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RESEARCH ARTICLE

Risk Factors Associated with Passive Immunity, Health, Birth Weight and Growth Performance in Lambs: II. Effects of Passive Immunity and Some Risk Factors on Growth Performance During the First 12 Weeks of Life [1]

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Summary

The primary objective of this study was to evaluate the relationship between passive immunity and growth performance in lambs in neonatal and post-neonatal periods. The study also evaluated the effect of gender, type of birth, birth weight and health of lambs, lambing season and dam's age on growth performance. This study included two crossbred Akkaraman flocks (n=301) in Kars, Turkey. The results disclosed that serum IgG concentration determined at 24^{th} of birth (SIgG-24) was significantly associated with growth performance in both periods (P<0.001) but this relationship was poor (R^2=0.148 to 0.198). Neonatal growth performance was influenced only by birth weight, health status, SIgG-24 and type of birth (R^2=0.527 to 0.721 P<0.001) on multiple stepwise regression analyses. The study also disclosed that post-neonatal growth performance was affected by all variables (P<0.001 R^2=0.471 to 0.472). This study suggested that passive transfer cause a significant amount of variation in growth performance for lambs from birth to 12 weeks of life, a conclusion that has not previously been identified. It also disclosed positive association among growth performance, birth weight, type of birth, gender, health status of lambs, dam's age and lambing season. The growth performance was rendered by dam's age (≤2 years old), twin lambs, female lambs, winter lambing, illness, and birth weight of ≤3 kg. These factors should be taken into consideration and dealt with in order to increase growth performance so that which farm productivity and profitability is maintained.

Keywords: *Lamb, Passive immunity, Growth performance, Risk factors*

Kuzularda Pasif İmmünite, Sağlık, Doğum Ağırlığı ve Büyüme Performansı İle İlişkili Risk Faktörleri: II- Pasif İmmünite ve Bazı Risk Faktörlerinin İlk 12 Haftalık Büyüme Performansı Üzerine Etkisi

Özet

Bu çalışmanın temel amacı kuzularda neonatal ve sonraki periyotta pasif immünite ve büyüme performansı arasındaki ilişkinin belirlenmesidir. Çalışmada ayrıca kuzunun cinsiyeti, doğum tipi, doğum ağırlığı ve sağlığı ile birlikte kuzulama sezonu ve anne yaşının büyüme performansı üzerine etkisi değerlendirildi. Çalışma Türkiye'de Kars'ta iki Akkaraman melezi sürüde (n=298) yürütüldü. Sonuçlar doğumdan sonra 24. saat serum IgG konsantrasyonu ve her iki dönem büyüme performansı arasında önemli (P<0.001) fakat zayıf (R^2=0.148-0.198) bir ilişki olduğunu göstermiştir. Çoklu adımsal regresyon modeli ile neonatal büyüme performansının sadece doğum ağırlığı, sağlık durumu, SIgG-24 ve doğum tipinden etkilendiği (P<0.001R^2=0.527-0.721) belirlendi. Aynı metot ayrıca post-neonatal büyüme performansının tüm değişkenlerden etkilendiği göstermektedir (P<0.001 R^2=0.471-0.472). Bu çalışma kuzularda pasif immunitenin ilk 12 haftalık dönem büyüme performası ile önemli oranda varyasyon gösterdiğini işaret etmektedir. Bu sonuç daha önce değerlendirilmemiştir. Çalışmada ayrıca doğum ağırlığı, doğum tipi, cinsiyet, sağlık durumu, anne yaşı ve kuzulama sezonunun da büyüme performansı üzerine etkili olduğu belirlendi. Kuzularda anne yaşının ≤2 olması, ikiz, dişi ve kış sezonunda doğması, hastalığa maruz kalması ve doğum ağırlığının ≤3 kg olmasıınn büyüme performansını azalttığı saptandı. Bu faktörler büyüme performansını artırmak için dikkatle ele alınması gerekmektedir. Böylece çiftlik verimliliği ve karlılığı arttırılabilir.

Anahtar sözcükler: *Kuzu, Pasif immünite, Büyüme performansı, Risk faktörleri*

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INTRODUCTION

Most of the outputs from livestock consist of food production in the form of meat, milk and other products. The profitability of sheep farm is significantly limited by cosideable growth performance, low market weight and ill-health [1-5]. Therefore, it is important for the sheep industry to be well informed about the external, controllable factors that affect live weight. For this reason, much work has been done on the effects of genetic and non-genetic factors on growth performance. The growth rate of lambs, particularly during the early stages, is influenced by several factors including breed, the ewe's diet, milk yield, parity or age of the ewe, type of birth, gender, birth weight and environmental factors such as the lambing season [1,2,4,6]. Thus, there is a need for evaluating the effects of animal-related and environmental factors on growth traits if adequate level of growth performance is to be attained. Nonetheless, not enough research has been carried out in Turkey to determine the relationship between risk factors and growth performance in lambs [7-9].

Recent studies indicate that passive immunity may be a significant factor that affects growth performance [10]. Lambs are born agammaglobulinemic at birth due to syndesmochorial placentation. Therefore, immunity during the neonatal period depends on the passive transfer of maternal IgG through the colostrum. This process is referred as passive transfer of immunity (PTI), determined by measuring serum IgG concentration (SIgGC) [10-13]. If neonatal lambs are unable to obtain and absorb a sufficient amount and quality of colostral IgG in the first 12 h of birth, secondary immunodeficiency disorder in other words Failure of Passive Transfer (FPT) develops. FPT results in hypogammaglobulinemia and predisposes neonataes to diseases [10-16]. There exists sufficient amount of knowledge on the association between PTI and the risk of illness and death in neonatal lambs [10,12,14,15], but not enough has been reported about the potential long-term implications of passive transfer. PTI appears to help predict health and productivity in juvenile ruminants, both before and after the neonatal period [10,11]. Studies to date have indicated that there appear a significant linear correlation between passive immunity and growth performance in different periods during the first 6 months of life in beef [17], dairy heifer [18] and buffalo [19] calves, as well as in dairy lambs [10,20] and dairy goat kids [21,22]. Furthermore, an association between PTI and first lactation, milk yield and milk fat content in dairy heifer calves [23] and pre- and post-weaning growth performance in crossbreed calves have been found [24,25]. Never-theless, very little information is available on how passive transfer affects growth performance in lambs, especially after the neonatal period.

To the authors' knowledge, no reports have been published on the predictive value of passive transfer for the growth performance of lambs in long term period. Therefore, the primary objectives of this study was to determine the relationship between passive immunity and growth performance in different periods of the first 12 weeks of life and the secondary purpose of this study was to evaluate the effect of gender, type of birth, birth weight, health of lambs, lambing season and dam's age on growth performance in lambs of two crossbred Akkaraman flocks in Kars, North-Eastern Anatolia, Turkey.

MATERIAL and METHODS

Animals, Data Collection and Farm Management

This study was carried out on two sheep farms located in the central of Kars province in North-Eastern Anatolia, Turkey in 2009. All ewes and lambs were kept under identical feeding and management conditions. Management was typical of North-Eastern Anatolian flocks with lambs being born in winter (December to February) or spring (March to May), and being raised intensively. Other than deworming agents and routine vaccines against clostridial diseases, no drugs and other compounds administered during gestation or parturition. Only lambs resulting from observed parturitions were included in the study. Plastic ear tags were attached to both ears of study lambs soon after their birth and the following data were recorded for each lamb: an individual identification number, gender, date of birth, age of dam, ear tag number of dam and type of birth. The lambs were weighed at birth (before colostrum intake) using a scale [CASIA DB2-150 kg (±30 g)]. After this procedure, lambs were allowed to naturally suckle their dams. The newborn lambs were kept with their dams during their first week of life. After this period, the lambs were transferred to a separate pen and allowed to suckle twice a day (in the morning and evening) for 3 months. Lambs had access to hay after the first week of neonatal life, and to straw and commercial growth feed (Bayramoglu AS, Turkey) from the third week of life. This feeding regime lasted for three months. Subsequently, lambs were turned on pasture and supplemented with hay and commercial feed when they were brought in for the night. No vaccines, drugs or other compounds were administered to lambs during the neonatal period. Deworming agents and routine vaccines against clostridial diseases were administered to the lambs after the neonatal period. The lambs were also weighed on day 28 and day 84 using the same scale.

Blood Sampling and IgG Measurement

Blood samples were collected from lambs by jugular venipuncture at 24±1 h. Serum was harvested by centrifugation and stored at –20°C until analysis. SIgG-24 was measured using a commercial ELISA kit (Bio-X Competitive ELISA Kit For Ovine Blood Serum IgG Assay-BIO K 350, Bio-X Diagnostics, Belgium).

Clinical Examination

Clinical examination was performed as previously defined by the authors [14]. The health status of the lambs was monitored by visiting farms daily during the neonatal period and every two days in the period covering 5 to 12 weeks of life referred as post-neonatal period in the text.

Statistical Analysis

The present study was conducted on 301 Akkaraman crossbreeds and 347 lambs born to these ewes. Those lambs whose birth weight, body weight on 28 and 84 days of life, gender, type of birth, health status, serum IgG concentration, birth date and dam's age were recorded and those survived neonatal or post-neonatal period were included in statistical analysis. Therefore, only 298 and 280 lambs were used to evaluate growth performance during neonatal and post-neonatal periods, respectively. Mean ± SD (Range) values for SIgG-24, birth weight, neonatal (day 28) and post-neonatal (day 28 to day 84) weight, neonatal (birth to day 28) and post-neonatal (from 28 to 84 days) Average Dailiy Gain (ADG) were calculated. The lambs were categorized as healthy or ill based on their clinical examination results. Birth weights were categorized as low (≤ 3 kg), medium (>3 to ≤4 kg) or high (>4 kg). Dam's age was categorized as ≤2, 3, 4 or ≥5 years. SIgG-24 was also categorized as <1000 mg/dL, 1001-2000 mg/dL or >2000 mg/dL. The Tukey HSD test was used to identify differences in growth performance in lambs grouped according to SIgG-24, birth weight and dam's age. Independent Samples T test was used to identify variations in growth performance according to gender, type of birth, birth date and health of the lambs. Multivariable stepwise linear regression analysis (MSRA) was used to evaluate the association between SIgG-24, birth weight, age of dams (considered as continuous independent variables), type of birth, gender and health status of lambs, lambing season (considered as categorical independent variables) and the growth performance outcomes, including ADG and body weight. The linear regression model with the all potential independent variables considered in the study defined as follows: $Y = \alpha + \beta_1X_1 + \beta_2X_2, \beta_3X_3 + \beta_4X_4 + \beta_5X_5 + \beta_6X_6 + \beta_7X_{7+\varepsilon}$. Where Y denotes the weight or ADG, X_1 is the birth weight, X_2 is the type of birth (twin=1 and single=0), X_3 is the health of the lambs (healthy=0 and ill=1), X_4 is the passive immune status (SIgG-24), X_5 is gender (male=0 and female=1), X_6 is age of the dam and X_7 is the lambing season [Spring (March, April, May)=0 and Winter (December, January, February)=1], α is the y-intercept, and β_1, β_2 β_3, β_4 β_5, β_6, β_7 are the regression coefficients and Ɛ, indicates the random part of the theoretical model. To identify the best models in the stepwise technique, the coefficients of determination (R^2) were used. The coefficient of determination was multiplied by 100 and expressed as a percentage to indicate the total variation in Y explained by the selected independent variables. The relationship between SIgG-24 and growth performance (weight or ADG) was explored by simple regression analysis. The methods of multivariable and simple regression have been described previously in detail [10,11]. The computer program SPSS was used for all analyses and values of P<0.05 were considered to be significant. The program Origin 6 was used to obtain scatter diagram illustrations (Origin 6 Copyright© 1991-1999 Microcol TM, Software, Inc) in regression analysis.

RESULTS

The study evaluated 298 lambs and mean SIgG-24 was 22.1±10.74 (2.71-53.02) mg/mL. Birth weight ranged from 2.260 to 5.900 g (mean ± SD, 4.075±631 g). Changes in growth performance based on birth weight, gender, type of birth, SIgG-24 and health status in lambs, age of dam and lambing season have been given in *Table 1*. In addition, the effects of these factors on neonatal and post-neonatal growth performance (ADG or body weight) have been presented in *Table 2* and *Table 3*, respectively.

Effect of Passive Immunity and Other Some Variables on Neonatal Growth Performance

Body weight at 28 days of life ranged from 4.364 to 14.015 g (8.852±1.930 g). Average daily gain from birth to day 28 ranged from 16 to 339 g/d (mean ± SD, 170±53 g/day). Lambs with SIgG-24 levels below 1000 mg/dL had significantly lower neonatal growth performance (ADG or body weight) than lambs with SIgG-24 in the range of 1001 to 2000 (P<0.001) and above 2000 mg/dL (P<0.001). Lambs having SIgG-24 in the range of 1001 to 2000 mg/dl had significantly lower growth performance when compared to lambs with SIgG-24 above 2000 mg/dL. With regard to birth weight, the neonatal growth performance in the low weight category was significantly lower than those of medium (P<0.01) and high birth weight category (P<0.001). Similarly, lambs with medium birth weight had significantly (P<0.001) lower weight or ADG than those with high birth weight. Neonatal growth performance was significantly lower in twins (P<0.001) and diseased (P<0.001) lambs. Body weight of day 28 was significantly (P<0.05) higher in male lambs when compare to female lambs. However, ADG from birth to 28 day was not significantly different between male and female lambs (P>0.05). There was no significant difference in growth performance between lambs born in spring and winter seasons (P>0.05). Dam's age did not significantly effect on neonatal growth performance.

The simple regression models disclosed that SIgG-24 was significantly (P<0.001) associated with both weight determined on day 28 (R^2 = 0.148; *Fig. 1A*) and ADG determined for the period of birth to 28 days (R^2 = 0.151; *Fig. 1B*). Each 1 mg/mL increase in SIgG-24 was associated with a 1.92 g/d increase in ADG and a 69.2-g increase in body weight of day 28.

On multiple regressions analysis, type of birth, SIgG-

Table 1. *Changes in growth performance of lambs according to various factors*
Tablo 1. *Kuzularda bazı faktörlere bağlı büyüme performansındaki değişiklikler*

Factor	Group	Period					
		Neonatal Growth Performance (g) (up to 4 Weeks)			Post-Neonatal Growth Performance (g) (5 to 12 Weeks)		
		n	WG1	ADG1	n	WG2	ADG2
SIgG-24 (mg/dL)	≤1000	25	7029±19513[a]	120±54[a]	22	8793±2066[a]	156±37[a]
	1001-2000	142	8631±2026[b]	165±55[b]	135	11077±2844[b]	197±51[b]
	>2000	131	9439±1530[c]	186±43[c]	123	12700±2313[c]	226±41[c]
Type of Birth	Twin	80	6794±1178***	118±34***	74	9639±2486***	172±44***
	Single	218	9606±1569	190±45	206	12320±2561	220±46
Gender	Male	160	9109±2011*	175±57	150	12069±2849**	215±51**
	Female	138	8554±1794	165±48	130	11084±2656	197±47
Dam Age (Years)	≤2	45	8545±1923[a]	168±58[a]	41	10696±2958[a]	190±53[a]
	3	134	8766±1880[a]	169±49[a]	126	11232±2787[ac]	200±50[ac]
	4	82	9087±1795[a]	176±51[a]	78	12109±2588[bc]	216±46[bc]
	≥5	37	9017±2370[a]	168±65[a]	35	12946±2520[b]	231±45[b]
Health Status	Ill	40	7411±2125***	129±60***	81	10313±2426***	184±43***
	Healthy	258	9075±1802	177±49	199	12141±2774	216±50
Lambing Season	Winter	91	8980±1835	176±52	87	10671±2615***	190±47***
	Spring	207	8796±1792	168±54	193	12036±2783	214±50
Birth Weight (g)	Low	17	6266±1175[a]	124±40[a]	16	8723±3074[a]	155±55[a]
	Medium	117	7622±1606[b]	143±51[b]	109	10512±2595[b]	187±44[b]
	High	164	9997±1308[c]	195±41[b]	155	12684±2799[c]	226±43[c]

**** P<0.001, ** P<0.01, * P<0.05,* ***WG1*** *= weight on day 28,* ***ADG1*** *= [(day 28 weight-birth weight)/28x1000],* ***WG2*** *= (weight on day 84-weight at day 28),* ***ADG2*** *= [(WG2/56)x1000]*

Table 2. *Regression models between independent variables and neonatal growth performance in lambs*
Tablo 2. *Kuzularda neonatal büyüme performansı ve bağımsız değişkenler arasındaki regresyon modelleri*

	Healthy Status	Formulas	R^2	P
Simple Regression Analysis *	General (n=298)	W=7328.9 + 69.2 x IgG	0.148	<0.001
		ADG=128.2 + 1.92 x IgG	0.151	<0.001
	Healthy (n=258)	W=7805.8 + 55.3 x IgG	0.105	<0.001
		ADG =141.8 + 1.53 x IgG	0.109	<0.001
	Ill (n=40)	W=5837.9 + 98.2 x IgG	0.215	<0.01
		ADG=86.27 + 2.67 x IgG	0.197	<0.01
Multiple Regression Analysis **	**Model**	**Formulas**	R^2	**P**
	Onset	W=2.4 x BW - 949.7	0.622	<0.001
	Final	W=1602 + 1.7 x BW - 1186 x TB - 796 x HS + IgG x 21.1	0.721	<0.001
	Onset	ADG=190.3-72*TB	0.364	<0.001
	Final	ADG=57.4 - 42 x TB + 0.28 x BW - 28.48 x HS + 0.75 x IgG	0.527	<0.001

W *= Weight (g),* ***ADG*** *= Average daily gain (g),* ***BW*** *= Birth weight (g),* ***TB*** *= Type of birth,* ***HS*** *= Health status of lambs,* ***IgG*** *= Serum IgG concentration at 24 h after birth,* ***AD*** *= Age of dam,* ***LS*** *= Lambing season, * Indepedent variable: IgG and dependent variable: (W or ADG), ** Independent variables: BW, TB, HS, IgG, Gender, AD and dependent variable: (W or ADG)*

24, birth weight and health of lambs were significantly associated with body weight at day 28 and ADG from birth to 28 days. The variation in weight at day 28 and ADG from birth to day 28 was 72% (R^2=0.721) and 53% (R^2=0.527) respectively *(Table 2)*.

Effect of Passive Immunity and Other Some Variables on Post-neonatal Growth Performance

Total body weight from day 28 to day 84 (post neonatal period weight) ranged from 3.400 to 18.650 g (mean ± SD:

***Table 3.** Regression models between independent variables and post-neonatal growth performance in lambs*
***Tablo 3.** Kuzularda post-neonatal büyüme performansı ve bağımsız değişkenler arasındaki regresyon modelleri*

	Healthy Status	**Formulas**	**R^2**	**P**
Simple Regression Analysis*	General (n=280)	W = 9010.9 + 118.5 x IgG	0.198	<0.001
		ADG = 160.4 + 2.1 x IgG	0.198	<0.001
	Healthy (n=199)	W = 9642.2 + 105.9 x IgG	0.167	<0.001
		ADG = 171.7 + 1.89 x IgG	0.168	<0.001
	Ill (n=81)	W = 8452.2 + 103.9 x IgG	0.145	<0.001
		ADG = 150.3 + 1.86 x IgG	0.146	<0.001
Multiple Regression Analysis**	**Model**	**Formulas**	**R^2**	**P**
	Onset	W = 2165.7 + 2.32 x BW	0.273	<0.001
	Final	W = 4918.5 + 1.2 x BW + 68.3 x IgG - 956.9 x LS - 1097.2 x HS - 1088.4 x TB + 440.2 x DA - 639.9 x Gender	0.471	<0.001
	Onset	ADG = 38.2 + 0.041 x BW	0.273	<0.001
	Final	ADG = 87.29 + 0.021 x BW + 1.2 x IgG - 17.1 x LS - 19.5 x HS - 19.4 x TB + 7.89 x AD - 11.5 x Gender	0.472	<0.001

***W** = Weight (g), **ADG** = Average daily gain (g), **BW** = Birth weight (g), **TB** = Type of birth, **HS** = Health status of lambs, **IgG** = Serum IgG concentration at 24 h after birth, **AD** = Age of dam, **LS** = Lambing season, * Indepedent variable: IgG and dependent variable: (W or ADG), ** Independent variables: BW, TB, HS, IgG, Gender, AD and dependent variable: (W or ADG)*

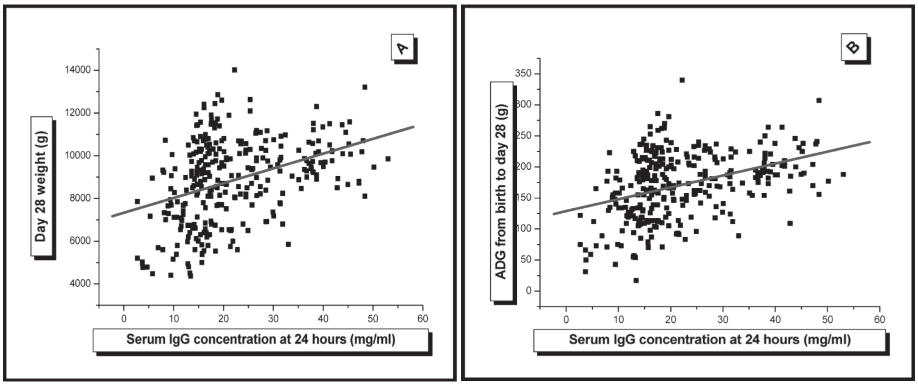

Fig 1. Scatterplots of serum IgG concentration (mg/mL) 24 h after parturition in 298 lambs versus neonatal growth performance [body weight (g) at day 28 (A), ADG (g/d) from birth to day 28 (B)]. In each graph, the solid line represents the best fit for the data, as determined by means of simple linear regression

Şekil 1. 298 kuzuda doğumdan sonra 24. saat serum IgG konsantrasyonu ve neonatal büyüme performansı [28. gün vücut ağırlığı (g) (A), doğumdan 28. güne kadar olan ADG (g/d) (B)] arasındaki ilişkiyi gösteren dağılım grafiğinin görünümü. Basit doğrusal regresyon ile belirlenen grafikte, koyu çizgi, iki değişken arasındaki en iyi uyum noktasını göstermektedir

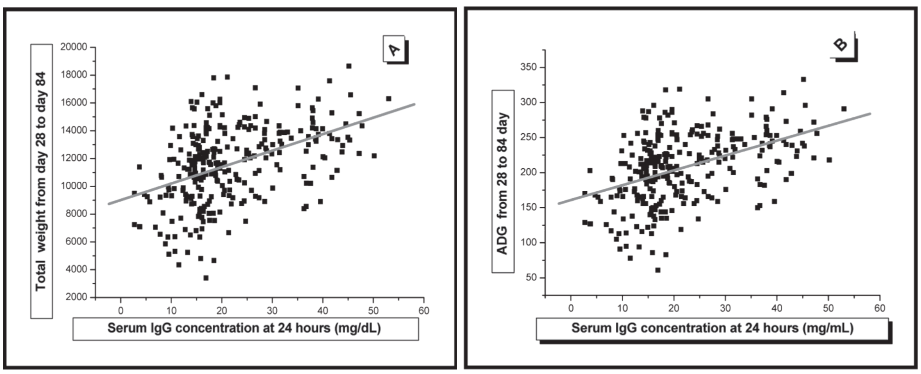

Fig 2. Scatterplots of serum IgG concentration 24 h after parturition in 298 lambs versus post-neonatal growth performance [total gain (g) (C) and ADG (g/d) (D) between day 28 and day 84)]. In each graph, the solid line represents the best fit for the data, as determined by means of simple linear regression

Şekil 2. 280 kuzuda doğumdan sonra 24. saat serum IgG konsantrasyonu ve post-neonatal büyüme performansı [28 ve 84. günler arasındaki gün vücut ağırlığı (g) (A), doğumdan 28. güne kadar olan ADG (g/d) (B)] arasındaki ilişkiyi gösteren dağılım grafiğinin görünümü. Basit doğrusal regresyon ile belirlenen grafikte, koyu çizgi, iki değişken arasındaki en iyi uyum noktasını göstermektedir

11.612±2.799 g). ADG during this period ranged from 60 to 333 g/d (mean ± SD: 207±50 g/d). Lambs with SIgG-24 levels below 1000 mg/dL had significantly lower post-neonatal growth performance than lambs with SIgG-24 in the range of 1001 to 2000 (P<0.001) and SIgG-24 above 2000 mg/dL (P<0.001). As the SIgG-24 increased the growth performance was enhanced *(Table 2)*. Lambs in low birth weight had significantly lower growth performance when compare to those born with medium (P<0.001) and high birth weight (P<0.001) in post-neonatal period. Lambs born from dams aged 4 (P<0.05) and ≥5 years old (P<0.01) had significantly better growth performance during the post-neonatal period when compare to other categories. Lambs born in the winter season, twin and female lambs and those with exposure to any disease had significantly lower growth performance from day 28 to day 84 than their contemporaries born in the spring season (P<0.001), singleton (P<0.01), male lambs (P<0.001) and those that remained healthy (P<0.001).

The simple regression models showed that SIgG-24 was significantly (P<0.001) associated with body weight gain (R^2 = 0.198; *Fig. 1C*) and ADG from day 28 to day 84 (R^2=0.198 *Fig. 1D*). Each 1 mg/mL increase in SIgG-24 was associated with a 2.1 g/d increase in ADG and a 118.5 g increase in weight during the post neonatal period.

Birth weight, gender, type of birth, SIgG-24 and health of lambs, age of dam and lambing season had significant relationship with body weight and ADG from day 28 to day 84 on multiple stepwise regression analysis. The final model showed that 47% (R^2=0.471) of the variance in total weight gain and 47% (R^2=0.472) in ADG from day 28 to day 84 was explained by the independent variables.

DISCUSSION

Recent studies have shown that passive immunity in newborn ruminants [17-22] not only helps to prevent disease but also enhances growth performance. However, the relationship between growth performance and passive immunity in lambs was studied for only healthy and small number of lambs (generally <40) and the period generally restricted to neonatal period (first 28 days of life) [10,15,20]. Therefore this study explained the relationship between passive immunity and other parameters and growth performance beyond the neonatal period for the first time.

Passive Immunity and Growth Performance

The results of our study indicated that passive transfer, was a significant source of variation in both neonatal and post-neonatal periods with regard to growth performance in lambs that were allowed to suckle naturally. Similar results were reported for dairy heifer calves [18,23,25], dairy healthy goats [21,22], beef calves [17,24] and healthy buffalo calves [19]. Our study determined a significant positive linear correlation between SIgG-24 and body weight at day 28 and ADG from birth to day 28 as reported by a single previous study [10] but this study was conducted only 20 healthy lambs. However, no study has yet investigated the relationship between growth performance and SIgG-24 in lambs during the post-neonatal period. The present study also revealed a significant linear relationship between SIgG-24 and post-neonatal growth performance as SIgG-24 increased, the growth performance also improved significantly in both periods of life.

The present study did not explicitly disclose the biological basis for relationship between SIgG-24 and growth performance. However, this relationship can be explained by a number of theories in the light of earlier studies [10,19,21]. First of all, there may be a direct cause-effect relationship between SIgG-24 and growth performance as passive transfer of immunity might have enhanced efficient metabolic systems and rendered disease occurrence which in turn contributes to better growth performance [10,12,21,26,27]. The positive linear relationship among SIgG-24, health status and growth performance in this study added credence to above assumptions as low serum IgG concentrations at 24 to 72 h associated with reduced performance of surviving lambs through increased susceptibility to diseases [10,12,21,27]. Secondly, Massimini et al.[10], suggested that lambs receives and absorbs not only IgG but also nonimmunoglobulin factors present in colostrums which may contribute to growth performance as it is well known that colostrum also contains nutrients, minerals, trace elements, vitamins, enzymes, hormones, growth factors, antibodies and other immunologically active component such as cells, cytokines and acute-phase proteins which are necessary for normal development [10-13,28-31]. Neonatal ruminants are pseudomonogastrics and maturation of their gastrointestinal tract is modulated by growth factors through absorption of colostrums [30,31]. In recent years, considerable number of researchers examined the relationships between the development of neonatal calves and various growth factors, such as insulin-like growth factor-I and the growth hormone [30,31] and yet this aspects remains to be explored in lambs. Studies also revealed the effect of non-immunoglubulin components such as neutrophils, serum opsonic activity, colostral cytokines, complement proteins and lactoferrin on improvement of weight gain by protecting against diseases [10,21,28-32] through boosting the immune and metabolic system. However, much is required to be performed with regard to the effect of non-immunoglobulin colostral content on neonatal and post-neonatal health and growth [10].

In contrast, many researchers also reported no correlation between passive immunity and growth performance in ruminants [15,20,26,33,34]. However, these studies had many different aspects to the present study such as small number of subjects (n<40) [15,20] and species of ruminant (goat, calves) studied [21,26,33,34], method of colostrum feeding (heat treated colostrums, bottle fed) [26,34], and measurement of Ig concentration (zinc sulfate turbidity test) [33,34], and length of study [20,21].

Other Factors that Affect Growth Performance

The present study revealed that the variation attributable to SIgG-24 accounted on average for 15% of the total variation in ADG and weight from birth to day 28 and 20% of the total variation in weight and ADG from day 28 to day 84. Thus, a large proportion of variation in growth performance was not explained by SIgG-24. Multi-variable stepwise linear regression analysis determined a considerable variation in growth performance by health status, gender, type of birth, birth weight, dam's age and lambing season. Of these factors, birth weight, type of birth and health status were considerable source of variation for growth performance in neonatal period, while post-neonatal growth performance was influenced by all variables.

Health Status

Health of the lambs was positively associated with growth performance and in both periods as healthy lambs had a better growth rate than lambs exposed to disease and disease caused 796 g and 1097 g decrease in body weight for each lamb that became ill in neonatal and post-neonatal period, respectively. It is well known that the severity and duration of the disease results in decreased growth performance [26,27]. This is attributed to the fact that diseased animal cannot fully take advantage of the nutrients for growth and development, since a portion of the ingested nutrients must be committed to attacking and eliminating pathogens as well as repairing any damage caused [18,35].

Birth Weight

A positive and strong linear relationship between birth weight and growth performance in both periods was evident in our study. As birth weight increased, growth performance also increased considerably. Similar results were reported by previous studies [2,4,36,37]. Several explanations have been put forward. Of these, lambs born with acceptable birth weight (generally >3 kg) are able to ingest sufficient amounts of colostrum earlier because they are physically strong and viable. This in turn not only increases their resistance to diseases, it also ensures that they ingest many components of the colostrum that affect growth performance [10,38]. On the other hand, lambs with lower birth weight are physically weak, to stand at birth and to suckle sufficient amount of colostrum and this consequently results frequent exposure to disease as was the case in our study where lambs with low birth weight were more prone to disease development and poor growth performance [35,38-40]. It is already known that lambs with a birth weight of ≤3 kg usually suffer failure of passive transfer and that most of them die during the neonatal period, or even if they survive, they do not exhibit good growth performance [5,12,35,39-41]. Other explanation may be that lambs with low birth weights are less mature than those with high birth weights with regard to the development of their metabolic and endocrine systems that improve lambs ability to generate energy from amino acids and sustain gluconeogenesis immediately after parturition [42,43].

Type of Birth

Type of birth had a significant effect on the weight of the lamb as single-born lambs were heavier and had higher ADG in the neonatal and post-neonatal periods as compared to twins in this study. Twin lambs were approximately 1088 g lighter than singleton lambs in the neonatal period and 1186 g in the post-neonatal period and ADG of twin lambs was 42 g lower than single lambs during the neonatal period and 19 g lower during the post-neonatal period. Single lambs have already been reported to attain better growth performance in comparison to twin lambs [2,4,7,44-48]. This has been attributed to competition between the siblings for dam's milk supply, inadequate milk to rear two lambs, lower birth weight of twins, mismothering, hypothermia, or the inability to obtain sufficient milk or colostrum due to physical weakness [1,6,8,12,35,41].

Gender

This study revealed no significant association between gender and growth performance in the first month of life on multiple regression analysis as reported by others [2,4,47]. On the contrary, studies reported that gender had a significant effect on ADG and weight in this period [36,45,48]. On the other hand, male lambs recorded a higher ADG and were heavier than female lambs from day 28 to day 84, and gender was a significant source of variation in post-neonatal growth performance in this study. Similar results have previously been reported [4,6,7,8,45]. The faster growth of male lambs could be due to hormonal differences in their endocrinological and physiological functions which play role in enhancement of growth and their superior weight at birth compared to females [4,6,44]. On the contrary studies also reported no significant effect of gender on ADG [1,2,36,44,47] and body weight [1,2,48] from birth to three months of life.

Age of Dam

Dam's age had no significant effect on growth performance in the neonatal period as earlier studies reported [2,4,44,45] but some studies found the effect of parity or dam's age on weight at day 28 or on ADG from birth to day 28 [36,47]. On the other hand multiple regression analysis revealed a significant positive effect of dam's age on growth performance in post-neonatal period. This effect might be explained by the difference in milk production and maternal care since maiden or first parity ewes are less mature physiologically and consequently produce less milk, and are less experienced in taking care of their lamb [2,4,6,9,44,47]. Additionally, younger ewes produce lighter lambs due to competition between fetus growth and maternal growth, which has a negative effect on birth weight and subsequent growth performance [1,38,41,49-51]. However, contradicting results suggesting no effect of parity on growth performance from birth to three months of life [1,2,4,44,45].

Lambing Season

Lambing season had no effect on growth performance in the neonatal period in this study as reported by Taye et al.[4]. In contrast, earlier studies reported that lambing season had a significant effect on neonatal growth performance [2,36,47]. However, a significant relationship between lambing season and growth performance was determined in the post-neonatal period on multiple stepwise regression analysis. Other studies have also reported positive association between lambing season and growth performance during the first three months of its life [6,9,36,47,51]. Studies suggested that lambing season could cause changes in growth performance due to temperature during the birth season, morbidity rates, birth weight due to the dam's nutrition in late pregnancy and milk yield due to feeding regime of dams in post-parturient period [6,8,35,44,46,51].

This study revealed association between growth performance and birth weight, type of birth, health status and SIgG-24 in neonatal period and additionally lambing season, dam's age and gender in post-neonatal period. Statistical models used in this study also suggested that variation in growth performance remained to be effected by some other factors noted previously [5,10,38,43,50]. These factors include, managemental interventions such as feeding regime and other animal-related factors such as body condition score, breed, placental development and function, dam and lamb behavior at birth, maternal ability, gastrointestinal absorptive ability of the lambs [2,6,7,38,43,50]. The amount of variation attributable to farm management procedures, the production system and the ewe's prenatal nutrition and breed was minimized in this study as all lambs were taken from two farms that had similar management practices and reared Akkaraman crossbreeds.

In conclusion, this study indicated that passive transfer causes a significant amount of variation in growth performance for lambs from birth to 12 weeks of life, a conclusion that was noted for the first time. It is possible for passive transfer monitoring programs to identify lambs suffering from FPT, but there are many factors that cause FPT [10,11,21,41]. That is to say that programs designed only to identify affected lambs will not be as effective as comprehensive flock management programs as our study has found that aside from passive immunity, growth performance is affected by birth weight, type of birth, health status of lambs, dam's age and lambing season. These factors may be improved by managemental intervention in order to increase growth performance and thus farm income and welfare.

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