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COMPARATIVE ANALYSIS OF SHEEP GROWTH TRAITS IN KARAKUL, AL-NAIMI, AND HAMDANI BREEDS

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ABSTRACT

The present study carried out a comparative analysis of various growth traits among three sheep breeds; Karakul, Al-Naimi, and Hamdani to evaluate variations in growth traits. The evaluated growth traits included body weight, circumferences (chest and abdomen), and linear dimensions (body length, wither height, and rump height) from birth to 12 months. After data collection, the impact of the studied factors on sheep growth was examined, and a correlation matrix analysis was performed to elucidate relationships between different growth metrics within and through sheep breeds. Results revealed significant breed-based variations in growth traits, with Karakul sheep consistently exhibiting superior performance in terms of body weight and linear dimensions. Minimal effects of birth season on growth traits were found across different age groups, suggesting that factors beyond seasonal variations played more substantial roles in sheep development. Highly positive correlations were observed between weight measurements at various ages, while age at puberty showed a negative correlation with weight at puberty, indicating breed-specific growth patterns. Furthermore, significant differences in growth traits between male and female lambs were identified, with males consistently exhibiting greater body weight, linear dimensions, and circumferences at all ages. In addition to the confirmed superiority of the Karakul breed over Hamdani and Al-Naimi, this analysis provides insight into the complex dynamics of sheep growth, informing breed selection, management strategies, and breeding practices in sheep farming.

Keywords: growth traits, Al-Naimi, Karakul, Hamdani, sheep

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INTRODUCTION

Various breeds of sheep are raised globally for meat, wool, milk, and skin purposes. Some breeds are specialized for specific traits, such as wool, while others serve dual purposes, producing both wool and meat (Næss, 2018). Among these, Middle Eastern sheep breeds, which play significant economic roles due to their superior growth traits and ability to withstand harsh environments and have adapted well to arid and semi-arid conditions (Chedid *et al.*, 2014), make them valuable in regions with limited water and forage resources.

These native sheep thrive on sparse vegetation, and their heat tolerance makes them well-suited for extensive grazing systems common in the region. Furthermore, Middle Eastern sheep breeds represent a rich genetic resource (Aljubouri *et al.*, 2020; Bayraktar, 2024; Parzhanov *et al.*, 2024). Their genetic diversity contributes to the resilience of local farming systems but offers opportunities for selective breeding programs aimed at enhancing desirable traits such as disease resistance, reproductive efficiency, and meat or wool quality.

The Awassi is one of the most well-known sheep breeds in Iraq. However, the breed's purity is now in question due to extensive crossbreeding with various Middle Eastern breeds. As a result, the genetic purity of the Awassi has been compromised, leading to distinct genetic subgroups. The current Awassi-derived breeds are generally smaller and exhibit traits similar to the emerging Al-Naimi breed. To ensure scientific accuracy and proper classification, the Awassi-derived sheep in this study are designated as Al-Naimi, reflecting their genetic divergence from the pure Awassi lineage. The Al-Naimi breed, believed to share a genetic background with the Awassi (Hadi *et al.*, 2020), has increased distribution in western Iraq, Saudi Arabia, and nearby countries and is known for its high milk production (Idell and Elhag, 2017).

Al-Naimi, Karakul, and Hamdani are indigenous sheep breeds of Iraq raised for both meat and wool purposes. These breeds are well-adapted to arid environments (Hızlı *et al.*, 2022). Livestock play a vital socioeconomic role in temperate and desert regions of various Middle Eastern countries. While Al-Naimi, Karakul, and Hamdani are suited to desert conditions, they differ in physical attributes such as face, coat, and tail shape. Hamdani sheep are among the most important indigenuous lines of the Karadi breed, known for their high twinning rate, large body frame, substantial fleece weight, and occasionally colorful fibers and coarse wool. This breed is characterized by large pendulous ears and the absence of horns in both sexes (Mustafa *et al.*, 2018; Fadhil and Al-Shuhaib, 2022). Hamdani sheep comprise approximately 18–20% of all sheep in Iraq and are indigenous to the northern highland settlements and rolling plains used for dry farming in the Kurdistan region (Oramari *et al.*, 2014). Al-Naimi is one of the most popular sheep breeds in Iraq, accounting for 58.2% of the total sheep population (Aljubouri and Al-Shuhaib, 2020).

Al-Naimi sheep can endure and reproduce in drought-ridden areas and regions with drastic climate changes (Al-Thuwaini *et al.*, 2020). However, they grow more slowly, are less fertile, and produce less milk than nearby breeds like Karakul and Assaf, despite having fat tails and fleece traits suitable for carpet production (Halil and Özbeyaz, 2020; Khazaal *et al.*, 2022). Nonetheless, Al-Naimi sheep are a valuable genetic resource for the sheep economy in over 30 Middle Eastern and international countries. Enhancing their productive performance in traditional breeding environments poses challenges due to factors such as diminished natural pastures, potential disease transmission, and susceptibility to heat stress from extreme temperatures (Talafha and Ababneh, 2011; Haile *et al.*, 2019). In contrast, Karakul sheep dominate many regions in Iran. This breed is widely found across various Asian countries and can be bred to produce milk, meat, and fiber while exhibiting strong resistance to adverse environmental conditions (Ferro *et al.,* 2017). Notably, Karakul sheep can have three births in two years due to their extended breeding season (Aljubouri *et al.*, 2021a and b). Iranian Karakul sheep have recently joined the indigenous Al-Naimi and Hamdani breeds in Iraq, sharing the same breeding stations.

Comparing the growth traits of sheep breeds such as Al-Naimi, Hamdani, and Karakul in Iraq offers several advantages. This comparison can assist breeders in selecting stock with desired traits, optimizing production efficiency through tailored management practices, identifying breeds better suited to local conditions, and aligning production systems with market demand. Given the importance of this data, this study aims to compare the growth traits of these three breeds and identify the breed with the highest growth trait indices based on the prevailing environmental conditions in the country.

MATERIALS AND METHODS

Ethical Approval

This work is part of research conducted at the College of Agriculture, Al-Qasim Green University (Decision no. 2266, dated 26 December 2022). The scientific committee of the College of Agriculture, Al-Qasim Green University, approved all animal trials under this project. The research was a collaboration between the Animal Production Department at Al-Qasim Green University and Al-Abbas Station, owned by the General Investment Company (Al-Khafeel Co.) in Karbala, Iraq. This station was located 32 meters above mean sea level, at a longitude of 32.6027° N and a latitude of 44.0197° E.

Animal resources

This study included 333 dams: 120 Al-Naimi, 110 Hamdani, and 103 Karakul breeds. Newborn lambs received special attention for two weeks while they were kept apart from their mothers in separate cages and fed colostrum during the first week of life, followed by alfalfa leaves, and oatmeal starter started at three weeks of age. By three months, the lambs were completely weaned from milk. The dams were provided with seasonal grass and concentrate feed ad libitum, constitutingabout 2.5% of their live body weight daily. This diet consisted of barley (59%), bran (40%), concentrated salt (1%), and freshwater. Feeding guidelines for lambs were referenced from Urbano *et al.,* (2017). All procedures involving animal care adhered to recommended welfare standards (Vaughn, 2012). In the designated breeding station, animals from both breeds were maintained under identical routines and cared for by the same staff to ensure consistent data collection.

Data collection

All newborn lambs during the three months of screened births (November, December, and January) had their ears tagged with unique identity numbers. Following the recommended protocols (Everett-Hincks and Dodds, 2008), the weight and age of their dams were recorded and monitored. The analyzed lambs from the Al-Naimi, Hamdani, and Karakul breeds were assessed for various growth traits from birth to twelve months, including weight and age at puberty. The characteristics evaluated in this study included body length (BL), wither height (WH), rump height (RH), chest circumference (CC), and abdominal circumference (AC). To ensure accuracy, all growth measurements were taken by the same personnel using consistent standards. The sheep were kept still during measurements, which were conducted in the same setting. A tape measure was used for chest and abdominal circumferences, while a measuring stick determined the wither height, rump height, and body length. A weighing scale recorded body weight in kilograms; all other measurements were made in centimeters. From the eighth month of life, the detector sheep for both breeds were released in the early morning to determine the age and weight of sexual maturity. On the farms with natural grazing, all animals had unrestricted access to feed and water.

Growth traits analysis

Descriptive statistics for various growth traits were recorded through the three distinct sheep breeds: Karakul, Al-Naimi, and Hamdani. The evaluated traits included body weight and length, wither and rump heights, and chest and abdominal circumference. The data were collected at different months of age, including birth, 3, 6, 9, and 12 months, and puberty. Additionally, the impact of birth season on the growth traits was examined among sheep born in November (n=121), December (n=105), and January (n=107). In order to evaluate the potential influence of maternal age on sheep growth traits, the growth trait indices were categorized into three distinct age groups. These groups consisted of ewes aged 2-3 years (n=104), 4-5 years (n=104), and over 5 years (n=125). Growth traits were directly compared between female and male lambs from birth to 12 months. Correlation included both numerical values and visual representations, using color-coded ellipses to indicate the direction and strength of the correlation for easier interpretation. Each cell contained a numerical value representing the correlation coefficient between the row and column variables. These coefficients ranged from -1 to 1. A value close to 1 indicated a strong positive correlation, meaning as one variable increased, the other tended to increase as well; A value nearing -1 signified a robust negative correlation, indicating that as one variable increased, the other tended to decrease. Values near 0 indicated a weak or negligible correlation. The ellipses were color-coded: blue for positive correlation and red for negative correlation. Additionally, upward-tilted ellipses indicated a positive correlation, while downward-tilted indicated a negative correlation.

Statistical analysis:

Statistical analyses were performed using IBM SPSS Statistics software, version 24.0 (IBM Corp., Armonk, NY, USA). A Completely Randomized Design (CRD) was used to structure the experimental setup and evaluate the effects of the factors under investigation. The General Linear Model (GLM) procedure analyzed variance among groups. Pairwise comparisons of group means were conducted using Duncan's multiple range test to identify statistically significant differences. A significance level (P value) of 0.05 or less was set as the threshold for statistical significance, while P values ≤ 0.01 were considered highly significant. This approach ensures the precise detection of meaningful differences and clarifies the degree of significance of the observed effects. Results are presented as means ± standard errors (SE) to illustrate central tendencies and variability. Additionally, Pearson correlation coefficients were calculated to examine relationships between weight measurements and age milestones across the investigated breeds, highlighting the degree and direction of associations among key variables. A correlation matrix was generated using the SRplot tool (Tang *et al.*, 2023) to visualize interdependencies among measured variables, aiding in data trend interpretation. By combining these statistical methods, the study ensures robust and interpretable analysis.

RESULTS

The descriptive data results revealed three modes of growth traits among the studied breeds. For body length (BL), Karakul exhibited the highest measurement at puberty (45.92 cm), followed by Hamdani (44.86 cm), and Al-Naimi (38.94 cm). The growth of BL indicated that Karakul and Hamdani had more consistent growth rates compared with Al-Naimi. Karakul showed a steady increase in BL, reaching approximately 45.92 cm by puberty. The Al-Naimi breed exhibited a similar pattern but with lower measurements, reaching around 38.94 cm by puberty. The Hamdani breed achieved a body length of approximately 44.86 cm by puberty (Fig. 1a).

In terms of body weight, all three breeds showed a similar growth pattern, with Karakul starting heavier and maintaining the heaviest weight throughout. The Karakul breed began at approximately 41.57 kg at birth and increased to about 74.5 kg by puberty. The Al-Naimi breed started with 40.07 kg of weight and grew to approximately 73.04 kg by puberty. Hamdani began slightly heavier than Al-Naimi at 40.87 kg and reached a weight of about 73.53 kg by puberty. At puberty, Karakul had the highest body weight (74.5 kg), followed by Hamdani (73.53 kg) and Al-Naimi (73.04 kg) (Fig. 1b).

In terms of wither height, Karakul had the highest measurement at puberty (76.57 cm), followed by Hamdani (73.85 cm) and Al-Naimi (73.52 cm). Both Karakul and Hamdani exhibited more consistent growth rates compared to Al-Naimi. The wither height in Karakul increased from 42.01 cm at birth to about 76.57 cm by puberty. The wither height of Al-Naimi breed started at 40.48 cm and progressed to around 73.52 cm by puberty. Hamdani began at 40.89 cm and reached approximately 73.85 cm by puberty (Fig. 1c).

The rump height of Karakul showed a significant increase from 42.37 cm at birth to 109.95 cm by puberty. While in Al-Naimi, it started at 41.54 cm and grew to around 105.44 cm by puberty. Hamdani began at 42.59 cm and reached approximately 102.97 cm by puberty. Thus, Karakul had the highest rump height at puberty (109.95 cm), followed by Hamdani (102.97 cm) and Al-Naimi (105.44 cm) (Fig. 1d).

In terms of the chest circumference, Karakul had the highest measurement at puberty (120.71 cm), followed by Hamdani (120.51 cm) and Al-Naimi (116.96 cm). Similar to the previously described traits, Karakul and Hamdani exhibited more consistent chest circumference compared to Al-Naimi. Karakul's chest circumference increased from 44.06 cm at birth to approximately 120.71 cm by puberty. The chest circumference of Al-Naimi started at 42.98 cm and grew to around 116.96 cm by puberty. Hamdani’s values began at 43.48 cm and reached about 113.65 cm by puberty (Fig. 1e).

As with other traits, Karakul exhibited the highest increase in abdominal circumference, followed by Hamdani and then Al-Naimi. This abdominal circumference index showed that Karakul had the highest measurement at puberty, increasing from 15.52 cm at birth to approximately 125 cm by puberty. Al-Naimi started at 25.45 cm and progressed to around 105 cm by puberty. Hamdani began at 54.56 cm and reached approximately 85 cm by puberty (Fig. 1f).

The birth season had no significant effect on the phenotypic differences observed among the three breeds. At birth, there were minimal differences in all traits among the breeds, with no significant variations noted across the birth seasons. As the sheep aged, growth trait differences remained non-significant across birth seasons. These linear measurements showed no significant differences among all measured traits at any age.

The breed factor significantly impacted the growth traits that were observed in the three studied sheep breeds at different age intervals. Karakul sheep consistently had the highest body weight over all ages, significantly higher than Al-Naimi sheep ($P < 0.01$) and often surpassing Hamdani as well. The difference in body weight becomes more pronounced as the sheep age, with the 12-month-old Karakul sheep weighing an average of 45.150 kg, significantly more advanced than the Al-Naimi (39.514 kg) and Hamdani (44.410 kg).

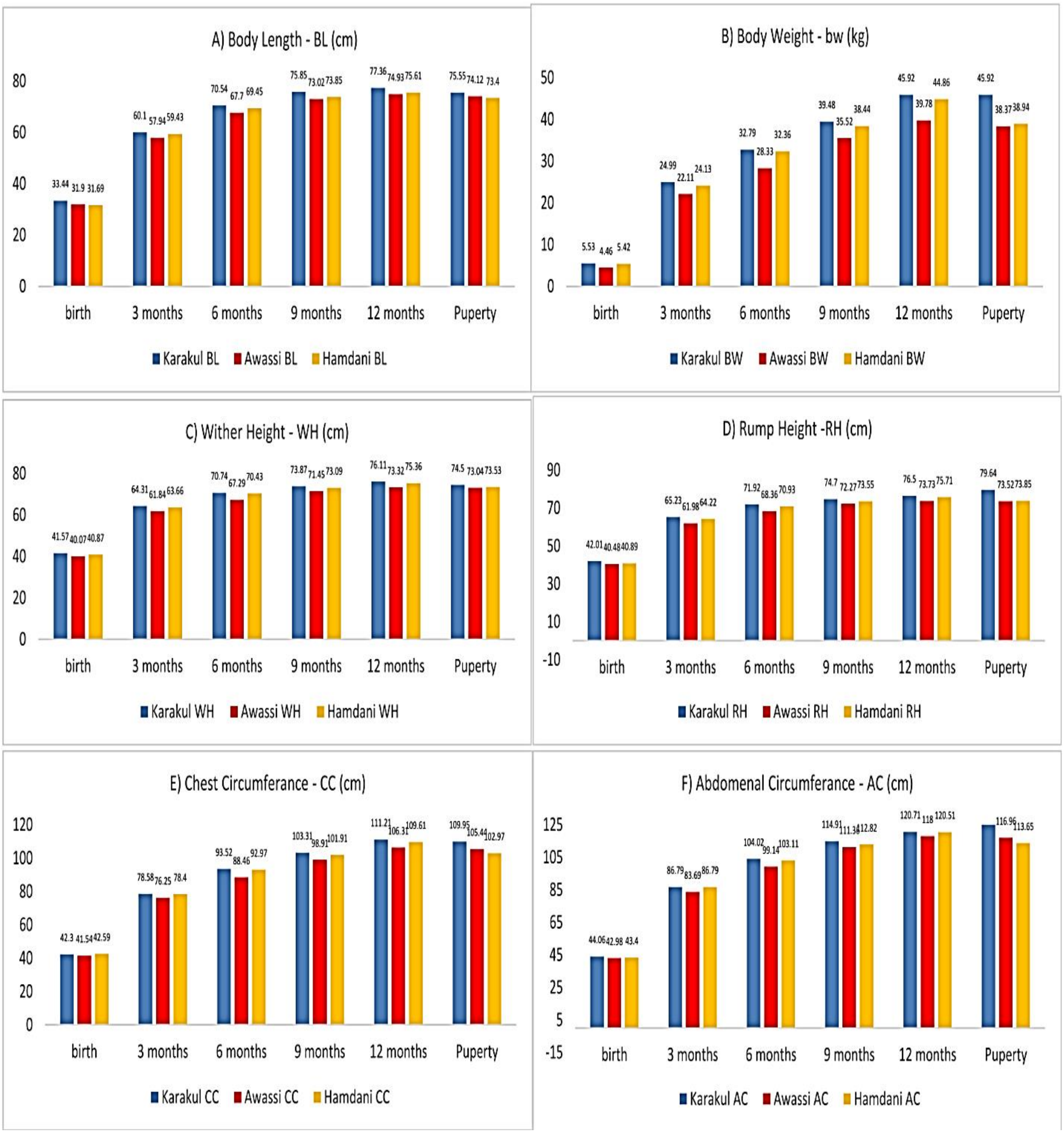

Figure 1. The comparison among the growth traits of Karakul, Al-Naimi, and Hamdani breeds on birth, 3, 6, 0, and 12 months, and puberty.

Similar to body weight, Karakul sheep exhibited the greatest measurements in body length, wither, and rump heights at all ages, significantly outperforming Al-Naimi ($P < 0.01$) and often exceeding Hamdani. These statistical differences indicate a clear breed advantage in terms of linear growth progression rates. Karakul sheep also showed larger chest and abdominal circumferences compared with the other breeds, particularly from the 3-month onwards. These differences were statistically significant in many cases, especially when comparing Karakul to Al-Naimi (Table 1). While Hamdani sheep do not consistently outperform the other breeds, they often rank between Karakul and Al-Naimi in growth traits, suggesting a moderate level of growth performance.

Table 1: The impact of breed (means ± standard errors) on growth traits in sheep.

		Breed			
	Measured parameter	**Karakul (n=103)**	**Al-Naimi (n=120)**	**Hamdani (n=110)**	**Significance**
Birth	Body weight (kg)	5.49±0.10 [a]	4.56±0.09 [b]	5.32±0.09 [a]	**
	Body length (cm)	32.94±0.34 [a]	31.94±0.30 [b]	31.32±0.32 [b]	*
	Wither height (cm)	41.55±0.24 [a]	40.07±0.21 [c]	40.47±0.23 [b]	**
	Rump height (cm)	41.90±0.25 [a]	40.56±0.23 [b]	40.42±0.24 [b]	**
	CC (cm)	42.20±0.31	41.68±0.28	42.43±0.30	ns
	AC (cm)	43.47±0.35	43.16±0.32	43.22±0.34	ns
3-month	Body weight (kg)	24.27±0.43 [a]	22.12±0.39 [b]	23.68±0.42 [a]	**
	Body length (cm)	59.85±0.50 [a]	58.22±0.45 [b]	59.25±0.49 [a]	*
	Wither height (cm)	64.10±0.40 [a]	62.18±0.36 [b]	63.67±0.38 [a]	*
	Rump height (cm)	64.96±0.39 [a]	62.33±0.35 [c]	64.25±0.37 [b]	**
	CC (cm)	77.86±0.63	76.29±0.57	77.96±0.62	ns
	AC (cm)	86.08±0.64 [a]	83.85±0.58 [b]	86.19±0.62 [a]	*
6-month	Body weight (kg)	31.77±0.64 [a]	27.99±0.57 [b]	31.76±0.61 [a]	**
	Body length (cm)	69.95±0.57 [a]	67.67±0.51 [b]	69.19±0.54 [a]	*
	Wither height (cm)	70.15±0.41 [a]	67.53±0.37 [b]	70.23±0.40 [a]	**
	Rump height (cm)	71.37±0.38 [a]	68.52±0.34 [c]	70.79±0.37 [b]	**
	CC (cm)	92.86±0.86 [a]	88.23±0.77 [b]	92.28±0.83 [a]	**
	AC (cm)	103.65±0.83 [a]	98.88±0.75 [b]	102.58±0.80 [a]	**
9-month	Body weight (kg)	38.62±0.59 [a]	35.13±0.53 [b]	37.98±0.56 [a]	**
	Body length (cm)	75.16±0.41 [a]	72.79±0.37 [b]	73.50±0.39 [b]	**
	Wither height (cm)	73.43±0.32 [a]	71.41±0.29 [c]	72.91±0.31 [b]	**
	Rump height (cm)	74.27±0.33 [a]	72.19±0.29 [c]	73.37±0.31 [b]	**
	CC (cm)	103.06±0.98 [a]	98.34±0.89 [b]	102.07±0.95 [a]	**
	AC (cm)	114.61±0.97 [a]	111.32±0.88 [b]	113.02±0.94 [ab]	*
12-month	Body weight (kg)	45.15±0.59 [a]	39.52±0.53 [b]	44.41±0.57 [a]	**
	Body length (cm)	76.82±0.36 [a]	74.74±0.32 [b]	75.34±0.35 [b]	**
	Wither height (cm)	75.65±0.29 [a]	73.25±0.26 [c]	75.24±0.28 [b]	**
	Rump height (cm)	76.19±0.28 [a]	73.67±0.25 [c]	75.56±0.27 [b]	**
	CC (cm)	111.21±0.89 [a]	106.09±0.80 [b]	109.55±0.86 [a]	**
	AC (cm)	120.76±0.95 [a]	117.77±0.86 [b]	120.24±0.92 [ab]	*

*Note***:** the data are expressed as means ± standard errors, ns, *, and ** refer to non-significant, significant at level $P < 0.05$; and significance at level $P < 0.01$, respectively. The superscript [a] refers to the higher indices than the superscript, and [b], respectively. Chest circumference (CC), and abdominal circumference (AC).

The effect of dams' age on sheep growth traits was assessed by categorizing the indices into three age groups: 2-3 years (n=104), 4-5 years (n=104), and over 5 years (n=125). A noticeable increase in body weight with the age of the dam was observed at birth, with the highest weights generally in lambs born to dams older than 5 years, showing significant differences at birth ($P < 0.05$) and a non-statistically significant trend toward heavier weights at older ages. Body length measurements tended to rise with the dam's age, much like body weight. At birth, lambs from older dams (particularly those older than five years) were taller and longer ($P < 0.05$). Other traits also showed increasing trends with the dams' age, but these values do not reach the same level of statistical significance between all breeds and ages (Table 2).

Table 2: Effect of dams' age (means ± standard errors) on growth traits in sheep.

		dam age			
Age	**Measured parameter**	**2-3 (n=104)**	**4-5 (n=104)**	**> 5 (n=125)**	**Significance**
Birth	Body weight (kg)	4.91±0.10 [b]	5.18±0.09 [a]	5.28±0.09 [a]	*
	Body length (cm)	31.12±0.34 [c]	32.15±0.32 [b]	32.83±0.31 [a]	*
	Wither height (cm)	40.22±0.24	40.82±0.23	40.98±0.22	ns
	Rump height (cm)	40.31±0.25	41.08±0.24	41.39±0.23	ns
	CC (cm)	41.58±0.31	42.33±0.30	42.38±0.29	ns
	AC (cm)	42.60±0.34	43.60±0.33	43.61±0.32	ns
3-month	Body weight (kg)	22.89±0.42	23.03±0.41	24.09±0.39	ns
	Body length (cm)	58.55±0.50	58.87±0.48	59.49±0.46	ns
	Wither height (cm)	62.94±0.39	62.91±0.38	64.06±0.37	ns
	Rump height (cm)	63.44±0.38	63.39±0.37	63.66±0.36	ns
	CC (cm)	77.60±0.62	76.18±0.60	78.31±0.58	ns
	AC (cm)	85.39±0.64	84.03±0.61	86.09±0.59	ns
6-month	Body weight (kg)	29.59±0.63	30.33±0.61	31.56±0.58	ns
	Body length (cm)	67.76±0.56	69.01±0.54	69.50±0.52	ns
	Wither height (cm)	68.42±0.41	69.22±0.39	70.02±0.38	ns
	Rump height (cm)	69.51±0.38	70.25±0.36	70.32±0.35	ns
	CC (cm)	89.78±0.85	90.98±0.82	92.53±0.79	ns
	AC (cm)	100.31±0.82	101.72±0.79	102.97±0.76	ns
9-month	Body weight (kg)	36.49±0.58	36.99±0.56	38.18±0.54	ns
	Body length (cm)	73.61±0.41	73.51±0.39	74.26±0.38	ns
	Wither height (cm)	72.10±0.32	72.44±0.30	73.16±0.29	ns
	Rump height (cm)	72.76±0.32	73.17±0.31	73.84±0.30	ns
	CC (cm)	100.38±0.97	100.36±0.94	102.63±0.91	ns
	AC (cm)	111.47±0.97	112.64±0.93	114.69±0.90	ns
12-month	Body weight (kg)	42.15±0.59	42.76±0.57	44.09±0.54	ns
	Body length (cm)	75.26±0.36	75.41±0.34	76.14±0.33	ns
	Wither height (cm)	74.21±0.29	74.66±0.28	75.23±0.27	ns
	Rump height (cm)	74.72±0.28	75.05±0.27	75.61±0.26	ns
	CC (cm)	108.01±0.88	108.74±0.85	109.97±0.82	ns
	AC (cm)	118.91±0.94	119.27±0.91	120.53±0.88	ns

Note: the data are expressed as means ± standard errors, ns, *, and ** refer to non-significant, significant at level $P < 0.05$; and significance at level $P < 0.01$, respectively. The superscript [a] refers to the higher indices than the superscripts [b], and [c], respectively. Chest circumference (CC), and abdominal circumference (AC).

In addition to assessing dams' age, the dam weights were evaluated using the same three grouping criteria. Hamdani sheep consistently showed the highest body weight across all ages, starting with a significant difference at birth (5.61 ± 0.09 kg) compared to Karakul (4.55 ± 0.11 kg) and Al-Naimi (5.163 ± 0.090 kg), respectively. This trend continued through 3, 6, 9, and 12 months, although differences at later ages were not statistically significant. Similar to body weight, at birth and 3 months of age, Hamdani sheep typically demonstrated the longest body length and the highest wither and rump heights. After these initial age intervals, Hamdani sheep also exhibited larger chest and abdominal circumferences compared to the other breeds, with significant differences became less pronounced and not statistically significant (Table 3).

Table 3: Effect of dams' weight (means ± standard errors) on growth traits in sheep.

		***dam weight* (kg)**			
Age	**Measured parameter**	**35-40 (n=82)**	**41-50 (n=127)**	**> 50 (n=124)**	**Significance**
Birth	Body weight (kg)	4.55±0.10 [c]	5.16±0.09 [b]	5.61±0.09 [a]	**
	Body length (cm)	31.07±0.36	32.42±0.30	32.54±0.31	ns
	Wither height (cm)	39.51±0.26 [c]	40.98±0.21 [b]	41.45±0.22 [a]	**
	Rump height (cm)	39.80±0.27 [c]	41.27±0.22 [b]	41.63±0.23 [a]	**
	CC (cm)	40.78±0.33 [b]	42.43±0.28 [a]	43.01±0.28 [a]	**
	AC (cm)	42.07±0.37 [b]	43.72±0.31 [a]	43.93±0.32 [a]	**
3-month	Body weight (kg)	21.31±0.46 [c]	23.44±0.38 [b]	25.13±0.39 [a]	**
	Body length (cm)	57.11±0.54 [c]	58.98±0.45 [b]	60.73±0.46 [a]	**
	Wither height (cm)	61.66±0.43 [c]	63.46±0.35 [b]	64.69±0.36 [a]	**
	Rump height (cm)	62.24±0.41 [c]	63.95±0.34 [b]	65.20±0.35 [a]	**
	CC (cm)	75.47±0.67 [c]	76.95±0.56 [b]	79.59±0.57 [a]	**
	AC (cm)	84.01±0.69	85.03±0.57	87.02±0.58	ns
6-month	Body weight (kg)	28.49±0.68	30.77±0.56	32.11±0.58	ns
	Body length (cm)	67.68±0.60	69.03±0.50	69.50±0.52	ns
	Wither height (cm)	68.89±0.44	69.30±0.37	70.62±0.37	ns
	Rump height (cm)	69.02±0.41	70.16±0.34	71.38±0.35	ns
	CC (cm)	89.32±0.92	90.82±0.76	93.10±0.78	ns
	AC (cm)	99.97±0.89	101.80±0.74	103.17±0.76	ns
9-month	Body weight (kg)	35.59±0.63	37.71±0.52	38.25±0.53	ns
	Body length (cm)	72.65±0.44	74.32±0.36	74.30±0.37	ns
	Wither height (cm)	71.90±0.34	72.48±0.28	73.27±0.29	ns
	Rump height (cm)	72.72±0.35	73.56±0.29	73.82±0.29	ns
	CC (cm)	99.27±1.05	101.88±0.88	102.09±0.90	ns
	AC (cm)	112.05±1.04	113.84±0.87	112.86±0.89	ns
12-month	Body weight (kg)	41.58±0.63	43.49±0.52	43.84±0.54	ns
	Body length (cm)	74.65±0.38	76.06±0.32	76.01±0.33	ns
	Wither height (cm)	73.53±0.31	75.26±0.26	75.22±0.26	ns
	Rump height (cm)	74.07±0.30	75.60±0.25	75.62±0.25	ns
	CC (cm)	108.01±0.96	109.98±0.79	108.64±0.81	ns
	AC (cm)	119.04±1.02	120.30±0.85	119.32±0.87	ns

Note: the data are expressed as means ± standard errors, ns, *, and ** refer to non-significant, significant at level $P < 0.05$; and significance at level $P < 0.01$, respectively. The superscript [a] refers to the higher indices than the superscripts [b], and [c], respectively. Chest circumference (CC), and abdominal circumference (AC).

The effect of the sex of sheep on the measured traits was analyzed. Male lambs weighed significantly more than female lambs at birth (5.34 kg vs. 4.93 kg, $p < 0.05$). This trend continued through all measured ages, with male lambs consistently weighing more than females. The difference becomes more pronounced with lambs' age, reaching 3.36 kg at 12 months (44.79 kg vs. 41.43 kg, $p < 0.01$).

Male lambs generally exhibited greater body length, wither, and rump heights than female lambs at all ages, with statistically significant at most ages, particularly from 6 months onwards. Notably, at 12 months, male lambs had significantly greater measurements: body length (76.59 cm vs. 74.74 cm, $p < 0.01$), wither height (75.54 cm vs. 73.97 cm, $p < 0.01$), and rump height (75.92 cm vs. 74.43 cm, $p < 0.01$) compared to females. Similar to the other growth traits, male lambs had larger chest and abdominal circumferences from 3 months of age onwards with statistically significant differences at most ages. At 12 months, male chest circumference was 111.11 cm compared to 106.97 cm in females ($p < 0.01$), and the abdominal circumference was 121.71 cm vs. 117.69 cm ($p < 0.01$) for males and females, respectively (Table 4).

Table 4: Effect of sex lambs (means ± standard errors) on growth traits in sheep.

		sex		
Age	**Measured parameter**	**Female (n=80)**	**Male (n=86)**	**Significance**
Birth	Body weight (kg)	4.93±0.07 [b]	5.35±0.07 [a]	*
	Body length (cm)	31.76±0.26	32.36±0.26	ns
	Wither height (cm)	40.37±0.19 [b]	41.02±0.18 [a]	*
	Rump height (cm)	40.65±0.20	41.25±0.19	ns
	CC (cm)	41.85±0.24	42.39±0.24	ns
	AC (cm)	43.01±0.27	43.58±0.27	ns
3-month	Body weight (kg)	22.38±0.34 [b]	24.43±0.33 [a]	**
	Body length (cm)	58.63±0.39	59.37±0.39	ns
	Wither height (cm)	62.79±0.31	63.90±0.31	ns
	Rump height (cm)	63.29±0.30 [b]	64.44±0.30 [a]	*
	CC (cm)	76.42±0.49 [b]	78.43±0.49 [a]	*
	AC (cm)	84.55±0.50	86.31±0.50	ns
6-month	Body weight (kg)	28.88±0.4 [b]	32.33±0.49 [a]	**
	Body length (cm)	67.54±0.44 [b]	70.15±0.44 [a]	**
	Wither height (cm)	68.51±0.32 [b]	70.19±0.32 [a]	**
	Rump height (cm)	69.38±0.30 [b]	71.14±0.29 [a]	**
	CC (cm)	89.13±0.67 [b]	93.34±0.66 [a]	**
	AC (cm)	99.89±0.65 [b]	103.70±0.64 [a]	**
9-month	Body weight (kg)	35.67±0.46 [b]	38.99±0.45 [a]	**
	Body length (cm)	72.77±0.32 [b]	74.95±0.31 [a]	**
	Wither height (cm)	71.77±0.25 [b]	73.47±0.25 [a]	**
	Rump height (cm)	72.43±0.25 [b]	74.20±0.25 [a]	**
	CC (cm)	99.21±0.77 [b]	103.30±0.76 [a]	**
	AC (cm)	111.25±0.76 [b]	114.87±0.75 [a]	**
12-month	Body weight (kg)	41.43±0.46 [b]	44.79±0.46 [a]	**
	Body length (cm)	74.74±0.28 [b]	76.58±0.28 [a]	**
	Wither height (cm)	73.97±0.23 [b]	75.54±0.22 [a]	**
	Rump height (cm)	74.43±0.22 [b]	75.92±0.22 [a]	**
	CC (cm)	106.97±0.70 [b]	111.11±0.69 [a]	**
	AC (cm)	117.68±0.74 [b]	121.71±0.74 [a]	**

Note: the data are expressed as means ± standard errors, ns, *, and ** refer to non-significant, significant at level $P < 0.05$; and significance at level $P < 0.01$, respectively. The superscript [a] refers to the higher indices than the superscripts [b], and [c], respectively.

The correlation matrix was used to compare various growth metrics of the three studied sheep breeds. The metrics examined included birth weight, weaning weight, weights at 6, 9, and 12 months, age at puberty, and weight at puberty. Correlations are quantified in the heatmap, with color intensity representing correlation strength (darker colors for stronger correlations). It was observed that birth weight displayed a positive correlation with weaning weight (0.54), 6 months weight (0.48), 9 months weight (0.33), and 12 months weight (0.37), puberty age (-0.24), and puberty weight (0.38). Similarly, weaning weight exhibited a positive correlation with 6 months weight (0.54), 9 months weight (0.57), 12 months weight (0.54), puberty age (-0.24), and puberty weight (0.59). Conversely, 6 months weight demonstrated a positive correlation with 9 months weight (0.78), 12 months weight (0.88), puberty age (-0.55), and puberty weight (0.87). Additionally, nine months weight showed a positive correlation with 12 months weight (0.88), puberty age (-0.72), and puberty weight (0.82). The 12-month weight also showed a positive correlation with puberty age (-0.72) and puberty weight (0.66). Finally, puberty age exhibited a negative correlation with puberty weight (-0.8) (Fig. 2).

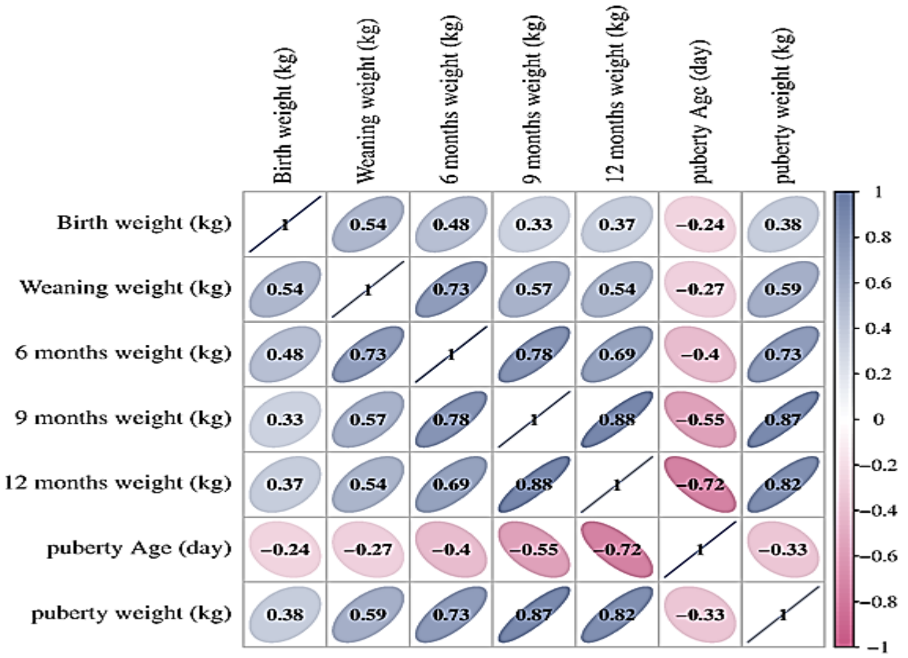

Figure 2. The correlation coefficients between various growth traits in Al-Naimi, Karakul, and Hamdani sheep. Each cell shows the strength and direction of the relationship between two traits, with values ranging from -1 to 1. Strong positive correlations are indicated by darker colors and more elongated ellipses, demonstrating the interconnectedness of these traits and their implications for sheep growth and development.

DISCUSSION

This study examines the growth traits of three prominent Middle Eastern sheep breeds and the factors influencing their development, including breed, birth season, and gender. A detailed analysis of various growth traits, such as body weight, linear dimensions (body length, wither, and rump heights), and circumferences (chest and abdominal measurements), was conducted across different developmental stages from birth to puberty. The primary focus was on comparing the Karakul, Al-Naimi, and Hamdani breeds to identify variations in growth traits. This approach provided insights into the unique growth trajectories and characteristics of these breeds, highlighting their developmental dynamics.

The study indicates that birth season does not significantly impact the growth traits of sheep measured, including body weight and length, wither and rump heights, and chest and abdominal circumferences. Sheep born in November, December, and January exhibited comparable growth patterns across ages, with no statistically significant differences observed. This suggests that factors beyond breed, such as genetics, nutrition, and management practices may have a greater influence on the growth and development. The values for birth season were relatively consistent, with slight variations that did not reach statistical significance. Measurements showed no significant differences among groups born in different months. Trends in all growth traits followed a pattern similar to that of body weight and linear measurements, with minor fluctuations over time.

This finding aligns with several studies examining the influence of birth season on livestock growth. These studies indicate that sheep, like other livestock, are affected by genetic predispositions and nutritional inputs that heavily influence their growth rates and development (González-Garduño *et al.*, 2021). Studies have shown that when animals are well-managed and receive adequate nutrition, environmental factors such as season of birth have a diminished effect on growth outcomes (Gowane *et al.,* 2017). The observation that sheep born in November, December, and January exhibit comparable growth patterns supports the notion that seasonal variations in environmental conditions (such as temperature and daylight hours) may not significantly impact growth when other conditions are constant (Macías-Cruz *et al.*, 2016). This is especially true in controlled farming environments where temperature and feeding can be managed year-round (Piccione *et al.,* 2011).

The present study revealed significant variations in growth traits among the three sheep breeds, with Karakul sheep demonstrating superior performance over most parameters, particularly body weight and linear dimensions. At 3 months, the Karakul breed continued to show higher mean values for the measured traits. At 6 months, it maintained higher mean values for all investigated traits. Although there were differences among the breeds at 9 months, the Karakul breed still had higher mean values than the Hamdani and Al-Naimi. Distinctions persist at 12 months, with Karakul notably surpassing Hamdani and Al-Naimi. Karakul maintained the highest average body weight, body length, wither height, rump height, chest circumference, and abdominal circumference during puberty. The findings suggest that the Karakul breed typically exhibits superior growth rate indices compared to Al-Naimi and Hamdani. Similar to our study, several studies have shown that the Karakul breed is recognized for its superior growth traits, including body weight and linear dimensions (Aljubouri *et al.*, 2021c; Aljubouri and Al-Shuhaib, 2023). Our study is also consistent with the findings from other studies that have shown that the Karakul breed had a higher growth rate compared to other breeds (Aljubouri *et al.,* 2021a).

Due to its usefulness in understanding the developmental stages of the prominent Middle Eastern sheep, the impact of age groups has also been explored in the study. The age of an animal influences management practices related to breeding, nutrition, and health. The data demonstrated a clear growth pattern, with older animals generally larger and heavier than younger ones. This is evident over all measured traits, though the rate of growth and the significance of differences vary between traits and age groups. The rate of growth varies between different traits and age groups. For instance, body weight tends to increase more rapidly than linear dimensions during the early stages of growth, and then the rate of increase slows down as the animal reaches maturity (Abdoli *et al.*, 2016; Ivanova *et al.*, 2021). The exterior measurements of the lambs confirmed high growth during weaning, with positive phenotypic correlations between growth traits indicating a strong relationship between these traits and growth intensity (Panayotov *et al.*, 2018).

This study found that the significance of differences in growth traits between different age groups varies. In some cases, differences between age groups are statistically significant, indicating a measurable increase in size and weight as the animal ages. In other cases, differences may not be statistically significant, suggesting that the increase in size and weight is more subtle or gradual.

The study indicated that Hamdani sheep outperform Karakul and Al-Naimi breeds in terms of the dam body weight and linear growth measurements during the early stages of life, from birth to 3 months. These findings suggest that Hamdani sheep may have a faster growth rate and potentially greater body development in their juvenile phase. However, the differences in growth traits among the breeds tend to narrow down as the sheep age, with no significant differences observed in most traits by 12 months. This could imply that the growth trajectories of the breeds converge over time. The early-stage growth advantage observed in Hamdani dams may be attributed to several factors, including genetics, nutrition, and management practices. Many accumulated data have demonstrated that genetics play a pivotal role in determining the growth rate of sheep, particularly during the juvenile phase. The superiority of Hamdani dams in early growth makes them an attractive option for farmers seeking to produce high-quality dams quickly. However, the convergence of growth trajectories among the breeds suggests that the long-term growth potential of these dam breeds may be more similar than initially thought.

The data indicate that male lambs exhibit superior growth in all measured parameters compared to female lambs. This difference is evident from birth and becomes increasingly significant as the lambs age. Male lambs were consistently heavier than female lambs at all time points, showcasing higher growth rates and achieving greater live weights, regardless of castration. Additionally, muscle depths were greater among male lambs, further emphasizing their superior growth characteristics (McGovern *et al.,* 2020).

The effects of dam age are statistically significant for body weight at birth, indicating that the age of dam has a direct impact on the initial size of lamb. This observation aligns with previous reports that dam age significantly affects lamb birth weight and other growth traits (Pettigrew *et al.,* 2021). Several factors may contribute to this effect. Older dams may have better-developed mammary glands, producing more milk, which can lead to higher birth weights. Additionally, older dams may possess improved uterine and placental function, enhancing nutrient transfer to the fetus and resulting in higher birth weights. Furthermore, older dams may have more developed immune systems, promoting better fetal health and contributing to increased birth weights (Şen and Önder, 2016).

The heatmap displays the correlation coefficients between various weight measurements taken at different stages of an animal's life, from birth to puberty. Early life factors, such as weight at different developmental stages, may influence later behaviors or psychological outcomes. Based on these intentions, the three breeds of sheep showed strong positive correlations between weight measurements taken at different ages. Age at puberty tends to have a negative correlation with these weights, while weight at puberty has a positive correlation. The strongest correlations were observed between weights, with the most substantial negative correlation linked to age at puberty. The high positive correlation between birth weight and weaning weight indicates that heavier animals at birth tend to be heavier at weaning. Conversely, a negative correlation between puberty age and puberty weight suggests that animals reaching puberty later tend to be heavier at that stage. Such data can explore the relationship between early growth patterns and later behaviors or health outcomes, which is relevant in developmental psychology. These findings have implications for breeding strategies and management practices in sheep farming, where selecting specific growth traits can yield economic and productivity benefits.

CONCLUSION

A significant finding is that birth season has little impact on sheep growth traits, suggesting that genetic predispositions, nutrition, and management practices play more critical roles in determining growth outcomes. The study revealed substantial differences among the three breeds, with Karakul sheep consistently exhibiting superior growth performance for measured parameters, particularly body weight and linear dimensions. Additionally, age influences sheep growth, with older animals generally larger and heavier than younger ones. The convergence of growth trajectories among breeds over time suggests that while initial differences may exist, long-term growth potential among breeds may be more similar. Moreover, gender is a significant factor, with male lambs demonstrating superior growth characteristics compared to females; the difference becomes more pronounced with age. Consistent with our findings, it has been proven that the growth traits of males were higher than females regarding live weights.

The effects of damage on lamb birth weight highlight the complex determinants of growth traits. Furthermore, the study's exploration of correlations between weight measurements at different developmental stages offers valuable insights for breeding strategies and management practices in sheep farming, potentially informing decisions that could yield economic and productivity benefits. This study significantly enhances our understanding of the developmental dynamics and inherent characteristics of Middle Eastern sheep breeds, offering implications for livestock management, breeding practices, and future research directions in animal science.

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تحليل مقارن لصفات نمو الأغنام بين سلالات الكراكول والنعيمي والحمداني

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اجرت الدراسة تحليلاً مقارنًا لصفات النمو المختلفة بين ثلاث سلالات بارزة من الأغنام: كاراكول، نعيمي، وحمداني لتقييم الاختلافات في صفات النمو. تضمنت صفات النمو التي تم تقييمها وزن الجسم، ومحيط الجسم (الصدر والبطن)، والأبعاد الخطية (طول الجسم، وارتفاع المقدمة والمؤخرة) في أعمار مختلفة، من الولادة إلى عمر ١٢ شهر. بعد تسجيل هذه الصفات، تم فحص تأثير العوامل المدروسة على نمو الأغنام، وأُجري تحليل مصفوفة الارتباط لتوضيح العلاقات بين مقاييس النمو المختلفة داخل سلالات الأغنام وبينها. كشفت النتائج عن اختلافات كبيرة قائمة على السلالة في صفات النمو، حيث أظهرت أغنام كاراكول باستمرار أداءً متفوقًا من حيث وزن الجسم والأبعاد الخطية. تم العثور على تأثيرات ضئيلة أو معدومة لموسم الولادة على صفات النمو عبر الفئات العمرية المختلفة، مما يشير إلى أن العوامل التي تتجاوز الاختلافات الموسمية لعبت أدوارًا أكثر أهمية في نمو الأغنام. لوحظت ارتباطات إيجابية قوية بين قياسات الوزن في مختلف الأعمار قبل البلوغ، في حين أظهر العمر عند البلوغ ارتباطًا سلبيًا بالوزن، مما يشير إلى أنماط نمو خاصة بالسلالة. وعلاوة على ذلك، تم تحديد فروق كبيرة في سمات النمو بين الحملان الذكور والإناث، حيث أظهر الذكور باستمرار وزنًا أكبر للجسم وأبعادًا خطية في جميع الأعمار. تستخلص الدراسة التفوق المؤكد لسلالة كاراكول على الحمداني والعواسي، يوفر هذا التحليل الشامل نظرة ثاقبة للديناميكيات المعقدة لنمو الأغنام، مما يوفر معلومات عن اختيار السلالة واستراتيجيات الإدارة وممارسات التربية في مزارع الأغنام.