question in this study is that what is the contribution of sex-chromosome in genetic variance for growth traits in Lori-Bakhtiari lambs? To determine optimal breeding strategies to increase the efficiency of sheep production, knowledge of genetic parameters for weight traits at various ages in the presence of autosomal and sex-linked additive inheritance is needed. Thus, the objective of this study was to determine systematic environmental effects affecting lamb weight and to estimate the genetic parameters for lamb's weight up to yearling age in Lori-Bakhtiari sheep for autosomal, sex-linked and maternal additive genetic effects.

MATERIALS AND METHODS

Data and flock management

The data set used in this study was collected from 8793 lambs descending from 320 rams and 2349 ewes and born between 1989 and 2014 in the Shooli station, Shahrekord, Iran (Table 1).

The flock is managed under a semi-migratory or village system. The animals were kept in the pastureland and cereal meadow from mid-spring to late-autumn and kept indoors from December to May at the station and fed a ration composed of alfalfa, barley and wheat straw. The breeding period extends from late August to late October (ewes were assigned randomly to the rams) and consequently, lambing starts in late January.

From 15 days of age, lambs have access to creep feed *ad libitum* and were weaned at an average age of 90 ± 5 days. After weaning, male and female lambs were separated. Surplus male lambs chosen for fattening were separated from the rest of the animals. Female lambs were kept in the pasture of cultivated alfalfa, while the rest of the males were kept indoors and fed a maintenance and growth ration (45% alfalfa hay, 39% barley, 7% beet pulp, 8% cottonseed meal, 1% salt and mineral supplements) to 12 months of age.

The lambs were classified in different groups based on date of birth and were weighted at birth before initiating suckling mother's milk, at weaning (3 months), at 6, 9, and 12 months of age. Traits studied were weight of lambs in kg at birth, weaning, 6, 9, and 12 months of age.

Statistical analysis

The GLM procedure of SAS (2000) was applied to identify the important non-genetic factors to be considered in the final linear model. The final statistical model included classified factors: year and month of birth, age of dam, birth type and sex of lamb as fitted fixed effects and continuous variables: age of lambs in days and the mother body weight of each lamb fitted as covariates in the following model.

$$y_{ijklmn}= \mu + B_i + M_j + A_k + T_l + S_m + b_1(EW_{ijklmn}-EW_{000000}) + b_2(LA_{ijklmn}-LA_{000000}) + e_{ijklmn}$$

Where:

y_{ijklmn}: observed weight in kg of n^{th} lamb.
μ: overall mean.
B_i: effect of i^{th} birth year (i=1989 to 2014).
M_j: effect of j^{th} month of birth (j=Jan, Feb or Mar).
A_k: effect of k^{th} age of dam (k=2,…,≥7).
T_l: effect of l^{th} type of birth (l=single, twin or triplet).
S_m: effect of m^{th} sex of lamb (m=male or female).
EW_{ijklmn}: mother's body weight of n^{th} lamb.
EW_{000000}: overall mean of mother's body weight.
LA_{ijklmn}: age of *n*th lamb in days.
LA_{000000}: overall mean of lamb age in days.
b_1: linear regression coefficient of mother's body weight.
b_2: linear regression coefficient of lamb age in days.
e_{ijklmn}: residual effects.

Table 1 Pedigree structure for weight analysis data set in Lori-Bakhtiari lambs

Item	Number	Item	Number
Original animals	9310	Sires with progeny	320
Animals with record	8793	Sires with record and progeny	246
Animals without offspring	6501	Dams with progeny	2349
Animals with offspring	2669	Dams with record and progeny	2046
Animals with offspring and record	2292	Founders	455
Animals with unknown sire	567	Inbred animals	4153
Animals with unknown dam	466	Average inbreeding coefficient in inbred animals	0.025

Variance components and genetic parameters were estimated from using the Wombat (Meyer, 2013) by fitting two single-trait animal models (with and without genetic sex-linked effects). The animal model included all fixed effects described above, random effects of animal (separated to autosomal and sex-linked), random maternal effects and residual effects. The following animal modelswere fitted to analyze the data set:

$\mathbf{y= Xb + Z_1a + Z_2m + e}$ M1

$\mathbf{y= Xb + Z_1a + Z_1s + Z_2m + e}$ M2

Where:

y, **b**, **a**, **s**, **m** and **e**: vectors of observations, fixed effects, direct additive genetic effects in autosomal chromosomes, direct additive genetic effects in sex-linked, maternal additive genetic effects and residual random effects, respectively.

X, $\mathbf{Z_1}$ and $\mathbf{Z_2}$: incidence matrices relating the observations to the respective effects.

The average information (AI) REML algorithm was used to maximize the likelihood (convergence criterion was 10^{-8}) and additional restarts were performed until no further improvement in log likelihood occurred. With one record for each individual, the BLUP breeding values of lamb's weight at different ages for autosomal effects ($\hat{\mathbf{a}}$), sex-linked effects ($\hat{\mathbf{s}}$) and maternal effects ($\hat{\mathbf{m}}$) are obtained using mixed model equations as follow:

$$\begin{bmatrix} \mathbf{X'X} & \mathbf{X'Z_1} & \mathbf{X'Z_1} & \mathbf{X'Z_2} \\ \mathbf{Z_1'X} & \mathbf{Z_1'Z_1} + \mathbf{A}^{-1}\frac{\sigma_e^2}{\sigma_a^2} & \mathbf{Z_1'Z_1} & \mathbf{Z_1'Z_2} \\ \mathbf{Z_1'X} & \mathbf{Z_1'Z_1} & \mathbf{Z_1'Z_1} + \mathbf{S}^{-1}\frac{\sigma_e^2}{\sigma_F^2} & \mathbf{Z_1'Z_2} \\ \mathbf{Z_2'X} & \mathbf{Z_2'Z_1} & \mathbf{Z_2'Z_1} & \mathbf{Z_2'Z_2} + \mathbf{A}^{-1}\frac{\sigma_e^2}{\sigma_m^2} \end{bmatrix} \begin{bmatrix} \mathbf{b} \\ \mathbf{a} \\ \mathbf{s} \\ \mathbf{m} \end{bmatrix} = \begin{bmatrix} \mathbf{X'y} \\ \mathbf{Z_1'y} \\ \mathbf{Z_1'y} \\ \mathbf{Z_2'y} \end{bmatrix}$$

The covariance matrix of $\hat{\mathbf{a}}$ is $\mathbf{A}\sigma_a^2$; **A**, is the matrix of the co-ancestries between relative for autosomal loci (Henderson, 1976) and σ_a^2 , is the variance of additive genetic values for autosomal loci. The covariance matrix of $\hat{\mathbf{s}}$ is $\mathbf{S}\sigma_F^2$; **S**, is a matrix whose elements are functions of co-ancestries between relative for X-chromosomal loci and σ_F^2 , is the additive genetic variance for X-chromosomal loci for noninbred females (Fernando and Grossman, 1990). The covariance matrix of $\hat{\mathbf{m}}$ is $\mathbf{A}\sigma_m^2$; **A**, is the matrix of the co-ancestries between relative and σ_m^2 , is the variance of maternal additive genetic values.

The inverse of A obtained by an algorithm described by Henderson (1976). The construction of **S** and its inverse obtained by an algorithm described by Fernando and Grossman (1990). Models were compared using the likelihood ratio test (LRT) to find the best model for each trait, which, defined as:

LRT= 2 × Log L(M_2-M_1)

Where:

Log L: log likelihood obtained for each model.

Genetic (autosomal, sex-linked and maternal) and phenotypic correlations were estimated using five-trait analysis models (with and without genetic sex-linked effects) as follows. The fixed effects included in the five-trait animalmodels were those in single-trait analyses.

$\mathbf{y_i= X_ib_i + Z_{1i}a_i + Z_{1i}s_i + Z_{2i}m_i + e_i}$

Where:

i: number of traits (i=weight of lambs at birth, weaning, 6, 9 and 12 months of age).

RESULTS AND DISCUSSION

The frequency of lambs from birth up to 12 months of age observed in this study is shown in Table 2. The number of lambs decreased from birth to yearling age due to involuntary culling (such as mortality due to disease and disorder, low milk of mother, etc.), voluntary culling (such as culling policy, male and female surplus, experimental slaughter, etc.). Table 2 show that 8793 lambs were weighed at birth and 3424 lambs (38.94%) remained in the flock up to yearling age. The values in Table 2 indicated that the number of male lambs higher than female lambs at birth (sex ratio 50.70:49.93), but culling rate in male was higher than female lambs and from the number of 3424 lambs at yearling age the number 1169 and 2255 lambs were male and female, respectively.

Table 2 The frequency of lambs from birth to 12 months of age

Weight at	Total		Cumulating culling		Male		Female	
	No.	%	No.	%	No.	%	No.	%
Birth	8793	100	0	0.00	4403	50.70	4390	49.93
Weaning	8255	93.88	538	6.12	4117	49.87	4138	50.13
6 months	6328	71.97	2465	28.03	3090	48.83	3238	51.17
9 months	3800	43.22	4993	56.78	1368	36.00	2432	64.00
12 months	3424	38.94	5369	61.06	1169	34.14	2255	65.86

In the other words, by increasing the age of lambs from birth to yearling, the reduction rate in male lambs were higher than female lambs and sex ratio at yearling reached to 34.14:65.86.

The least squares means of lamb's weight at birth up to yearling for different levels of fixed effects are shown in Table 3. The overall mean of lamb's weight at birth (5.01 kg) to 12 months of age (56.52 kg) showed that this breed is of large size and lambs could achieved more than 50 percent of yearling weight by to weaning age (90 days of age). There were significant (P<0.01) variation in lamb's weight at all ages between different birth years, but the least squares means of various birth years omitted in Table 3, because no clear trend were observed during 1989 to 2014. The month of birth had a significant effect (P<0.01) on lamb's weight at all ages except weight at 6 months of age. The least squares mean of lamb's weight increased with increasing month of birth significantly at birth and weaning and non significantly at 6 month of age, and then decreased at 9 and 12 months of age significantly. However, the differences between lamb's weight values at birth and weaning age were not significant for the second and third of the lambing months, but the differences in lamb's weight at 9 and 12 months of age increased and were significant for all of the lambing periods. The least squares means of lamb's weight at all ages were significantly lower in lambs born from the younger (2 years) and older (7 years) ewes compared to 4-5 years old (P<0.05 or 0.01), but the differences in lambs born from 3 and 6 years old ewes were not significant different from 4-5 years old (P>0.05). The birth type had significant effect on weight of lambs from birth to yearling (P>0.01). The lambs born as singles had the highest weight at all considered ages in comparing to twins and triplets, and twins lambs also had higher weight at all ages compared with triplets. Male lambs were found to have a higher weight than females at all considered ages. The differences between weight in males and females were significant at all ages (P<0.01). The model showed that the linear relationship between ewe body weight and lamb's weight at all ages was significant (Table 3). All regression coefficients were significant from zero (P<0.01) and the positive sign of them indicated that the weight of lambs increased by the weight of ewe.

On the other words, by increasing one kg in weight of dams, the weight of lambs increased by 0.02 kg at birth to 0.22 kg at yearling age. Also, the model showed that the linear relationship between age of lambs (days) with lamb's weight at all ages was significant (Table 3).

The regression coefficients of weight of lambs from age of lambs were significant from zero (P<0.01) and the positive sign of them showed by increasing one day in age of lambs, the weight of them increased by 0.20 kg in weaning weight up to 0.08 kg in yearling weight. The coefficient of variation (CV %) of weight increased from birth to weaning, then decreased with age of lambs for post weaning weights.

Heritability estimates of lamb's weight at different ages obtained from models without (M_1) and with (M_2) sex-linked effects are shown in Table 4. The direct heritability (h^2) estimates by M_1 model ranged from 0.08 for weaning weight to 0.23 for yearling weight and corresponding values estimated by M_2 model with sex-linked effects were 0.08 and 0.22, respectively.

The maternal heritability (m^2) estimates derived for each trait by two models are the same and decreased by increasing age of lambs (0.20 for birth weight to 0.04 for yearling weight). The proportion of sex-linked additive genetic variance to phenotypic variance (s^2) could be named sex-linked heritability derived by M_2 were 0.01 for birth weight, increased to 0.14 for weight at 6 months of age and then decreased to 0.04 for yearling weight of lambs.

The results of residual variance (e^2) derived from two models showed that the values estimated by M_1 were higher than values derived by M_2. In the other words, lower estimates of residual variance for each trait resulted by M_2 in comparing by corresponding values resulted by M_1 indicated that M_2 fitted better than M_1 for lamb's weight traits. Although, the lower estimates of residual variance and also the higher values of Log L in M_2 compared with M_1, showed that the M_2 with sex-linked effects is better than M_1, but the likelihood ratio test (LRT) in the last column of Table 4 indicated that there is not any significant difference between M_1 and M_2 for birth and weaning weight, but the significant values of LRT for lamb's weight after weaning showed that M_2 fitted better than M_1 for weight of lambs at 6, 9 and 12 months of age.

Table 3 The least squares means of lamb's weight at various ages for different levels of fixed effects

Weight (kg) at	Birth	Weaning	6 months	9 months	12 months
Overall mean	5.01±0.00	28.93±0.06	41.42±0.11	51.33±0.16	56.52±0.18
Year of birth	**[1]	**	**	**	**
Month of birth	**	**	NS	**	**
January	4.34±0.02[b]	25.54±0.17[b]	37.88±0.27[a]	50.73±0.34[a]	57.07±0.36[a]
February	4.42±0.02[a]	26.33±0.17[a]	37.90±0.28[a]	49.73±0.36[b]	56.46±0.38[b]
March	4.44±0.03[a]	27.12±0.22[a]	38.13±0.38[a]	48.59±0.51[c]	55.36±0.52[c]
Age of dam (yr)	**	**	**	*[1]	*
2	4.10±0.02[c]	25.78±0.19[c]	37.77±0.31[c]	49.83±0.40[a]	56.59±0.40[a]
3	4.42±0.02[b]	26.74±0.19[ab]	38.61±0.30[a]	50.13±0.39[a]	56.74±0.40[a]
4	4.45±0.02[a]	26.75±0.19[a]	38.36±0.31[b]	49.84±0.40[a]	56.54±0.41[a]
5	4.47±0.03[a]	26.58±0.20[ab]	38.01±0.32[ba]	49.80±0.41[a]	56.31±0.42[a]
6	4.44±0.03[ab]	26.44±0.21[b]	38.04±0.34[bc]	49.74±0.43[a]	56.42±0.45[a]
7	4.45±0.03[ab]	25.67±0.24[c]	37.03±0.38[d]	48.78±0.51[b]	55.20±0.54[b]
Type of birth	**	**	**	**	**
Single	5.34±0.01[a]	30.92±0.07[a]	42.72±0.12[a]	53.65±0.17[a]	59.63±0.17[a]
Twin	4.30±0.01[b]	24.96±0.10[b]	37.57±0.17[b]	49.63±0.24[b]	56.22±0.24[b]
Triplet	3.56±0.06[c]	23.10±0.46[c]	33.62±0.76[c]	45.77±0.98[c]	53.06±1.02[c]
Sex of lamb	**	**	**	**	**
Male	4.56±0.02[a]	28.06±0.17[a]	43.60±0.28[a]	57.04±0.37[a]	65.49±0.38[a]
Female	4.24±0.02[b]	24.60±0.17[b]	32.34±0.28[b]	42.33±0.36[b]	47.11±0.38[b]
LREBW	0.02±0.00**	0.13±0.01**	0.18±0.01**	0.19±0.02**	0.22±0.02**
LRLA	-	0.20±0.01**	0.18±0.01**	0.09±0.02**	0.08±0.02**
R^2	0.48	0.50	0.61	0.69	0.75
CV (%)	11.56	14.09	13.62	10.57	9.67

LREBW: linear regression of ewe body weight and LRLA: Linear regression of lamb age (day).
The means within the same column with at least one common letter, do not have significant difference (P>0.05).
* (P<0.05) and ** (P<0.01).
NS: non significant.
CV: coefficient of variation.

Table 4 Heritability estimates of weight in Lori-Bakhtiari lambs obtained from different models

Age	Model	$h^2 \pm$ SE	$m^2 \pm$ SE	$s^2 \pm$ SE	$e^2 \pm$ SE	Log L	LRT
Birth	M_1	0.22±0.02	0.20±0.01	-	0.58±0.02	547.86	0.12[ns]
	M_2	0.22±0.03	0.20±0.01	0.01±0.01	0.57±0.02	547.92	
Weaning	M_1	0.08±0.02	0.16±0.01	-	0.76±0.02	-15590.00	0.20[ns]
	M_2	0.08±0.02	0.16±0.01	0.01±0.01	0.75±0.02	-15589.90	
6 months	M_1	0.18±0.02	0.04±0.01	-	0.78±0.02	-14061.08	67.84**
	M_2	0.16±0.02	0.04±0.01	0.14±0.02	0.66±0.03	-14027.16	
9 months	M_1	0.22±0.03	0.04±0.01	-	0.74±0.03	-8291.23	12.14**
	M_2	0.22±0.03	0.04±0.01	0.09±0.02	0.65±0.03	-8285.16	
12 months	M_1	0.23±0.03	0.04±0.01	-	0.73±0.03	-7495.36	4.36*
	M_2	0.22±0.03	0.04±0.01	0.04±0.02	0.70±0.03	-7493.18	

LRT= 2 × Log L(M_2-M_1)
* (P<0.05) and ** (P<0.01).
NS: non significant.

The results for estimates of genetic and phenotypic correlations between weights at different ages of lambs derived from M_2 only are shown in Table 5, because the LRT in five-trait analysis using M_1 (without sex-link genetic effects) and M_2 (with sex-link genetic effects) showed that M2 was better fit to data than M_1. The direct autosomal genetic correlations (below diagonal) between lamb's weights at different ages were positive and ranged from 0.33 (at birth and 12 months of age) to 0.96 (at 6 and 9 months of age). Also, the direct sex-link genetic correlations (above diagonal) between lamb's weights at different ages were positive and ranged from 0.01 (at birth and 12 months of age) to 0.96 (at 9 and 12 months of age).

The estimates of maternal genetic correlations between weights of lambs at different ages were positive and changed from 0.30 (at birth and 12 months of age) to 0.99 (at weaning and 9 months of age). The estimates of phenotypic correlations between lamb's weights at different ages were positive (ranged 0.25 to 0.85), but lower than corresponding values for genetic correlations relatively. All genetic correlations between weights of lambs at time periods close to each other were high and reduced with increasing distance between them.

Birth weight is the earliest available growth trait and lambs with higher birth weights are expected to grow faster in life.

In agreement with Vatankhah *et al.* (2005), the overall mean of birth weight obtained in this study (5.01 kg) shows the Lori-Bakhtiari lambs is one of the largest size breed at birth compared to other Iranian breeds of sheep. Reason of high birth weight could be attributed to the low twining rate in this breed compared to more prolific sheep breeds. Weaning weight is highly correlated with the mothering ability (milk yield and maternal instinct to care) of the ewe as the lamb meets most of its requirement through suckling and therefore the differences in weaning weight are essentially the reflections of mothering ability as well as inherent difference in growth (Lalit *et al.* 2016). The age at weaning varies from flock to flock both within and between breeds, but in Lori-Bakhtiari flocks reared in village system; lambs are generally weaned at 3 months of age. The overall mean of weaning weight in Iranian breeds ranged from 19.77 to 27.30 kg with mean value equal to 23.75 kg (Vatankhah *et al.* 2005) and show that this breed is larger than other Iranian breeds for weaning weight. Hence weaning weight reflected both mothering ability and genetic potential for growth rate up to 3 months of age, this trait could use as a selection criteria to improve efficiency in Lori-Bakhtiari sheep, because more than 50% of overall yearling weight in this breed obtained up to weaning age. The economy of sheep rearing mainly depends on weight at 6 months of age as this is the age which the surplus animals are sold for meat purpose and weight at this age indicates the genetic potential in fattening period. The overall mean estimated for weight of lambs at 6 months of age in this study (41.42 kg) showed that more than 73% of yearling weight in Lori-Bakhtiari lambs are obtainable up to 6 months of age and this breed is in the top of list compared to other Iranian breed of sheep (with weighted mean equal to 31.42 kg, Vatankhah *et al.* 2005).

There was very low information available in the literature on weight of lambs at 9 and 12 months of age. The weighted mean value of yearling weight in some Iranian breed estimated as 39.17 (ranged from 24.39 to 49.30 kg), which shows this breed (with an average weight of 56.52 kg) has the highest yearling weight among the other Iranian breeds (Vatankhah *et al.* 2005). Due to this fact that surplus male lambs were fattened and sold up to 6 months of age and that the survival rate of male lambs during birth to 12 months of age was lower than female lambs in this breed (Vatankhah *et al.* 2016), the overall means obtained for lamb's weight at 9 and 12 months of age are under estimated. As the coefficient of variation (CV %) indicated the variation of trait, the values estimated in this study shows the high variation in growth traits, but the observed quadratic trend for CV could be attributed to this fact that after weaning reduced some of variation because the culling rate in male lambs was higher than female lambs.

In general, growth traits are good indicators of adaptability of an animal to the existing environmental conditions and essential for production, reproduction and survivability. Fast growth rate ultimately determines their meat producing capability up to marketing age hence used as a selection criteria. They are largely affected by both genetic and non-genetic factors (Lalit *et al.* 2016) which need to be taken into account in genetic evaluation of potential breeding animals.

One of the aims of the present study was to evaluate the impact of the non-genetic factors on weight of lambs at different ages in Lori-Bakhtiari sheep breed. Our hypothesis is the by understanding and improving growth traits we can improve overall flock productivity. By determining factors influencing on lamb weight it is hoped that these results could serve as a guide for management decisions to improve production. In describing the year and month of birth as factors which are influenced by nutrition, climate, temperature changes, the availability of animals and diseases all have a significant influence on the weight of the lambs at all ages ($P<0.01$ or $P<0.05$, Table 3). The significant effect of year of birth on growth traits supports the results obtained in this study (Mohammadi *et al.* 2010; Simeonov *et al.* 2015; Lalit *et al.* 2016). In these studies reported that differences due to years arise mainly due to varying climatic conditions affecting the availability of pastures to the ewes carrying lambs as well as effect of these factors on the well-being of ewes and lambs. The differences in lamb's weight at different ages between years and months of birth are normal occurrence that is caused by fluctuations in environmental conditions (climate, temperature, pasture, disease) and according to Assan and Mekuza (2005) are difficult to control. The significant effect of age of dam at lambing on growth traits in lambs was observed by Rashidi *et al.* (2008); Mokhtari *et al.* (2008) and Gholizadeh and Ghafouri-Kesbi (2015). The significant effects of age of dam could be attributed to nursing, maternal behavior and maternal ability of dam in different ages. The results obtained in this study shows that to improve efficiency of sheep the younger and older ewes should be supported by complementary feeding.

The significant effect of type of the birth on growth traits results in this study is in accordance with results obtained in other studies (Atkins, 1980; Petrovic *et al.* 2011; Simeonov *et al.* 2015). The reducing weight of lambs at birth and weaning by increasing the number of lambs in each litter could be attributed to the competition for nutrients in the mother's womb before birth and the competition in the amount of mother's milk from birth to weaning (Galal *et al.* 1972). According to Gamasaee *et al.* (2010) during pregnancy, twins and triplets are limited the space available in uterus and receipt of nutrients.

Table 5 Estimates of genetic and phenotypic correlation between weights at different ages in Lori-Bakhtiari lambs derived from five-trait analysis by M_2†

Age	Birth	Weaning	6 months	9 months	12 months
Direct genetic correlation (autosomal below diagonal, sex-link above diagonal)					
Birth	-	0.45±0.08	0.20±0.09	0.06±0.10	0.01±0.10
Weaning	0.56±0.09	-	0.73±0.10	0.69±0.10	0.56±0.10
6 months	0.40±0.08	0.85±0.06	-	0.93±0.03	0.88±0.10
9 months	0.35±0.08	0.84±0.06	0.96±0.02	-	0.96±0.07
12 months	0.33±0.09	0.81±0.07	0.93±0.03	0.94±0.02	-
Maternal genetic correlation below diagonal, phenotypic correlation above diagonal					
Birth	-	0.34 ± 0.01	0.28±0.01	0.26±0.02	0.25±0.02
Weaning	0.33±0.06	-	0.62±0.01	0.56±0.01	0.53±0.01
6 months	0.32±0.07	0.99±0.07	-	0.84±0.01	0.74±0.01
9 months	0.31±0.10	0.99±0.10	0.99±0.05	-	0.85±0.01
12 months	0.30±0.11	0.96±0.10	0.96±0.08	0.98±0.08	-

† LRT= 2 × Log L(M_2-M_1)= 2 × [-39496.53 - (-39560.52)]= 127.98**

This shows that in the womb, singles have more favorable conditions for growth and receive more nutrients than the twins and triplets. Therefore, the type of birth has significant influence on the weight at birth (Petrovic *et al.* 2011) and weaning and consequently weight at 3 to 12 months of ages influenced by weight at birth and weaning. The found significant differences in least squares means between male and female lambs for weight at birth to 12 months of age is in accordance with finding in other breed of sheep (Rashidi *et al.* 2008; Mokhtari *et al.* 2008; Gholizadeh and Ghafouri-Kesbi, 2015; Lalit *et al.* 2016). In all of these studies reported that the heavier weight in male lambs at all ages that tend become larger by increasing age of lambs could be attributed to the physiological development of the fetus in the womb, male and female endocrine system, the presence of the Y-chromosome in males and sex-linked inheritance which is the main objective in this study. Effect of ewe's body weight at lambing on lamb's weight at all ages has been widely studied. Significant effect of ewe's body weight at lambing on lamb's weight in agreement with results obtained in this study has been observed in the other breed of sheep (Lalit *et al.* 2016). Prince *et al.* (2010) reported that heavier dams gave birth to heavier lambs because of better nutrition and more uterine space provided by them for developing fetus. Also, because heavy dams carry genes for high body weight and therefore fast growth. Hussain *et al.* (2014) recommended better farm management and the use of breeding sheep with higher body weight which will improve the weight of the lamb at each age point.

One of the objectives of the present study was to evaluate the impact of sex-link genetic variation on weight of lambs at different ages in Lori-Bakhtiari sheep. Our hypothesis was the by that sex-chromosomes influenced variation of lamb's weight and including it in the model for genetic analysis, may improve the efficiency of genetic selection by predicted breeding values for growth traits more accurately.

Most of the heritability estimates derived by two models were the same for each of considered lamb's weight at different ages. These results indicated that the M_1 model without sex-linked genetic effects didn't account for genetic effects on X-chromosome for lamb's weight, and when this effect entered in the model (M_2), there was not any decrease in the estimates of direct (autosomal) heritability, while the estimates of sex-linked heritability (s^2) for all of considered traits were bigger than zero (0.01 to 0.14). In the other words, the existence sex-linked effects in the model (M_2) without any reduction in direct heritability reduced the residual variance (e^2) by the amount of sex-linked heritability estimated for each trait.

The estimates of direct and maternal heritability for lamb's weight at different ages in this study were in range reported in the literature. In a review from estimates published reported that the weighted means of heritability for growth traits were generally moderate in magnitude and ranged from 0.15 to 0.41 (Safari *et al.* 2005). These researchers in contrast with results obtained in this study reported that the heritabilities for weight at birth and weaning were similar and heritability increased with age to post weaning and adult weights. The higher estimates of direct heritability of birth weight in compared to estimates for weaning weight obtained in this study could be attributed to differences in genetic structure and non-genetic factors affecting on weaning weight. By reviewed137 published estimates in 35 studies using 126857 growth traits records from 13 breeds of Iranian sheep the weighted mean for direct heritability of lamb's weight at birth, weaning, 6 and 12 months of age were 0.16, 0.16, 0.19 and 0.25, respectively. However, the weighted mean for maternal heritability decreased by increasing age of lambs and calculated as 0.13, 0.05, 0.05 and 0.03, respectively (Vatankhah *et al.* 2005).

The curve trend observed for sex-linked derived by M_2in this study (0.01 for birth weight, increased to 0.14 for weight at 6 months of age and then decreased to 0.04 for yearling weight of lambs) could be due to reduced genetic variation of considered traits through removing ram lambs after 6 months of age (Table 2 shows that 64.00% and 65.86% of lambs in data file to estimating variance component and heritability of weight at 9 and 12 months of age are female lambs, respectively). Because surplus male lambs fattened and sold up to 6 months of age firstly and secondly the mortality rate of male lambs during birth to 12 months of age was higher compared to female lambs in this breed (Vatankhah *et al.* 2016). If the number of male and female lambs were the same and culling rate of two sexes was the same expected the sex-linked heritability estimates similar to direct (autosomal) heritability, increased with age of lambs. In review the literature, there was not any report on the heritability of sex-chromosome for growth traitsin sheep. Based on the likelihood ratio test (LRT) in the last column of Table 4 the most appropriate model to genetic analysis of weight of lambs up to weaning and after weaning were M_1 model without sex-linked effects, and M_2 with sex-liked genetic effects, respectively. The different heritability estimates (autosomal, sex-linked and maternal) are useful for construction of selection indices, prediction of genetic response to selection, deciding how much one can rely upon individual's own phenotype for selection and what effects should be in the model to genetic analysis and prediction breeding values. Hence, accurate estimates of different sources of heritability for growth traits are indispensable in sheep breeding programs.

Genetic correlations between two traits may arise from pleiotropic action of genes and linkage. The extent and direction of genetic correlations are needed to evaluate direct and correlated responses and net genetic gain, when simultaneous selection for several traits is practiced. The medium to high autosomal direct and maternal genetic correlations estimated between lamb's weights at different age in this study were in agreement with other reports (Safari *et al.* 2005; Lalit *et al.* 2016). The higher genetic correlations for weights at adjacent age classes and increased with age from birth to yearling, shows that the genes which control weights at adjacent age are the same and increased in later ages. The phenotypic correlations were generally slightly lower than the corresponding genetic correlations. These positive and favorable correlations indicated that selection for increased weight at any age of lambs will also improve weights at other ages. Although, the autosomal direct and maternal genetic correlations between birth weight with other weights at later ages indicates the scope for early selection of lambs for faster improvement in growth, but the low estimates of sex-linked genetic correlation between birth weight and post weaning weight indicated that if selection practiced based on birth weight, the sex-linked genetic correlated response for post weaning weights will be low. However, selection of lambs based on the weight at later ages such as weaning or 6 month ages, improved weights at other ages of lambs through correlated response at all of genetic effects (direct autosomal, sex-linked and maternal).

CONCLUSION

A wide range of variation were observed for weight of lamb's at different ages. As they are largely affected by both genetic and non-genetic factors, it is concluded that in order to improve the growth traits of lambs at different ages primarily should be adjustment non-genetic factors and management conditions. The moderate heritability of growth traits indicated the presence of genetic variability within this breed and there is wide scope for genetic improvement of growth performance in this breed. Break up direct additive genetic variance of lamb's weights in to autosomal and sex chromosomes in this study showed that some of genetic variation of growth traits accounted by the sex-chromosome (sex-linked heritability) and genetic analyzing of lamb's weights using animal models which able to partitioning total additive genetic variation in to direct autosomal, sex-linked and maternal, could make a more effective genetic selection to improve growth traits in lambs.

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