World Applied Sciences Journal 14 (9): 1313-1319, 2011
ISSN 1818-4952

Investigation on Direct and Maternal Effects on Growth Traits and the Kleiber Ratio in Moghani Sheep

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Abstract: The objective of this study was to estimate genetic parameters for growth traits and kleiber ratio in Moghani lambs. Traits included birth weight (BW), weaning weight (WW), 6-month weight (6MW), average daily gain from Birth to Weaning (ADG_{0-3}), average daily gain from Weaning to 6 months of age (ADG_{3-6}), Kleiber ratio from Birth to Weaning (KR_{0-3}) and Kleiber ratio from weaning to 6 months of age (KR_{3-6}). Data were collected by Moghani Sheep Breeding Station at Jafarabad, Iran, during 1995 to 2008. (Co) variance components and genetic parameters were estimated by univariate and multivariate animal models using Restricted Maximum Likelihood (REML) procedure. The log likelihood ratio test (LRT) was carried out to determination the most suitable model for each trait. The effects of year and season of birth, birth type and sex of lamb were significant for each trait ($p<0.01$). The age of dam was significant for BW, WW, ADG_{0-3}, ADG_{3-6}, KR_{0-3} and KR_{3-6} ($p<0.01$). Direct heritability estimates for BW, WW and 6MW, ADG_{0-3}, ADG_{3-6}, KR_{0-3} and KR_{3-6} based on most appropriate models were 0.104±0.03, 0.098±0.01, 0.085±0.02, 0.212±0.04, 0.023±0.04, 0.132±0.04 and 0.014±0.01, respectively. Estimation of maternal heritability varied from 0.017±0.01 for KR_{3-6} to 0.127±0.03 for ADG_{0-3}. Indeed, estimations of fraction of variance due tomaternal permanent environmental effect were 0.099±0.01, 0.046±0.02 and 0.068±.05 for 6MW, ADG_{0-3} and KR_{0-3} respectively. Direct genetic correlations among different traits ranged from -0.70 for BW and ADG_{3-6} to 0.98 for WW and ADG_{0-3}.

Key words: Moghani sheep · Heritability · Genetic correlations · Growth traits · Kleiber ratio

INTRODUCTION

Increasing the level and the efficiency of lamb production is of interest to commercial sheep producers because the percentage of gross receipts from lambs' sale has increased relative to wool production in recent years [1]. Most performance recording programs for sheep have been focused on growth traits because the heritability is relatively high and they are much easier to be measured. In the most of country, genetic improvement in growth traits is major goals in sheep breeding programs. So, estimates of genetic parameters and correlations among growth traits are important to design appropriate breeding programs aimed to maximizing genetic improvement [2], heritability as the most important genetic parameters, indicates whether there is the possibility to obtain genetic gain through its selection or not [3]. Several studies reported the effects of direct and maternal genetic and permanent environmental on lamb growth [4-10], but there were a few studies describing maternal environmental effects in sheep breeds. Body weight at birth and early growth rate, especially up to weaning, are determined not only by its own genetic potential but also the maternal environment [11]. Hence, to achieve optimum genetic progress in a selection program both the direct and maternal components should be taken into account,

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especially if there is an antagonistic relationship between them [7, 12]. A high percentage of the sheep population in Iran is managed under a migratory system. Hence, they are mostly kept on village and semi-intensive system and nature pasture is the main source of feed. The Moghani sheep population is composed of fat-tail native breeds in the north western part of Iran and it is estimated, there are about 2 million head of Moghani sheep in Ardebil province. They are of value for meat production, their milk and wool is also important [13]. The objective of this study was to estimate the direct, maternal genetic and maternal environmental effects on pre and post weaning growth traits and Kleiber ratio for Moghani sheep using fitting different models. Also the genetic and phenotypic relationships between traits were investigated.

MATERIALS AND METHODS

Data and Flock Management: Data were collected from Japharabad sheep breeding station in Ardabil province of Iran during 1995-2008. The Moghani sheep Breeding Station located at north of Ardabil province in North West of Iran. The mating period began from late summer (August) and early autumn (September) and continued approximately 50 days. The season of lambing was in February and March and the lambs were weaned of 3 months of age. Seven traits were considered: birth weight (BW), weaning weight (WW), 6-month weight (6MW), average daily gain from birth to weaning (ADG_{0-3}) and average daily gain from weaning to 6 months of age (ADG_{3-6}), Kleiber ratio from Birth to Weaning (KR_{0-3}) and Kleiber ratio from weaning to 6 months of age (KR_{3-6}). The Kleiber ratio ($ADG/WW^{0.75}$) suggested as a suitable selection criteria for food efficiency under range conditions [14].

Statistical Methods: The General Linear Model (GLM) procedure of SAS [15] was used to identify non-genetic factors which influenced studied traits. Weaning weight was adjusted by birth weight, whereas age at weaning weight was considered as covariate for both WW and 6MW.

(Co) variance components and genetic parameters were estimated by Restricted Maximum Likelihood method using DFREML 3.1 [16]. The convergence criterion was 10^{-8} and the AI-REML algorithm was employed to control whether a global maximum had been reached. Initially 6 univariate animal models which ignore or include the maternal genetic and maternal permanent environmental effect in the model were fitted for each trait as below. A full model (model 6) included the direct genetic, maternal genetic and maternal environmental effect (permanent environment), considered covariance between direct and maternal genetic effects.

Model 1:	$y = Xb + Z_1a + e$	
Model 2:	$y = Xb + Z_1a + Z_3c + e$	
Model 3:	$y = Xb + Z_1a + Z_2m + e$	$Cov(a,m) = 0$
Model 4:	$y = Xb + Z_1a + Z_2m + e$	$Cov(a,m) \neq 0$
Model 5:	$y = Xb + Z_1a + Z_2m + Z_3c + e$	$Cov(a,m) = 0$
Model 6:	$y = Xb + Z_1a + Z_2m + Z_3c + e$	$Cov(a,m) \neq 0$

Where y was a vector of records on the different traits; ***b***, ***a***, m, ***c*** and ***e*** were vectors of fixed, direct additive genetic, maternal additive genetic, maternal permanent environmental and the residual effects, respectively. $\mathbf{X}$, $\mathbf{Z_1}$, $\mathbf{Z_2}$ and $\mathbf{Z_3}$ were corresponding design matrices associating the fixed, direct additive genetic, maternal additive genetic and maternal permanent environmental effects. It was assumed that direct additive genetic, maternal additive genetic, maternal permanent environmental and residual effects to be normally distributed with mean 0 and variance $\mathbf{A}\sigma^2_a$, $\mathbf{A}\sigma^2_m$, $\mathbf{I_d}\sigma^2_c$ and $\mathbf{I_n}\sigma^2_e$, respectively. Where σ^2_a, σ^2_m, σ^2_c and σ^2_e were direct additive genetic variance, maternal additive genetic variance, maternal permanent environmental variance and residual variance, respectively. $\mathbf{A}$ was the additive numerator relationship matrix, $\mathbf{I_d}$ and $\mathbf{I_n}$ were identity matrices that had order equal to the number of dams and number of records, respectively and σ_{am} denoted the covariance between direct additive genetic and maternal additive genetic effects.

In univariate analysis, log likelihood ratio tests were applied to choose the most appropriate model for each trait [12]. The direct and maternal genetic correlation between traits estimated by bi-variate analysis based on the best model for each trait, which found in univariate analysis.

RESULTS AND DISCUSSION

Fixed Effects: Basic statistical information of traits is given in Table 1. Means of BW, WW, 6MW, ADG_{0-3}, ADG_{3-6}, KR_{0-3} and KR_{3-6} were 4.61, 25.10, 34.69kg, 0.223, 0.140, 19.55 and 9.46 gr, respectively. These results agreed well with estimates found in literatures [17-20]. Least square means (±SE) of traits are shown for each subclass in Table 2. The least square analysis indicated that environmental factors (sex, birth type, year and season of birth) were important sources of variation for growth traits [21] and KR in Moghani sheep ($p<0.01$).

Table 1: Basic statistical information about growth traits of Moghani sheep (1995-2008)

Character	BW	WW	6MW	ADG_{0-3}	ADG_{3-6}	KR_{0-3}	KR_{3-6}
Mean(kg)	4.61	25.10	34.69	0.223	0.140	0.019	0.009
Standard deviation(kg)	0.79	5.65	6.26	0.070	0.073	0.003	0.004
Coefficient of variation (%)	17.14	22.51	18.04	31.39	52.14	14.17	45.14
Number of records	6184	5351	5065	5351	4428	5351	4428
Number of sires	269	263	250	263	246	263	246
Number of dams	1600	1444	1424	1444	1331	1444	1331

BW, birth weight; WW, weaning weight; 6MW, 6-month weight; ADG_{0-3}, average daily gain from birth to weaning; ADG_{3-6}, average daily gain from weaning to 6 months of age; KR_{0-3}, Kleiber ratio from Birth to Weaning ; KR_{3-6}, Kleiber ratio from weaning to 6 months of age

Table 2: least square means (±SE) for studied traits

Fixed effect	BW	WW	6MW	ADG_{0-3}	ADG_{3-6}	KR_{0-3}	KR_{3-6}
Lambing year	**	**	**	**	**	**	**
Season	**	**	**	**	**	**	**
1	$4.55^{b}\pm0.05$	$21.39^{d}\pm0.39$	$34.2^{a}\pm2.3$	$181.09^{c}\pm7$	$130.59^{a}\pm35.13$	$17.73^{b}\pm0.29$	$11.48^{a}\pm2.39$
2	$4.47^{b}\pm0.06$	$24.13^{c}\pm0.34$	-	$223.68^{b}\pm4.1$	-	$19.61^{a}\pm0.15$	-
3	$4.72^{a}\pm0.04$	$28.23^{a}\pm0.25$	$34.83^{a}\pm0.25$	$233.40^{a}\pm3.08$	$120.07^{a}\pm3.21$	$19.93^{a}\pm0.11$	$8.04^{b}\pm0.19$
4	$4.68^{a}\pm0.01$	$24.89^{b}\pm0.08$	$34.67^{a}\pm0.09$	$224.06^{b}\pm1.06$	$143.21^{a}\pm1.17$	$19.57^{a}\pm0.04$	$9.63^{ab}\pm0.07$
Dam age	**	**	ns	**	**	**	**
2	$4.66^{a}\pm0.02$	$24.44^{c}\pm0.17$	-	$218.65^{b}\pm0.22$	$130.63^{b}\pm2.29$	$19.34^{b}\pm0.08$	$9^{ab}\pm0.14$
3	$4.64^{a}\pm0.02$	$25.38^{ab}\pm0.16$	-	$228.028^{a}\pm2.14$	$148.47^{a}\pm2.45$	$19.73^{a}\pm0.08$	$9.9^{a}\pm0.14$
4	$4.66^{a}\pm0.02$	$25.06^{b}\pm0.17$	-	$222.042^{ab}\pm2.11$	$148.45^{a}\pm2.51$	$19.49^{ab}\pm0.08$	$9.85^{a}\pm0.14$
5	$4.73^{a}\pm0.03$	$25.58^{ab}\pm0.18$	-	$227.24^{a}\pm2.31$	$139.58^{ab}\pm2.69$	$19.71^{a}\pm0.09$	$9.35^{ab}\pm0.16$
6	$4.72^{a}\pm0.04$	$25.32^{ab}\pm0.22$	-	$227.63^{a}\pm2.85$	$139.05^{ab}\pm3.18$	$19.71^{a}\pm0.11$	$9.42^{ab}\pm0.2$
7	$4.67^{a}\pm0.06$	$25.11^{b}\pm0.29$	-	$215.87^{b}\pm3.54$	$136.02^{b}\pm4.31$	$19.28^{b}\pm0.14$	$9.15^{b}\pm0.25$
8	$4.68^{a}\pm0.12$	$25.91^{a}\pm0.54$	-	$228.97^{a}\pm7.08$	$137.87^{b}\pm8.13$	$19.76^{a}\pm0.28$	$9.094^{b}\pm0.48$
Sex	**	**	**	**	**	**	**
Female	$4.49^{b}\pm0.01$	$23.68^{b}\pm0.09$	$32.31^{b}\pm0.10$	$210.50^{b}\pm1.28$	$122.54^{b}\pm1.36$	$19.05^{b}\pm0.05$	$8.76^{b}\pm0.08$
Male	$4.85^{a}\pm0.01$	$26.48^{a}\pm0.11$	$36.95^{a}\pm0.13$	$237.06^{a}\pm1.43$	$159.09^{a}\pm1.66$	$20.07^{a}\pm0.05$	$10.19^{a}\pm0.09$
Birth type	**	**	**	**	**	**	**
Single	$5.04^{a}\pm0.01$	$26.65^{a}\pm0.09$	$36.07^{a}\pm0.10$	$240.21^{a}\pm1.23$	$151.22^{a}\pm1.42$	$20.22^{a}\pm0.04$	$9.93^{a}\pm0.08$
Twine	$4.19^{b}\pm0.01$	$22.56^{b}\pm0.11$	$32.39^{ab}\pm0.13$	$197.68^{ab}\pm1.43$	$123.93^{a}\pm1.71$	$18.52^{ab}\pm0.05$	$8.73^{a}\pm0.10$
Triplet	$3.41^{c}\pm0.08$	$20.18^{b}\pm0.64$	$29.58^{b}\pm0.69$	$175.79^{b}\pm7.41$	$108.01^{a}\pm9.89$	$17.61^{b}\pm0.32$	$8.13^{a}\pm0.64$

Means with similar letters in each subclass within a column do not differ from another at $P<0.05$; ns, non significant ($P>0.05$). **Significant effect at $P<0.01$. Abbreviations are as defined for Table 1.

Indeed, all traits except of 6MW were significantly affected by age of dam ($p<0.01$). Male lambs showed higher KR, ADG and body weights at any age than females ($p<0.01$). The effects of lamb's gender could be due to difference in the secretion of hormones in male and females. Birth type had a significant effect on all traits and the highest body weight was related to singles. The differences of traits related to type of lambing might be because of limited uterine space and competition in milk suckling. Type of birth had also significant effect on pre and post weaning ADG; because the highest values of ADG_{0-3} and ADG_{3-6} were found in singles and twins, respectively. It was also observed that BW and WW of lambs increased by increasing age of dams, however pre and post weaning growth rate of lambs originating from three years old were higher than other ones. The significant effect of dam's age could be due to differences in maternal behavior (nursing), uterus space and milk production of ewes in different ages. Lambs born in autumn showed the highest mean in growth traits expect for ADG_{3-6} and KR_{3-6}. However birth year significantly affected traits, but there was no recognized trend in weight during 14 years. Due to different management, climate condition and feedstuff availability, growth traits could be varied among year and season.

Table 3: Estimates of variance components and genetic parameters from single- trait analyses based on most appropriate models

Traits	Model	δ_p^2	δ_e^2	δ_a^2	δ_m^2	δ_{pe}^2	Cov_{am}	r_{am}	h^2±S.E.	m^2±S.E.	*pe*±S.E.
BW	4	0.368	0.267	0.038	0.039	-	0.023	0.59	0.104±0.03	0.107±0.02	-
WW	4	15.989	13.186	1.574	1.852	-	-0.62	-0.36	0.098±0.01	0.116±0.07	-
6MW	2	24.015	19.579	2.047	-	2.387	-	-	0.085±0.02	-	0.099±0.01
ADG_{0-3}	6	3141.547	2200.986	666.114	399.183	-	-269.265	-0.52	0.212±0.04	0.127±0.03	0.046±0.02
ADG_{3-6}	4	3881.408	3626.095	87.935	82.305	-	85.073	1	0.023±0.04	0.021±0.04	-
KR_{0-3}	6	4.753	3.783	0.628	0.244	0.322	-0.225	-0.57	0.132±0.04	0.051±0.05	0.068±0.05
KR_{3-6}	4	13.876	13.241	0.193	0.231	-	0.211	0.99	0.014±0.01	0.017±0.01	-

Abbreviations are as defined for Table 1.
Symbols are as defined for Table 2.

(Co) Variance Component: (Co) variance components estimated from single-trait analyses and the most appropriate model for every trait was presented in Table 3. Regarding to log likelihood ratio test (LRT), models 4, 4, 2, 6, 4, 6 and 4 were chosen as the most appropriate models for BW, WW, 6MW, ADG_{0-3}, ADG_{3-6}, KR_{0-3} and KR_{3-6} respectively. It indicated that direct genetic, maternal genetic and correlation between these effects had significant effect on all traits except for 6MW. Indeed, based on LRT, maternal permanent environmental effect was significant on 6MW, ADG_{0-3} and KR_{0-3}. Mayer [12] showed that the heritability could be overestimated if maternal genetic effect be ignored in such a trait.

Direct heritability's of BW, WW and 6MW, ADG_{0-3}, ADG_{3-6}, KR_{0-3} and KR_{3-6} were estimated 0.104± 0.03, 0.098±0.01, 0.085±0.02, 0.212±0.04, 0.023±0.04, 0.132±0.04 and 0.014±0.01 based on most appropriate models, respectively. The heritability estimated for body weight at birth, weaning and 6 months of age were consistent with other sheep breeds. Heritability was reported from 0.04 to 0.39 for BW, from 0.09 to 0.25 for WW and from 0.18 to 0.514 for 6MW [7-9, 22-26]. In this study, heritability was obtained relatively low, but it is in agreement with results of Ozcan *et al*. [25] in Turkish merino sheep, who reported 0.09, 0.04 and 0.04 for BW, WW and ADG_{0-3} respectively. Miraei Ashtiani *et al*. [19] reported estimates for body weight at birth, weaning and 6 months of age 0.33, 0.17 and 0.49 respectively, although they had worked in Sangsari breed and their results were higher than ours. Yazdi *et al*. [6] reported estimates of h^2 for BW and WW as 0.14 and 0.13 in another Iranian sheep breed, Bluchi. They reported that relatively lower heritability estimates for BW and WW might be explained by the low nutritional level and poor quality of the pasture at the sheep breeding station, which created large environmental variation. Snyman *et al*. [27] showed a wide variation of estimated heritability for birth weight (0.04-0.39) and weaning weight (0.09-0.52) according to different models used in their study. Zamani and Mohammadi [28] reported the estimates for direct heritability ranged from 0.26 to 0.53; 0.18 to 0.32 and 0.15 to 0.33 for BW, WW and ADG_{0-3} for Mehraban sheep, respectively. Direct heritability estimate for pre-weaning kleiber ratio (0.13) was higher than that reported by Rashidi *et al*. [18] and Matika *et al*. [29], but is in consistent with those published by Van Wyk *et al*. [30].

In this study, the estimates of maternal heritability for BW, WW, ADG_{0-3}, ADG_{3-6}, KR_{0-3} and KR_{3-6} were 0.107, 0.116, 0.127, 0.021, 0.051 and 0.017 respectively. Mohammadi *et al*. [31] reported estimates of direct and maternal heritability for ADG_{0-3} as 0.149 and 0.09, respectively. In our study, direct and maternal heritability for KR and ADG traits at pre weaning were very higher than post weaning. Also, fraction of variance due to maternal permanent environmental effects were estimated 0.099, 0.046 and 0.068 for 6MW, ADG_{0-3} and KR_{0-3}. The fraction of variance due to maternal permanent environmental effect for 6MW was estimated higher than direct genetic effect estimate (0.099 vs. 0.085). This showed that the maternal permanent environmental effect was important for 6MW in this breed. Cloete *et al*. [32] reported direct, maternal genetic and permanent environmental estimates for birth weight 0.18, 0.15 and 0.08 and for weaning weight 0.30, 0.08 and 0.07, respectively. Similar findings were also reported that genetic effects were high than maternal permanent environmental for pre-weaning weight traits; 0.19 vs. 0.09 in Turkish merino sheep for BW [24], 0.1 vs. 0.38 (BW), 0.06 to 0.10 vs. 0.05 to 0.11 (WW) and 0.06 to 0.09 vs. 0.04 to 0.10 (ADG_{0-3}). Maria *et al*. [7] reported that maternal environmental effects on birth weight could be possibly determined by uterine capacity, feeding level during late gestation and maternal behavior of the ewe. Maternal heritability estimated in several studies ranged from 0.01 for WW in Romanov sheep [7] to 0.65 for BW in Sangesari sheep [19]. Higher estimates of maternal heritability were reported by El Fadili *et al*. [33] in Timahidit breed. Their estimates were 0.59 and 0.22 for body weight at birth and average daily gain from 30-90 days.

Table 4: Estimates of direct and maternal genetic and phenotypic correlations between growth traits (1 and 2)

Trait1	Trait2	r_{a12}	r_{m12}	r_{p12}
BW	WW	0.39	0.31	0.23
	6W	0.28	0.31	0.28
	ADG_{0-3}	0.44	0.14	0.17
	ADG_{3-6}	-0.70	0.50	0.14
	KR_{0-3}	0.05	0.26	0.007
	KR_{3-6}	0.03	0.66	-0.01
WW	6W	0.66	0.99	0.64
	ADG_{0-3}	0.98	0.98	0.97
	ADG_{3-6}	0.12	0.03	0.02
	KR_{0-3}	0.41	0.99	0.68
	KR_{3-6}	0.37	-0.58	-0.01
6MW	ADG_{0-3}	0.67	-	0.45
	ADG_{3-6}	0.86	-	0.39
	KR_{0-3}	0.10	-	0.11
	KR_{3-6}	0.13	-	0.01
ADG_{0-3}	ADG_{3-6}	0.56	0.71	0.29
	KR_{0-3}	0.90	0.50	0.85
	KR_{3-6}	0.54	0.23	0.11
ADG_{3-6}	KR_{0-3}	-0.09	0.02	0.0008
	KR_{3-6}	0.06	0.34	0.03
KR_{0-3}	KR_{3-6}	0.61	0.19	-0.01

Abbreviations are as defined for Table 1. r_{a1a2}, Direct genetic correlations between 1 and 2 traits; r_{m1m2}, Maternal genetic correlations between 1 and 2 traits; r_{e1e2}, residual correlations between 1 and 2 traits; r_{p1p2}, phenotypic correlations between 1 and 2 traits.

Correlations between direct and maternal genetic effects were negative for WW (-0.36), ADG_{0-3} (-0.52) and KR_{0-3} (-0.57) traits, although they were positive for other traits and ranged from 0.59 (for BW) to unit (for ADG_{3-6}). Tosh and Kemp [8] reported correlations between direct and maternal genetic effects -0.56 and -0.74 for BW and 100W, respectively. They concluded that antagonism between direct and maternal genetic might be due to natural selection. Miraei-Ashtiani *et al*. [19] reported negative direct-maternal genetic correlation for BW, WW, 6MW and ADG_{0-3} traits ranged from -0.66 to -0.18 in Sangsari sheep. Although, negative estimates of the direct-maternal correlations were common in most recently research carried out using field data analysis, but positive estimates have also been reported, such as Nasholm and Danell [9], Yazdi *et al*. [6], who reported positive estimates of direct-maternal genetic correlation for BW and WW in Finwool and Bluchi breeds. Neser *et al*. [22] and Duguma *et al*. [2] reported such results for BW in Dorper and Tygerhoek Merino breeds, as well.

Correlations Estimates: Estimates of phenotypic, direct and maternal genetic correlation between traits are presented in table 4. Direct genetic correlations estimated were positive (except BW with ADG_{3-6} and ADG_{3-6} with KR_{0-3}) and was in ranged from 0.03 (for BW– KR_{3-6}) to 0.98 (for WW-ADG_{0-3}). Genetic correlations between body weight traits were positive and moderate. BW-WW, BW-6MW and WW-6MW relationships were estimated 0.39, 0.28 and 0.66, respectively. These results were in consistent with other published reports, which showed genetic correlation between body weights traits were declined with increasing the time interval of traits [19]. Negative estimates of genetic correlation were obtained for BW-ADG_{3-6} (-0.70) and ADG_{3-6}-KR_{0-3} (-0.09), as well. Direct genetic, maternal genetic and phenotypic correlation between WW and ADG_{0-3} were estimated very high (toward unit). These estimates were 0.98, 0.98 and 0.97 for parameters mentioned above, respectively. Duguma *et al.* [2] reported that the high direct genetic correlation between WW and ADG_{0-3} implied that they were genetically the same trait or selection could consequently be applied on either one or the other trait. Low correlation between WW and ADG_{3-6}, which was in agreement with Sargolzaii *et al*. [34] and Miraei-Ashtiani *et al*. [19], might be related compensatory growth of some poorly nursed lambs, in post weaning period.

Estimates of maternal genetic correlation were negative and low to positive and high and varied from -0.58 between WW–KR_{3-6} to 0.99 for both WW-6MW and WW-KR_{0-3}. Maternal genetic correlations were estimated positive for most of pair traits except for WW-KR_{3-6}, which was high in negative sign. Estimated maternal genetic effects in some of traits were higher than those reported for direct genetic effects. In this case, the highest relationship differences observed between BW and KR_{3-6} (0.66 vs. 0.03).

In this study, phenotypic correlations BW-KR_{3-6}, WW-KR_{3-6} and KR_{0-3}-KR_{3-6} were estimated negative and close to zero (-0.01). Other estimations for phenotypic correlations were very variable and ranged from 0.0008 (for ADG_{3-6}-KR_{0-3}) to 0.97 (for WW-ADG_{0-3}). Indeed, all of phenotypic correlations were lower than genetic correlation (direct or maternal), which could be due to environmental factors affecting expression of genetic effects. Negative phenotype correlations in our study were between KR_{3-6} with some of pre weaning traits such as BW, WW and KR_{0-3}.

CONCLUSION

Heritability of early growth ranged from moderate to moderately high based on different models. In conclusion, ignoring the maternal effects; either maternal genetic or maternal environmental; could be lead to an overestimation of the h^2 estimates. The low estimates of direct heritabilities for growth traits obtained in this study indicated that selection for growth traits would result in slow genetic improvement. Maternal effects were significant on weights in different ages of Moghani sheep and should be taken account in any selection program to improve the efficiency of this breed. WW was positively and genetically correlated with pre and post weaning growth traits. Therefore, WW should be considered as an effective selection criterion in breeding program. In such a situation, improvement in the other pre and post weaning growth traits would be accepted without undesirable increasing in mature weight.

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