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Genetic Evaluation of Growth Rate and Efficiency Related Traits in Raeini Cashmere Goat

Research Article

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ABSTRACT

Growth efficiency-related traits are of economic importance for genetically improving of small ruminants especially in tropics with pastures of low quality and quantity. Data on body weights of Raeini Cashmere goat collected from 1979 to 2012 in Raeini breeding station, Kerman province, south-eastern part of Iran were used for estimating the genetic parameters of average daily gain from birth to weaning (ADG1), average daily gain from weaning to six months of age (ADG2), average daily gain from birth to six months of age (ADG3), Kleiber ratio from birth to weaning (KR1), Kleiber ratio from weaning to six months of age (KR2), Kleiber ratio from birth to six months of age (KR3), growth efficiency from birth to weaning (GE1), growth efficiency from weaning to six months of age (GE2) and growth efficiency from birth to six months of age (GE3). The numbers of final edited records were related to 2817, 2541 and 2701 kids for the traits considered from birth to weaning, from weaning to six months of age and from birth to six months of ages periods, respectively. Direct heritability estimates for ADG1, ADG2, ADG3, KR1, KR2, KR3, GE1, GE2 and GE3 were 0.08, 0.03, 0.06, 0.19, 0.03, 0.07, 0.07, 0.09 and 0.08, respectively. Maternal heritability estimates for ADG1, KR1 and GE1 were 0.09, 0.11 and 0.10, respectively. Genetic correlations between traits were ranged from -0.95 for ADG3-KR1 to 0.99 for ADG1-KR1, ADG2-KR2, ADG3-KR3 and KR1-GE1. Phenotypic correlations were positive and high for traits measured in the same period i.e. among ADG1, KR1 and GE1, among ADG2, KR2 and GE2 and among ADG3, KR3 and GE3; ranged from 0.77 for ADG2-GE2 to 0.96 for ADG3-KR3. The obtained results revealed little additive genetic variation in growth rate or efficiency related traits of Raeini Cashmere goat, implying little opportunity for genetic improvement of these traits in this breed through selection.

KEY WORDS goat, growth efficiency, growth rate, Kleiber ratio, maternal effects.

INTRODUCTION

Raeini Cashmere breed constitutes the most important Iranian Cashmere goat with approximately 2 million heads and it is predominantly distributed in the south and south-eastern parts of the country (Maghsoudi *et al.* 2009). Raeini Cashmere goats are small-sized and characterized by white, light and dark brown Cashmere color. The breed is maintained as a dual-purpose breed because of its quality in meat and Cashmere, (Ansari-Renani, 2013). The breed is mainly reared by small holder farmers under traditional management systems and harsh climatic conditions. Indigenous breeds of small ruminants in developing countries are mainly reared by local herders under low-input production systems. The livelihood of the flock holders depends on promoting the production under such systems (Kosgey and

Okeyo, 2007). To date, goat production in Iran has relied mainly on natural pastures. However, in the recent years, the pasture area has decreased at an alarming rate due to destruction by human activities, significant decreases in annual precipitation and the occurrence of long periods of drought (Sefidbakht, 2011).

In domestic animals, body weight at different ages has a determinant effect on profitability of breeding enterprises. Such traits may be considered as efficient selection criteria in any breeding systems (Tosh and Kemp, 1994). Selection of the best animals for weights gain at different ages as parents of the next generation is a possible way for increasing meat production (Boujenane and Kansari, 2002). However, the selection of animals for higher body weights and growth rate would increase the cost of maintenance (Fitzhugh and Taylor, 1971). Therefore, selection of animals for improving the efficiency of feed conversion will reduce the cost of production (Ghafouri-Kesbi *et al.* 2011). Since Raeini Cashmere goat is raised in pastures where food shortage is common, breeding objectives should be focused on increasing growth efficiency of animals. However, selection for this trait is difficult due to limitations in measurements, especially in animals raised on pasture. Kleiber ratio (growth rate in a certain period divided by final body weight$^{0.75}$) is an indirect measurement of feed conversion that can be easily measured in any production system (Kleiber, 1947). Animals with higher values of Kleiber ratio are considered efficient users of feed and growth efficiency (Ghafouri-Kesbi *et al.* 2011).

In order to construct a selection index for improvement of animals for body weights and feed conversion, estimates of genetic parameters for these traits are needed. The objective of this study was to estimate genetic parameters for early average daily gain, Kleiber ratio and growth efficiency in Raeini Cashmere goat.

MATERIALS AND METHODS

Data, flock management and the studied traits

The breeding station of Raeini Cashmere goat, is in Baft, Kerman province, south-eastern of Iran. It was established in 1965 with 180 goats including 120 does, 8 bucks and 52 kids for improving economic traits of Raeini Cashmere goats such as body weight at different ages and Cashmere weight via recording of these traits and genetic evaluation of animals (Mokhtari *et al.* 2017). The pedigree information used in this study was collected from 1979 to 2012 at Raeini Cashmere goat breeding station and included 4341 animals descended from 1389 dams and 227 sires. Raeini Cashmere goats were reared under semi-intensive managerial conditions which were similar to the prevalent conditions on nomadic flocks of the region.

Mating period was extended from August to October with the corresponding kidding period from December to February. Does were first exposed to the bucks at approximately 18 months of age.

In the present study, records on live body weights at birth (BW), at weaning (WW) and at six month of age (SIMW) were used for calculating the traits of interest. The investigated traits were considered in three periods; from birth to weaning (2817 records on 1508 male kids and 1309 female kids), from weaning to six months of age (2451 records on 1303 male kids and 1148 female kids) and from birth to six months of age (2701 records on 1410 male kids and 1291 female kids). For editing purposes, records on BW, WW and SIXW which were in the range of mean ± 2.5 standard deviations were kept and kids of unknown sex, birth type and birth date were discarded. Data edition was performed applying Microsoft Visual FoxPro program 9.0. The traits were included average daily gain from birth to weaning (ADG1), average daily gain from weaning to six months of age (ADG2), average daily gain from birth to six months of age (ADG3), Kleiber ratio from birth to weaning (KR1) calculated as ADG1/WW$^{0.75}$, Kleiber ratio from weaning to six months of age (KR2) calculated as ADG2/SIXMW$^{0.75}$, Kleiber ratio from birth to six months of age (KR3) calculated as ADG3/ SIXMW$^{0.75}$, growth efficiency from birth to weaning (GE1) calculated as (WW-BW/BW)×100, growth efficiency from weaning to six months of age (GE2) calculated as (SIXMW-WW/WW) × 100 and growth efficiency from birth to weaning (GE3) calculated as (SIXMW-BW/BW) × 100 (Ghafouri-Kesbi and Gholizadeh, 2017). The structure of the data set is presented in Table 1.

Statistical models

Significance testing of fixed effects considered for the studied traits including sex of kids in 2 classes (male and female), dam age at kidding in 6 classes (2-7 years old), birth type in 3 classes (single, twin and triplet) and birth year in 23 classes (1997-2013) and were accomplished applying general linear method (GLM) procedure of SAS software (SAS, 2004). Least squares means of the studied traits were compared by Duncan multiple range test (P<0.05).

In mammalian species growth traits especially in early of life are determined not only by the animal's own additive genetic merit but also by maternal effects. The maternal effects generally denote those related to the milk production of dam and its mothering ability (Roy *et al.* 2008). Therefore, for studying the role of maternal effects on the genetic evaluation of the studied traits a restricted maximum likelihood (REML) procedure under a derivative free algorithm was used and six animal models including different combinations of direct additive effects and maternal ones (maternal additive genetic and maternal permanent environmental effects) were tested applying WOMBAT program (Meyer, 2007). The considered models (in matrix notation) are as below:

$\mathbf{y= Xb + Z_1a + e}$ Model 1
$\mathbf{y= Xb + Z_1a + Z_3c + e}$ Model 2

$\mathbf{y= Xb + Z_1a + Z_2m + e}$ Model 3
$\mathbf{Cov\ (a, m)= 0}$

$\mathbf{y= Xb + Z_1a + Z_2m + e}$ Model 4
$\mathbf{Cov\ (a, m)= A\sigma_{am}}$

$\mathbf{y= Xb + Z_1a + Z_2m + Z_3c + e}$ Model 5
$\mathbf{Cov\ (a, m)= 0}$

$\mathbf{y= Xb + Z_1a + Z_2m + Z_3c + e}$ Model 6
$\mathbf{Cov\ (a, m)= A\sigma_{am}}$

Where:
y: vector of records for the studied traits.
b, **a**, **m**, **c** and **e**: vectors of fixed, direct additive genetic, maternal additive genetic, maternal permanent environmental and the residual effects, respectively.
X, $\mathbf{Z_a}$, $\mathbf{Z_m}$ and $\mathbf{Z_c}$: design matrices associating the corresponding effects to vector of y. It was assumed that direct additive genetic, maternal additive genetic, maternal permanent environmental and residual effects to be normally and independently distributed with mean 0 and variances $\mathbf{A}\sigma^2_a$, $\mathbf{A}\sigma^2_m$, $\mathbf{I_d}\sigma^2_{pe}$ and $\mathbf{I_n}\sigma^2_e$, respectively.
A: numerator relationship matrix.
$\mathbf{I_d}$ and $\mathbf{I_n}$: identity matrices that have order equal to the number of dams and records, respectively.
σ^2_a, σ^2_m, σ^2_{pe}, and σ_{am}: direct additive genetic variance, maternal additive genetic variance, maternal permanent environmental variance and covariance between additive and maternal effects, respectively.

The normal distribution was confirmed for the studied traits by Kolmogorov-Smirnov test. Univariate analyses were performed for determining the most appropriate model for each trait.

The Akaike's Information Criterion (AIC) was applied for the determination of the most appropriate model among the tested models (Akaike, 1974) as follows:

$$AIC_i = -2 \log L_i + 2 P_i \quad (1)$$

Where:
$\log L_i$: maximized log likelihood.
p_i: parameters fitted for model i.

In each case, the model with the lowest AIC is considered as the best model. Direct additive genetic coefficient of variation (CV_A) was calculated as square root of direct additive genetic variance which divided by phenotypic mean of the trait. Genetic, phenotypic and residual correlations were estimated under bivariate analyses considering the same model determined as the best one under univariate analyses.

RESULTS AND DISCUSSION

General considerations

As shown in Table 1, pre-weaning studied traits including ADG1, KR1 and GE1 were higher in magnitude than the corresponding post-weaning traits of ADG2, KR2 and GE2. Least square means (±SE) for the traits studied are shown in Table 2.

The year of birth of the kids contributed significantly ($P<0.01$) to the variation of all the considered traits. The sex of the kids had significant effects on all the studied traits except for GE1 and GE2. In these cases, male kids had higher growth rate (ADG1, ADG2 and ADG3), Kleiber ratio (KR1, KR2 and KR3) and post-weaning growth efficiency (GE2) than the female kids. Birth type of kids significantly influenced ADG1, ADG3, GE3 ($p<0.01$), GE1 and GE2 ($P<0.05$) but not in the case of ADG2, KR1, KR2 and KR3 ($P>0.05$).

Single-born kids had higher ADG1 and ADG3 than twin and triplet-born kids ($P<0.01$), with no significant difference between twins and triplets ($P>0.05$). Triplet-born kids had significantly higher GE1 and GE2 than the twin and single-born kids ($P<0.05$), with no significant difference between twin and single-born kids ($P>0.05$). In addition, triplets had significantly higher GE3; followed by twins and single-born ones ($P<0.01$). All the studied traits except KR2, GE1 and GE3 significantly influenced by age of dam at kidding ($P<0.01$).

Model comparisons

The AIC values under the tested animal models are presented in Table 3, with the most appropriate model in bold face for each trait. For all the studied traits Model 1, that included the direct additive genetic effect as the unique known random effect had the highest AIC value. For the pre-weaning traits including ADG1, KR1 and GE1, Model 4, which included the direct additive and maternal additive genetic effects by considering covariance between these effects, was detected as the most appropriate model. For the remaining traits, the model including direct additive genetic and maternal permanent environmental effects (Model 2) was determined as the most appropriate model.

Table 1 Descriptive statistics for the studied traits

Item	Traits								
	ADG1	ADG2	ADG3	KR1	KR2	KR3	GE1	GE2	GE3
No. of records	2817	2451	2701	2817	2451	2701	2817	2451	2701
Mean	89.73	42.16	66.21	15.27	5.54	8.81	371.42	40.77	556.46
SD	33.80	23.03	20.24	3.92	2.56	1.11	149.71	22.42	196.37
CV (%)	37.67	54.62	30.57	25.67	46.21	12.60	40.31	54.99	35.29
No. of dam	1290	1209	1254	1290	1209	1254	1290	1209	1254
No. of sire	182	187	190	182	187	190	182	187	190
Average No. of progeny per sire	15.48	13.11	14.21	15.48	13.11	14.21	15.48	13.11	14.21
Average No. of progeny per dam	2.18	2.03	2.15	2.18	2.03	2.15	2.18	2.03	2.15

ADG1: average daily gain from birth to weaning; ADG2: average daily gain from weaning to six months of age; ADG3: average daily gain from birth to six months of age; KR1: Kleiber ratio from birth to weaning; KR2: Kleiber ratio from weaning to six months of age; KR3: Kleiber ratio from birth to six months of age; GE1: growth efficiency from birth to weaning; GE2: growth efficiency from weaning to six months of age and GE3: growth efficiency from birth to six months of age.

Table 2 Least squares means (±SE) for the studied traits

Fixed effect	Traits								
	ADG1	ADG2	ADG3	KR1	KR2	KR3	GE1	GE2	GE3
Sex	**	**	**	**	**	**	NS	**	NS
Male	95.80±1.70^{a}	45.81±4.36^{a}	71.47±1.12^{a}	15.52±0.14^{a}	5.84±0.48^{a}	9.06±0.06^{a}	355.57±7.51^{a}	42.54±1.56^{a}	556.06±10.20^{a}
Female	82.55±1.69^{b}	37.17±4.35^{b}	60.94±1.11^{b}	14.76±0.14^{b}	5.39±0.48^{b}	8.63±0.06^{b}	351.40±7.64^{a}	40.39±1.56^{b}	550.31±10.07^{a}
Birth type	**	NS	**	NS	NS	NS	*	*	**
Single	93.95±0.73^{a}	42.57±1.53^{a}	69.40±0.43^{a}	15.17±0.06^{a}	5.40±0.17^{a}	8.89±0.02^{a}	349.65±3.17^{b}	38.74±0.59^{b}	522.37±4.06^{c}
Twin	88.17±1.06^{b}	43.54±1.68^{a}	66.29±0.70^{b}	15.03±0.09^{a}	5.72±0.18^{a}	8.85±0.04^{a}	350.22±5.24^{b}	41.65±0.97^{b}	539.51±6.63^{b}
Triplet	85.40±4.46^{b}	41.10±4.54^{a}	62.95±3.08^{b}	15.21±0.38^{a}	5.76±0.50^{a}	8.80±0.17^{a}	360.59±9.97^{a}	43.01±4.41^{a}	597.66±27.11^{a}
Dam age (year)	**	*	**	*	NS	**	NS	*	NS
2	82.82±2.17^{c}	39.39±4.28^{b}	61.92±1.45^{b}	14.93±0.18^{a}	5.58±0.47^{a}	8.72±0.08^{b}	353.67±9.35^{a}	40.84±1.96^{ab}	555.12±13.39^{a}
3	88.95±1.93^{b}	43.38±4.18^{a}	67.06±1.28^{a}	15.09±0.16^{a}	5.82±0.46^{a}	8.90±0.07^{a}	353.75±8.74^{a}	43.19±1.77^{a}	551.19±11.52^{a}
4	91.69±1.85^{a}	44.98±4.14^{a}	68.15±1.22^{a}	15.37±0.15^{a}	5.96±0.45^{a}	8.97±0.07^{a}	345.69±8.31	43.08±1.67^{a}	543.94±11.00^{a}
5	91.49±1.92^{a}	43.76±4.19^{a}	67.80±1.27^{a}	15.30±0.15^{a}	5.75±0.46^{a}	8.89±0.07^{a}	358.02±8.59^{a}	42.44±1.74^{a}	561.60±11.31^{a}
6	91.26±2.06	42.81±4.25	66.54±1.36^{a}	15.26±0.17^{a}	5.64±0.47^{a}	8.82±0.07^{ab}	351.78±9.07^{a}	39.78±1.91^{b}	552.23±11.88^{a}
7	87.48±3.08^{b}	39.31±6.82^{b}	65.78±1.24^{a}	14.71±0.25^{b}	5.48±0.53^{b}	8.78±0.07^{ab}	357.99±8.50^{a}	39.46±1.72^{b}	555.06±11.30^{a}
Birth year	**	**	**	**	**	**	**	**	**

ADG1: average daily gain from birth to weaning; ADG2: average daily gain from weaning to six months of age; ADG3: average daily gain from birth to six months of age; KR1: Kleiber ratio from birth to weaning; KR2: Kleiber ratio from weaning to six months of age; KR3: Kleiber ratio from birth to six months of age; GE1: growth efficiency from birth to weaning; GE2: growth efficiency from weaning to six months of age and GE3: growth efficiency from birth to six months of age.
The means within the same column with at least one common letter, do not have significant difference (P>0.05) and (P>0.01).
* (P<0.05) and ** (P<0.01).
NS: non significant.

Table 3 Akaike's Information Criterion (AIC) values for the studied traits under different models with the best model in bold face

Model	Traits								
	ADG1	ADG2	ADG3	KR1	KR2	KR3	GE1	GE2	GE3
Model 1	24614.92	17893.24	18510.40	8372.91	6526.20	2174.47	29664.03	15663.71	29495.87
Model 2	24596.29	**17884.36**	**18483.13**	8364.68	**6517.50**	**2160.76**	29640.6	**15660.14**	**29477.44**
Model 3	24603.10	17887.74	18494.21	8370.53	6521.18	2170.17	29641.77	15662.23	29491.77
Model 4	**24506.00**	17889.97	18496.08	**8363.48**	6521.95	2170.41	**29624.16**	15661.25	29491.09
Model 5	24598.21	17886.16	18485.06	8366.68	6519.35	2162.76	29640.94	15662.14	29479.44
Model 6	24600.19	17888.11	18487.04	8367.60	6520.97	2163.25	29625.8	15660.67	29479.61

ADG1: average daily gain from birth to weaning; ADG2: average daily gain from weaning to six months of age; ADG3: average daily gain from birth to six months of age; KR1: Kleiber ratio from birth to weaning; KR2: Kleiber ratio from weaning to six months of age; KR3: Kleiber ratio from birth to six months of age; GE1: growth efficiency from birth to weaning; GE2: growth efficiency from weaning to six months of age and GE3: growth efficiency from birth to six months of age.

Genetic parameter estimates

Univariate analysis

The estimates of genetic parameters for the studied traits under the best univariate selected model are presented in Table 4. Direct heritability estimates were of low magnitude for all traits and ranged from 0.03 for ADG2 and KR2 to 0.19 for KR1. Maternal heritability for ADG1 (0.09) was relatively similar to that obtained for its direct heritability (0.08). Obtained ratio of maternal permanent environmental variances to phenotypic variances (pe^2) for ADG2 and ADG3 were 0.08 and 0.13, respectively. The estimates of pe2 for GE2 and GE3 were 0.04 and 0.11, respectively. In the present study, correlations between direct and maternal additive genetic effects were only estimated for pre-weaning traits of ADG1, KR1 and GE1 and were -0.38, -0.65 and 0.99, respectively.

Table 4 Variance components and genetic parameters of the studied traits under the best model

Trait[¥]	$h^2 \pm SE$[¥¥]	$m^2 \pm SE$[¥¥]	$pe^2 \pm SE$[¥¥]	$r_{am} \pm SE$[¥¥]	σ^2_p[¥¥]	CV_A (%)[¥¥]
ADG1	0.08±0.04	0.09±0.03	-	-0.38±0.14	704.56	8.37
ADG2	0.03±0.02	-	0.08±0.02	-	364.84	7.85
ADG3	0.06±0.03	-	0.13±0.02	-	248.15	5.83
KR1	0.19±0.06	0.11±0.04	-	-0.65±0.15	4.72	6.20
KR2	0.03±0.02	-	0.08±0.03	-	4.45	6.59
KR3	0.07±0.03	-	0.10±0.02	-	0.76	2.62
GE1	0.07±0.03	0.10±0.02	-	0.79±0.20	16044.10	9.02
GE2	0.09±0.02	-	0.04±0.02	-	271.92	12.13
GE3	0.08±0.04	-	0.11±0.02	-	22066.3	7.55

[¥] ADG1: average daily gain from birth to weaning; ADG2: average daily gain from weaning to six months of age; ADG3: average daily gain from birth to six months of age; KR1: Kleiber ratio from birth to weaning; KR2: Kleiber ratio from weaning to six months of age; KR3: Kleiber ratio from birth to six months of age; GE1: growth efficiency from birth to weaning; GE2: growth efficiency from weaning to six months of age and GE3: growth efficiency from birth to six months of age.

[¥¥] h^2: direct heritability; m^2: maternal heritability; pe^2: ratio of maternal permanent environmental effects to phenotypic variance; r_{am}: correlation between direct and maternal additive genetic effects; SE: standard error; σ^2_p: phenotypic variance and CV_A: direct additive genetic coefficient of variation.

Bivariate analyses

The estimates of direct genetic and phenotypic correlations for the studied traits are presented in Table 5. Genetic correlation estimates of ADG1-ADG2, ADG1-ADG3, ADG1-KR2, ADG1-GE2, ADG2-GE1, ADG3-GE1, KR2-GE1, GE1-GE2 and GE1-GE3 were negative but not statistically significant (Table 5). Phenotypic correlations were positive and high for traits measured in the same period i.e. among ADG1, KR1 and GE1, among ADG2, KR2 and GE2 and among ADG3, KR3 and GE3; ranged from 0.77 for ADG2-GE2 to 0.96 for ADG3-KR3 (Table 5).

The estimates of residual and permanent environmental correlations for the studied traits are presented in Table 6. Residual correlation estimates among the studied traits were ranged from -0.87 for ADG1-KR2 to 0.96 for ADG3-KR3 and ADG3-GE3. A high estimate of 0.92 was also obtained for KR3-GE3. Positive and medium to high estimates were obtained for permanent environmental correlations among the studied traits which were influenced by permanent environmental effects (ADG2, KR2, GE2, ADG3, KR3 and GE3) and varied from 0.51 for ADG3-GE2 to 0.99 for ADG2-KR3, ADG2-GE3, ADG3-KR2 and KR2-KR3. In the present study all the estimates of maternal genetic correlations among the studied influenced by maternal additive genetic effects (ADG1, KR1 and GE1).

Raeini Cashmere kids are less influenced by environmental factors because of the maternal support during the suckling period. After the suckling, stresses related to weaning may decrease growth of kids. Such trend has been reported by Ghafouri-Kesbi and Gholizadeh (2017) in Baluchi lambs. Traits measured in the pre-weaning growth phase had the smallest phenotypic coefficients of variation (CV) compared to those of post-weaning phase. The differences between male and female kids can be explained by differences in endocrine system related to sexual hormones. Estrogen limits growth of the long bones in females whereas testosterone has a positive effect on growth in males.

Testosterone enhances weight gain in a manner that is similar in that of growth hormone (Zung *et al.* 1999).The significant effect of dam age on the studied traits can be explained by limited uterine space in young dams, maternal effects and maternal ability of dams in different ages. The effect year of birth results from differences in climatic conditions and differences in nutrition and management conditions through different years (Dass *et al.* 2004). The influences of the considered fixed effects on growth rate, Kleiber ratio and growth efficiency of several goat breeds are well documented in the literature (Shaat and Maki-Tanila, 2009; Gowane *et al.* 2011; Rashidi *et al.* 2011).

Maternal additive genetic effects contributed only in the phenotypic variation of the pre-weaning studied traits and disappeared after weaning. For the post-weaning traits and traits measured from birth to six months of age, maternal permanent environmental effects accompanied by direct additive genetic effects constitute influencing known random effects. In the present study, maternal permanent environmental effects were not disappeared after weaning due to a carry-over effect maternal effects and constitute a noticeable part of phenotypic variance as large as direct additive genetic effects for all traits except ADG1, KR1 and GE1.

In this situation, pre-weaning growth of kids is restricted because of low dam milk production either due to high litter size or seasonal constraints on feed and maternal effects would carry-over to post-weaning period (Snyman *et al.* 1995). Such carry-over of maternal permanent environmental effects to post-weaning period was also reported by Gowane *et al.* (2011) in Sirohi goat breed.

In a previous study, Barazandeh *et al.* (2012) reported values of 0.10 and 0.06 for direct heritability estimates of ADG1 and KR in Raini goat which agrees with the values obtained in the present study. Gowane *et al.* (2011) estimated direct heritability values of 0.10 and 0.04 for pre-weaning average daily gain and average daily gain from weaning to six months of age in Sirohi goat.

Table 5 Estimates of genetic (above diagonal) and phenotypic (below diagonal) correlations between the studied traits

Traits	ADG1	ADG2	ADG3	KR1	KR2	KR3	GE1	GE2	GE3
ADG1	-	-0.05±0.27	-0.09±0.64	0.99±0.25	-0.18±0.30	0.39±0.08	0.98±0.12	0.01±0.18	0.21±0.05
ADG2	-0.04±0.02	-	0.98±0.23	-0.59±0.07	0.99±0.01	0.97±0.03	-0.09±0.20	0.97±0.02	0.97±0.48
ADG3	0.14±0.02	0.29±0.03	-	-0.95±.02	0.69±0.15	0.99±0.02	-0.07±0.50	0.87±0.08	0.89±0.06
KR1	0.78±0.01	-0.05±0.02	0.10±0.02	-	-0.82±0.02	0.18±0.04	0.99±0.04	-0.63±0.07	0.97±0.03
KR2	-0.04±0.02	0.92±0.01	0.26±0.03	-0.06±0.02	-	0.65±0.14	-0.03±0.18	0.97±0.01	0.73±0.13
KR3	0.22±0.02	0.28±0.03	0.96±0.01	0.10±0.02	0.27±0.03	-	0.88±0.05	0.86±0.06	0.78±0.10
GE1	0.88±0.01	-0.04±0.02	0.13±0.02	0.48±0.02	-0.04±0.02	0.90±0.01	-	-0.01±0.16	-0.28±0.50
GE2	-0.01±0.03	0.77±0.01	0.38±0.02	-0.04±0.02	0.88±0.01	0.45±0.02	-0.04±0.02	-	0.87±0.08
GE3	0.18±0.02	0.30±0.03	0.95±0.01	0.08±0.02	0.27±0.03	0.90±0.01	0.09±0.02	0.37±0.03	-

ADG1: average daily gain from birth to weaning; ADG2: average daily gain from weaning to six months of age; ADG3: average daily gain from birth to six months of age; KR1: Kleiber ratio from birth to weaning; KR2: Kleiber ratio from weaning to six months of age; KR3: Kleiber ratio from birth to six months of age; GE1: growth efficiency from birth to weaning; GE2: growth efficiency from weaning to six months of age and GE3: growth efficiency from birth to six months of age.

Table 6 Estimates of residual (above diagonal) and permanent environmental (below diagonal) correlations between the studied traits

Traits	ADG1	ADG2	ADG3	KR1	KR2	KR3	GE1	GE2	GE3
ADG1	-	-0.07±0.05	0.16±0.03	0.78±0.01	-0.87±0.04	0.23±0.04	0.88±0.01	-0.79±0.08	0.20±0.04
ADG2	-	-	-0.08±0.06	-0.09±0.05	0.84±0.02	-0.06±0.06	-0.05±0.05	0.61±0.06	-0.13±0.06
ADG3	-	0.99±0.07	-	0.11±0.03	-0.07±0.07	0.96±0.01	0.16±0.03	-0.02±0.09	0.96±0.01
KR1	-	-	-	-	-0.11±0.06	0.11±0.03	0.46±0.02	-0.10±0.07	0.10±0.03
KR2	-	0.89±0.03	0.99±0.14	-	-	-0.05±0.07	-0.09±0.06	0.73±0.04	-0.12±0.07
KR3	-	0.99±0.07	0.94±0.02	-	0.99±0.14	-	0.92±0.01	0.05±0.09	0.92±0.01
GE1	-	-	-	-	-	-	-	-0.13±0.07	0.12±0.03
GE2	-	0.74±0.09	0.51±0.02	-	0.95±0.05	0.53±0.21	-	-	-0.11±0.10
GE3	-	0.99±0.07	0.89±0.03	-	0.92±0.13	0.87±0.05	-	0.63±0.18	-

ADG1: average daily gain from birth to weaning; ADG2: average daily gain from weaning to six months of age; ADG3: average daily gain from birth to six months of age; KR1: Kleiber ratio from birth to weaning; KR2: Kleiber ratio from weaning to six months of age; KR3: Kleiber ratio from birth to six months of age; GE1: growth efficiency from birth to weaning; GE2: growth efficiency from weaning to six months of age and GE3: growth efficiency from birth to six months of age.

Estimated values in the present study collaborate with results found by these authors. A higher estimate of 0.21 was reported by Rashidi *et al.* (2011) for direct heritability of pre-weaning average daily gain in Markhoz goat breed. The pe^2 estimates were higher than the estimated values for direct heritability of ADG2 and ADG3. Gowane *et al.* (2011) estimated pe^2 of 0.02 for average daily gain from weaning to six months of age in Sirohi goat. This value was lower than the corresponding estimated value for ADG2 in Raeini Cashmere goat in the present study.

The Kleiber ratio in a certain period is the growth rate scaled by metabolic weight at the final of that period and can be considered as an indirect selection criterion for improvement of feed efficiency and growth traits under extensive breeding systems (Abegaz *et al.* 2005). Selection for increased body weights in kids usually leads to increased mature weight and nutritional requirements for mature does.

Furthermore, such selection practice increases sensitivity to environmental factors such as drought and decreases rate of reproduction (Lasslo *et al.* 1985). Thus, selection based on Kleiber ratio has been suggested as a means for addressing the mentioned issues, as it will impose less selection pressure on mature weight of animals. Direct and maternal heritability estimates for KR1 were 0.19 and 0.11, respectively.

Rashidi *et al.* (2011) reported direct and maternal heritability estimates of 0.27 and 0.04 for pre-weaning Kleiber ratio in Markhoz goat, respectively.

The estimates of pe^2 for KR2 and KR3 of Raeini Cashmere goat were 0.08 and 0.10, respectively. Gowane *et al.* (2011) reported an estimate of 0.02 for Kleiber ratio from weaning to six months of age in Sirohi goat which was lower that the corresponding estimated value for KR3 in the present study.

To our knowledge there are no published estimates on genetic parameters of growth efficiency related traits in goat breeds. In the present study, direct heritability estimates for GE1, GE2 and GE3 were 0.07, 0.09 and 0.08, respectively. Ghafouri-Kesbi and Gholizadeh (2017) estimated genetic parameters for growth efficiency-related traits including growth efficiency from birth to weaning, from weaning to six months of age and from weaning to yearling age in Baluchi sheep breed. The authors reported direct heritability estimate of 0.06 for both growth efficiency from birth to weaning and from weaning to six months of age. Those results were in mostly agreement with the estimated values in the present study for direct heritability of GE1 and GE2. Among the investigated growth efficiency traits discussed in the present study, only GE1 was influenced by maternal additive genetic effects; the maternal heritability estimate for GE1 was 0.10.

Ghafouri-Kesbi and Gholizadeh (2017) obtained an estimate of 0.04 for maternal heritability of pre-weaning growth efficiency in Baluchi sheep.

Direct-maternal genetic correlation estimates for both ADG1 (-0.38) and KR1 (-0.65) were negative, suggesting that selection for increasing ADG1 and KR1 in Raeini Cashmere kids unfavorably affects maternal ability of does for these traits. In other words, the performance of Raeini Cashmere kids for pre-weaning average daily gain and Kleiber ratio may be negatively influenced by the corresponding ability of their dams. Contrary to us, Van Niekerk *et al.* (1996) reported values of 0.1137 and 0.4955 for direct-maternal genetic correlation in Adelaide Boer goat breed.

Rashidi *et al.* (2011) reported a value of -0.62 for direct-maternal genetic correlation of pre-weaning Kleiber Ratio in Markhoz goat which agrees with the corresponding value in the present study (-0.65). Negative value for direct–maternal additive correlations might be induced by environment or amplified by management system (Swalve, 1993).

Correlation for direct-maternal additive genetic effects for GE1 was positive, indicating that selection for improving pre-weaning growth efficiency of kids would also favorably supported by the maternal ability of does. Maniatis and Pollott (2003) pointed out that the correlation between direct and maternal additive genetic effects may be influenced by the factors such as data structure proportion of dams with their own records.

Genetic correlations between traits were ranged from -0.95 for ADG3-KR1 to 0.99 for ADG1-KR1, ADG2-KR2, ADG3-KR3 and KR1-GE1; implying that non-all the studied traits can be improved simultaneously following selection and that at each time, selection should focus on the trait of the highest importance. Genetic correlations among the studied traits in the same period were near unity; implying that genetic selection for any of studied traits in the same period will bring positive genetic change for two remaining ones (Table 5). High and positive estimates for genetic correlation among the studied traits in the same period indicate that the genes with pleiotropic effect may be involved in each considered period.

A high genetic correlation estimate of 0.97 was obtained between pre-weaning average daily gain and Kleiber ratio by Van Niekerk *et al.* (1996) in Adelaide Boer goat breed. Ghafouri-Kesbi and Gholizadeh (2017) also found high genetic correlation estimate of 0.939 between pre-weaning growth rate and pre-weaning Kleiber ratio in Baluchi sheep breed but found lower genetic correlation (0.475) between pre-weaning growth rate and pre-weaning growth efficiency than that of estimated in the present study (0.98).

Similar to us, Ghafouri-Kesbi *et al.* (2011) reported high genetic correlation for pre-weaning average daily gain and pre-weaning Kleiber ratio (0.97) and post-weaning average daily gain and post-weaning Kleiber ratio (0.86) in Zandi sheep breed.

In general, phenotypic correlations among the studied traits were lower than those of genetic correlations. Phenotypic correlations among the studied traits in the same period were positive and high, ranged from 0.77 for ADG2-GE2 to 0.96 for ADG3-KR3, implying favorable phenotypic changes for any of the studied traits by selection in the same period.

Such trend was also found by Ghafouri-Kesbi *et al.* (2011) in Zandi sheep. High genetic (0.92), phenotypic (0.85) and residual (0.98) correlation estimates were obtained between pre-weaning average daily gain and Kleiber ratio in Markhoz goat (Rashidi *et al.* 2011) which were in agreement with the obtained estimates in the present study. Genetic, phenotypic and environmental correlation estimates between average daily gain from birth to weaning and from weaning to six months body weight were estimated as -0.19, -0.003 and 0.01 in Sirohi goat breed by Gowane *et al.* (2011) which were in general agreement with the corresponding estimates in the present study. Similar to us, Shaat and Maki-Tanila (2009) reported negative and low genetic correlation between ADG1 and ADG2 in Zairabi goat.

In a previous study, Barazandeh *et al.* (2012) estimated values of 0.88, 1.00 and 0.85 for phenotypic, direct genetic and residual correlations of pre-weaning average daily gain and Kleiber ratio in Raini Cashmere goat which were in concordance with the corresponding estimates obtained in the present study.

CONCLUSION

Generally, all the studied traits were influenced by maternal effects. Maternal genetic effects were significant sources of variation in the pre-weaning period while maternal permanent environmental effects were sizeable in post-weaning period. The estimates of direct heritability and direct additive genetic coefficient of variation for the studied traits in Raeini Cashmere goat showed little additive genetic variability in these traits which may decrease the efficiency of breeding programs aimed at increasing the growth efficiency of Raeini Cashmere goat flocks. The traits considered in the same period had high and positive genetic, phenotypic and residual correlations. In general, genetic, phenotypic and residual correlations between pre-weaning (ADG1, KR1 and GE1) and post-weaning (ADG2, KR2 and GE2) studied traits were negative and low estimates.

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