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The Interrelationship of Morphological, Reproductive, and Growth Traits in Assaf Sheep in Palestine

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ABSTRACT

This study was conducted to explore the associations between morphometric, reproductive, and growth traits of Palestinian Assaf sheep raised in the northern West Bank, Palestine. Data were collected from January to May 2025, with a total of 520 ewes sampled from 26 flocks. Studied traits (not limited to) were pelvic width (PW), chest depth (CD), body condition score (BCS), number of lambs born per birth (NLB), prolificacy (PRO), weight at first lambing (WAL), lamb birth weight (LBW), and weaning weight (WWT). Results from statistical analysis revealed strong correlations (r= 0.79; p<0.01) between NLB and PRO. PW had a positive correlation (r>0.3) with reproductive performance traits. Additionally, WWT was linked to both BCS and ADM (r= 0.45; p<0.01). It was concluded that introducing morphometric traits, mainly those indicated as body capacity and pelvic structure in breeding programs for Assaf sheep, can improve not only the performance of reproduction and milk production, but also on-farm production levels, adaptability, and multi-trait merit.

Keywords: Palestine; prolificacy; morphometric traits; assaf; parity

INTRODUCTION

Sheep farming impacts the Scio economies of numerous regions around the globe, including the West Bank in Palestine. However, farmers need to understand the relationships between different traits to improve sheep farming systems and increase profits (Salman *et al*., 2024a). The Assaf sheep breed was developed by crossing Awassi and East Friesian sheep. This breed is characterized by high milk production and has become popular in many countries (Seroussi *et al*., 2017; Milán *et al*., 2011). Assaf sheep are becoming increasingly prevalent in Palestinian farming; however, the interrelationships among their morphological, reproductive, and growth traits in the West Bank remain poorly understood (Salman *et al*., 2024b).

Morphological characteristics are key components of the structure of the animal and are a good indicator of productivity (Sarma *et al*., 2024; Raji *et al*., 2018; Gwalal *et al*., 2015). Previous studies have shown that certain morphometric characteristics related to size, such as height, length, and weight, correlate with reproductive performance. As Wu *et al*. (2019) have pointed out, polymorphisms at insertion and deletion loci in the QTL of the PLAG1 gene were associated with sheep growth, adult body weight, and some morphometric measurements. Lin *et al*. (2021) further supported the genetic basis of these morphometric characteristics by documenting CD8B gene polymorphisms as important determinants of body size and weight.

Reproductive traits (e.g., litter size, lambing interval) have been reported as main contributors to flock productivity (Salman *et al*., 2024b, Mokhtar *et al*., 2022). The number of lambs born per birth is directly related to farm income (Yang *et al*., 2022). Genetic studies that have been conducted in Iranian Ghezel sheep (Nabavi *et al*., 2014) as well as cross-breed comparisons (Rosati *et al*., 2002) have put forward the notion of using reproductive traits as selection criteria when implementing genetic selections. Growth traits are also important as they have key impacts on meat yield and economy (Mateo *et al*., 2023) as well as show significant genetic correlation with reproductive traits (Abdoli *et al*., 2019; Mohammadi *et al*., 2015). The relationships between morphometric, reproductive, and growth traits are complex and are influenced by genetic and environmental factors (Li *et al*., 2024a). This complex set of traits should be studied to guide breeding program design and implementation for improvement of flock productivity (Zhang *et al*., 2018). Multi-omics approaches may help to advance the understanding of the genetic basis of these morphometric traits (Li *et al*., 2024b).

Although genetic and environmental factors influence sheep traits, few studies have examined their combined effects within a single population, particularly in Assaf sheep raised under semi-arid, resource-limited conditions. This study addresses this gap by integrating the morphological, reproductive, and growth traits of Assaf sheep in the northern West Bank into a unified framework. Relationships between these traits are analyzed to provide a further basis for sustainable and locally adapted breeding approaches.

MATERIALS AND METHODS

Ethical Approval and Informed Consent

This study was carried out in Palestine, where there is no statutory animal ethics committee. Nevertheless, all experiment procedures were done strictly adhering to the World Organization for Animal Health (WOAH) standards of animal welfare without any unnecessary stress or harm to animals. Field operations were managed and carried out by trained veterinarians and livestock professionals. The farm owners verbally consented before the study to ensure that the study was ethically transparent.

Study Population and Data Collection

The study involved a sample of 520 ewes aged from 1.5 to 6 years from 26 flocks located in 4 governorates in the northern West Bank, Palestine (Jenin, Tulkarm, Tubas, and Jericho). Data were collected from the first of January until the end of May, 2025, representing the production season of sheep in the region. The study design and geographic characteristics are summarized in Table 1.

Studied Traits

This study investigates a number of phenotypic traits in Assaf sheep in order to examine the interrelationships between morphological traits, reproductive traits, and growth traits.

Morphometric traits. It included head length (HL), ear length (EL), ear width (EW), body length (BL), tail length (TaL), height at wither (HAW), heart girth (HG), chest depth (CD), udder depth (UD), shoulder width (SW), rump width (RW), pelvic width (PW), teat width (TeW), udder width (UW), cannon circumference (CC), teat circumference (TC), teat length (TL), udder length (UL), body condition score (BCS), and live weight (LW).

Reproductive traits. It included weight at first lambing (WAFL), parity (PR), prolificacy (BRO), and number of lambs at birth.

Growth traits. It included lamb birth weight (LBW) and lamb weaning weight (LWW). Both traits are important as indicators for preweaning lamb growth rate.

The morphometric traits were measured based on Food and Agriculture Organization of the United Nations guidelines (FAO, 2012). The estimation of reproductive traits was in reference to Vlahek *et al*. (2023), while growth traits were assessed as per the International Committee for Animal Recording (ICAR) Guidelines (2021).

Data Analysis

The relationships among the morphometric, reproductive, and growth traits of Assaf sheep were examined using several statistical techniques. Data validated and stored in an XL sheet. Mean and standard deviation were calculated and analyzed by the descriptive statistic model in SPSS 22 for Windows. Pearson's correlation coefficient (r) was calculated to estimate the relationships between the studied traits. Significance was set at $p<0.05$ and $p<0.01$. The formula used was

$$r = \frac{\sum(xi - \bar{x}) * (yi - \bar{y})}{(\sqrt{(xi - \bar{x})^2}) * (\sqrt{(yi - \bar{y})^2})}$$

Where xi and yi are the individual data points, $\bar{x}$ and $\bar{y}$ are the sample means, and $\sum$ is the sum of values of the set.

RESULTS

The means and standard deviations of the phenotypic, reproductive, and production traits of Assaf sheep are displayed in Table 2. Each morphometric trait included body length (BL), pelvic width (PW), and heart girth (HG); every reproductive trait included number of lambs at birth (NLB) and prolificacy (PRO); and the traits associated with milk production included ADM and UDi.

Table 1. Study design overview and regional characteristics for phenotypic assessment of Assaf ewes in Northern West Bank, Palestine

Category	Variable	Description	Unit
Study details	Study population	520 Assaf ewes aged between 1.5–6 years	Ewes
	Study duration	January–May 2025	Months
	Number of flocks	26	Flocks
	Study area	Northern West Bank, Palestine (Jenin, Tulkarm, Tubas, Jericho)	Geographical regions
Regions	Jenin	Mediterranean climate, 400–600 mm annual rainfall, mild winters, hot summers	Coordinates: 32.4614°N, 35.2811°E
	Tulkarm	Mediterranean, 600–700 mm annual precipitation, fertile agricultural lands	Coordinates: 32.3104°N, 35.0308°E
	Tubas	Semi-arid, 300–400 mm annual rainfall, summer temperatures exceeding 35 °C	Coordinates: 32.3209°N, 35.3704°E
	Jericho	Arid, 150–200 mm annual rainfall, summer temperatures surpassing 40 °C	Coordinates: 31.8561°N, 35.4600°E

Table 3 shows the traits that are significantly correlated with the prolificacy of Assaf sheep. Moderate and strong correlations emerged between the prolificacy and some of the demographic and management-related independent variables: (1) region (specific geographic area) (r= 0.11, p<0.05; minor effect) and flock (r= 0.09, p<0.05; minor effect); and (2) age (of dam) (r= 0.27, p<0.01; moderate effect). Influential correlates that approached weak correlation (less than r= 0.2) included cannon circumference (r= 0.10, p<0.05; minor effect) and pelvic width (r= 0.10, p<0.05; minor effect), indicating some value for skeletal measurements in reproductive capability but a negligible role (or consequence) for prolificacy. Total weight at first lambing may have made a small contribution to prolificacy as well (r= 0.32, p<0.01; moderate effect). Indeed, the value of body condition at the first reproductive event likely greatly contributed to prolificacy. Parity showed a strong correlation as well with r= 0.30, p<0.01, indicating that increasing parity contributed to concurrent increases in prolificacy (litter size). Prolificacy and the number of lambs produced per birth, however, had the greatest strength of correlation (r= 0.79, p<0.01) and is likely the variable that explained most of the differences in reproductive performance in Assaf sheep.

Table 4 presents morphometric and reproductive traits that indirectly influence prolificacy through their associations with primary correlates such as pelvic

Table 2. Means and standard deviations of phenotypic characterization and production traits of Assaf sheep: morphometric measurements, reproductive performance, and milk production data

Trait	Mean	Standard deviation (SD)
HL	22.09	2.13
HW	10.03	2.08
EL	18.12	1.98
EW	9.18	1.03
BL	74.08	8.79
TaL	31.35	4.86
HAW	76.75	5.77
HG	106.36	12.27
CD	27.73	2.90
SW	21.48	2.32
RH	79.28	5.52
RW	21.77	3.09
CC	9.34	0.89
PW	24.20	4.43
TL	4.43	1.19
TeW	2.96	0.87
TC	5.86	1.20
UL	20.55	4.32
UW	20.97	5.26
UD	15.11	3.38
BCS	3.72	0.92
LW	76.29	10.51
WAFL	56.40	6.91
PR	3.38	1.24
NLB	1.86	0.35
PRO	1.46	0.25
ADM	2.32	0.76
LBW	4.98	1.27
WW	16.13	2.36

Note: HD = Head Length (cm); HW = Head Width (cm); EL = Ear Length (cm); EW = Ear Width (cm); BL = Body Length (cm); TaL = Tail length; HAW = Height at Withers (cm); HG = Heart Girth (cm); CD = Chest Depth (cm); SW = Shoulder Width (cm); RH = Rump Height (cm); RW = Rump Width (cm); CC = Cannon Circumference (cm); PW = Pelvic Width (cm); TL = Teat Length (cm); TeW = Teat Width (cm); TC = Teat Circumference (cm); UL = Udder Length (cm); UW = Udder Width (cm); UD = Udder Depth (cm); BCS = Body Condition Score; LW = Live Weight (kg); WAFL = Weight at First Lambing (kg); PR = Parity; NLB = Number of Lambs per Birth; PRO = Prolificacy; ADM = Average Daily Milk (kg); LBW = Lamb Birth Weight (kg); WW = Weaning Weight (kg).

Table 3. Traits showing significant correlation with prolificacy in Assaf sheep

Trait	Correlation
Region	0.11*
Flock	0.09*
Age	0.27**
Cannon circumference	0.10*
Pelvic width	0.10*
Weight at first lambing	0.32**
Parity	0.30**
Number of lambs per birth	0.79**

Note: * Correlation is statistically significant at the 0.05 level (2-tailed).
** Correlation is statistically significant at the 0.01 level (2-tailed).

Table 4. Traits demonstrating indirect correlation with prolificacy through their association with traits significantly correlated with prolificacy (cannon circumference, pelvic width, weight at first lambing, parity, and number of lambs per birth) in Assaf sheep

Trait	CC	PW	WAFL	PR	NLB
H L	0.18**	0.34**	ns	ns	ns
HW	Ns	0.48**	ns	ns	ns
EL	0.22**	0.33**	ns	ns	0.10*
EW	0.121**	0.34**	ns	ns	ns
BL	0.29**	-0.25**	ns	ns	ns
HAW	0.21**	-0.24**	ns	ns	ns
HG	0.24**	0.47**	ns	ns	ns
CD	0.17**	0.21**	ns	ns	ns
SW	0.24**	0.45**	ns	ns	ns
RH	0.21**	0.79**	ns	ns	ns
RW	0.11**	ns	ns	ns	ns
PW	0.20**	0.20**	0.10*	ns	ns
TL	0.15**	0.11*	ns	ns	ns
TeW	0.11**	0.38**	ns	-0.08*	ns
TC	0.11**	0.64**	ns	ns	ns
UW	ns	0.26**	ns	ns	ns
U D	0.14**	0.13**	ns	ns	ns
BCS	0.28**	0.27**	ns	ns	ns
LW	0.38**	0.25**	ns	ns	ns
WAFL	ns	0.10*	ns	0.29**	0.27**
PR	ns	ns	0.29**	ns	ns
NLB	ns	ns	0.27**	0.32**	0.32**

Note: HD = Head Length (cm); HW = Head Width (cm); EL = Ear Length (cm); EW = Ear Width (cm); BL = Body Length (cm); HAW = Height at Withers (cm); HG = Heart Girth (cm); CD = Chest Depth (cm); SW = Shoulder Width (cm); RH = Rump Height (cm); RW = Rump Width (cm); CC = Cannon Circumference (cm); PW = Pelvic Width (cm); TL = Teat Length (cm); TeW = Teat Width (cm); TC = Teat Circumference (cm); UW = Udder Width (cm); UD = Udder Depth (cm); BCS = Body Condition Score; LW = Live Weight (kg); WAFL = Weight at First Lambing (kg); PR = Parity; NLB = Number of Lambs per Birth. ** Correlation is statistically significant at the 0.01 level (2-tailed). * Correlation is statistically significant at the 0.05 level (2-tailed). ns = not statistically significant.

width, parity, and number of lambs at birth. Cranial, skeletal, and udder-related measurements, together with body condition score and live weight, contribute to reproductive performance, likely through structural and physiological pathways.

Table 5 contains characteristics that have statistically significant associations with lamb birth weight (LBW) and lamb weaning weight (LWW) in Assaf sheep. The table indicates environmental issues (region and flock), morphometry (ear length, ear width, body length, height at withers, heart girth, chest depth, shoulder width, height at the rump, width at the rump, width at the pelvis), measurements of udder and teats (width of teats, circumferences of teats, length of udder), body condition score, the number of lambs per birth, average daily yield of milk produced during lactation, and the association of LBW with LWW.

Table 5. Traits showing significant correlation with lamb birth weight and lamb weaning weight in Assaf sheep

Trait	LBW	LWW
Region	0.29**	0.02
Flock	0.28**	0.06
EL	0.25**	0.13**
EW	0.20**	0.02
BL	-0.02	0.22**
HAW	-0.13**	0.08
HG	0.01	-0.13**
CD	0.25**	0.34**
SW	0.13**	0.05
RH	-0.11*	-0.004
RW	0.26**	-0.008
PW	0.27**	0.05
TeW	0.19**	0.22**
TC	0.17**	0.007
UL	0.15**	0.14**
BCS	0.10*	0.09*
NLB	-0.04	0.10*
ADM	0.36**	0.45**
LBW	1	0.25**

Note: EL = Ear Length (cm); EW = Ear Width (cm); BL = Body Length (cm); HAW = Height at Withers (cm); HG = Heart Girth (cm); CD = Chest Depth (cm); SW = Shoulder Width (cm); RH = Rump Height (cm); RW = Rump Width (cm); PW = Pelvic Width (cm); TeW = Teat Width (cm); TC = Teat Circumference (cm); UL = Udder Length (cm); BCS = Body Condition Score; NLB = Number of Lambs per Birth; ADM = Average Daily Milk (kg); LBW = Lamb Birth Weight (kg). ** Correlation is statistically significant at the 0.01 level (2-tailed). * Correlation is statistically significant at the 0.05 level (2-tailed).

Table 6 summarizes the statistically significant correlations between morpho-production traits, showing strong associations among indicators of milk yield and among body conformation measurements. Significant correlations were observed among productivity traits, udder morphology, and skeletal dimensions, indicating interdependence between structural and functional characteristics in Assaf sheep.

DISCUSSION

Traits Showing Significant Correlation with Prolificacy in Assaf Sheep

The positive relationship between age and prolificacy measured for sheep in Table 3 is in line with the results of Ajafar *et al*. (2022), who indicated that litter size increases with physiological maturity of the ewe, plateaus around 4 to 8 years of age, and decreases with aging in older sheep. The studies summarized in this work indicate that both age and parity can essentially affect reproductive traits, where the most prolific days between births and age are typically found in the 4th and 5th parities. The current results showed that the non-genetic effect contributes to prolificacy in Assaf sheep, which we know is generally the case in sheep reproduction. Contextual factors, such as lambing year and parity, appeared to have a strong effect on litter size at birth and weaning (Abuzahra *et al*., 2024), indicating that external environmental and management

Table 6. Traits demonstrating indirect correlation with lamb birth weight and lamb weaning weight through their association with traits significantly correlated with birth weight and weaning weight in Assaf sheep

Trait	EW	BL	HAW	HG	CD	SW	SW	RW	PW	TeW	TC	UL	BCS	NLB	ADM
EL	0.50**	0.04	ns	0.21**	0.27**	0.18**	0.15**	0.32**	0.33**	0.28**	0.25**	ns	0.22**	0.10*	ns
EW	1	ns	0.10*	0.30**	0.22**	0.30**	0.17**	0.33**	0.34**	0.13**	0.27**	ns	0.21**	ns	ns
BL		1	0.51**	ns	0.25**	ns	0.26**	-0.18**	-0.25**	-0.16**	-0.22**	ns	0.34**	ns	ns
HAW			1	ns	0.23**	ns	0.71**	-0.19**	-0.24**	-0.33**	-0.29**	-0.22**	0.18**	ns	ns
HG				1	0.18**	0.39**	0.37**	0.42**	0.47**	0.10*	0.35**	ns	0.35**	ns	ns
CD					1	0.30**	0.21**	0.26**	0.21**	ns	0.12**	ns	0.23**	ns	ns
SW						1	0.15**	0.55**	0.45**	ns	0.30**	ns	0.21**	ns	ns
RH							1	ns	ns	-0.13**	ns	-0.21**	0.21**	ns	ns
RW								1	0.79**	0.23**	0.53**	ns	0.25**	ns	ns
PW									1	0.38**	0.64**	ns	0.27**	ns	ns
TeW										1	0.51**	0.33**	0.10*	ns	ns
TC											1	0.16**	0.18**	ns	ns
UL												1	ns	ns	0.14**
BCS													1	ns	0.30**

Note: EL = Ear Length (cm); EW = Ear Width (cm); BL = Body Length (cm); HAW = Height at Withers (cm); HG = Heart Girth (cm); CD = Chest Depth (cm); SW = Shoulder Width (cm); RH = Rump Height (cm); RW = Rump Width (cm); PW = Pelvic Width (cm); TW = Teat Width (cm); TC = Teat Circumference (cm); UL = Udder Length (cm); BCS = Body Condition Score; NLB = Number of Lambs per Birth; ADM = Average Daily Milk (kg). ** Correlation is statistically significant at the 0.01 level (2-tailed). * Correlation is statistically significant at the 0.05 level (2-tailed). ns = not statistically significant.

conditions had an effect on reproduction. All of this is in agreement with the notion that prolificacy is subject to both environmental and genetic influences, whereby managerial practices and factors within a sheep's environment determine lambing interval and litter size (Seroussi *et al*., 2017).

Prolificacy was also linked to key reproductive and morphological characteristics. Specifically, NLB had a strong positive correlation with PRO (r= 0.79, p<0.01), which showed that the maximum number of lambs born per lambing was linked to reproductive output, consistent with that of Ziadi *et al*. (2025), where moderate to strong genetic correlations were found between NLB and prolificacy effects from multiple parities in the Barbarine sheep population.

Parity (PR) had a moderate positive correlation with NLB (r= 0.32, p<0.01) and PRO (r= 0.30, p<0.01), which is expected since PR dictates patterns of improvement in reproductive performance in the current observations from repeat parities due, at least in part, to physiological maturation and accumulating reproductive experience. Haldar *et al*. (2014) reported the same trends in the reproductive performance of Black Bengal goats and reported parity and body weight to be strong predictors of NLB and productivity and profitability of the Black Bengal goat reproduction program. Overall, this study also found WAFL to have moderate correlations with PRO (r= 0.32, p<0.01) and NLB (r= 0.27, p<0.01), indicating that adequate growth during early stages of development is essential for ongoing reproductive success. In this aspect, Haldar *et al*. (2014) again found that body weight and structural size were strong determinants of prolificacy in caprine species.

Traits Demonstrating Indirect Correlation with Prolificacy

Table 4 shows the indirect effects of prolificacy (PRO) on morphological traits with mediator factors like cannon circumference (CC), pelvic width (PW), weight at first lambing (WAFL), parity (PR), and udder or teat morphology. This indicates that the overall reproductive potential of Assaf sheep is determined by a composite of structural, developmental, and physiological factors rather than a single morphologic factor.

Cannon circumference (CC) was strongly positively associated with body conformation traits such as head length (HL), ear length (EL), body length (BL), heart girth (HG), and live weight (LW). This reveals that CC is a measuring anthropometric variable representing an integrated view of the growth of the skeleton and of whole-body size. Similar associations were found in studies of Black Bengal goats, which reported that larger skeletal dimension was positively associated with more reproductive efficiency and higher multiplicity of births (Haldar *et al*., 2014). Furthermore, positive genetic correlations of LW with linear body traits were found to affect the breeding outcomes of Menz sheep (Sezenler *et al*., 2016).

Pelvic width (PW) was the strongest and broadest mediator variable, and it was associated with head width, heart girth, shoulder width, hump height, and teat circumference. These relationships support the notion that PW reflect several aspects of rear-body conformation. Functionally, PW can affect prolificacy (1) by providing space for multiple fetuses during the gestation period and (2) providing space for delivery. There is supporting evidence for this conclusion: observations have been made in Black Bengal goats proposing that the distance between the intertubers was correlated with the number of births (Haldar *et al*., 2014) and in Menz sheep, where the pelvic area was correlated with both dystocia and the number of lambs born per ewe (Sezenler *et al*., 2016). In addition, the strong relationship between PW and teat circumference supports the conclusion that the pelvic and mammary structures develop from common precursors.

WAFL was weakly to moderately correlated with PW, NLB, and PR. Bandirma ewes showed comparable results where parity (age) significantly affected body condition score and milk yield (Sezenler *et al*., 2016). Comparative studies on tropical hair sheep demonstrated greater lifetime productivity when the female body weight at first breeding was greater (Arcos-Álvarez *et al*., 2020). The PR showed a positive and expected correlation with WAFL and NLB, whereas a weak negative correlation was found with TeW. These findings are consistent with previously reported observations of body condition and reproductive performance changes across parities (Sezenler *et al*., 2016; Haldar *et al*., 2014).

The udder and teat morphology also had meaningful relationships and associations. Udder depth was positively associated with CC and PW, and TC was strongly associated with PW. In Pelibuey ewes, the pre-milking udder circumference was strongly associated with milk yield, impacting lamb growth and lamb survival (Arcos-Álvarez *et al*., 2020). In Suffolk ewes, abnormal udder conformation negatively influenced colostrum protein concentration more than normal conformation. This again highlighted the functional reputation of udder characteristics and the importance given to udder morphology (Richardson *et al*., 2023).

Two notable exceptions were observed. First, BL and HAW were negatively associated with PW, and it is typically expected that morphometric characteristics are positively associated with each other. Second, TeW had a weak negative association with PR, similar to Richardson *et al*. (2023) findings, where Romney ewes appeared to demonstrate age-related changes in mammary tissue.

Lastly, all of the associations reported here were based on traditional manual measurements that demonstrate variability and practical limitations. One emergent form of image-based morphometry (e.g., Zhang *et al*. (2018) accurately estimated sheep body dimensions with camera-based, non-contact technology); this possible new avenue for studying morphometry would decrease all of the sources of variation and confounding factors previously discussed.

Traits Showing Significant Correlation with Lamb Birth Weight and Lamb Weaning Weight

The strong example of positive correlation between region and LBW supports important region-dependent effects by the multiplications of environmental variables that influence fetal growth. This finding supports previous studies that have shown that LBW is affected by both genetic and non-genetic factors (diet, year of birth, and season). For example, regional differences in climatic, forage, or management practices can differentially affect ewe nutrition and therefore influence lamb development (Bancheva *et al*., 2022). In addition, the positive relationship between flock and LBW indicates that management or environmental differences influenced LBW because ewe nutritional, age, and body condition differences have been noted between flocks that influenced birth weight (Quintana, 2025).

The positive relationships noted between LBW and morphometric traits (EL, CD, and PW) suggest increasingly larger dimensions at birth are associated with higher LBW. This is biologically feasible, as a more developed fetus increases in size. Morphometric traits may be useful predictors of LBW. Although not consistently measured in earlier studies, the relationships with LBW further provide corroborating evidence of previously described relationships between body dimensions in lambs and early growth performance in sheep broadly (Quintana, 2025).

The large positive relationship between BCS and LBW is consistent with Haslin *et al*. (2023), noting that maternal nutrition is an important factor in fetal growth and subsequent survival. However, the negative relationships between skeletal measurements (HAW and RH) and LBW demonstrate a more complex relationship whereby maternal BCS appears to have a stronger influence on reproductive outcomes than linear body conformation. Kutan and Keskin (2022) reported a significant positive correlation between body length and slaughter body weight in Awassi lambs during the fattening period (r= 0.639, p<0.01). In this study, a positive correlation was observed between lamb LWW and BL (r= 0.22, p<0.01), furthering the discussion that morphometric traits can be good estimates of lamb performance measures such as growth, body weight, and body weight gain.

The effects of environmental factors on growth generally show moderate consistency across studies. For example, Kutan and Keskin (2022) found that lambs born in spring had higher growth rates due to better quality pastures and nutrition. Nevertheless, their study demonstrates weak correlations between lamb weight at weaning and location (r= 0.020) or flock (r= 0.061), and it does suggest that postnatal (0-17 weeks of age) growth is less a function of environmental factors and more a manifestation of compensatory growth or genetics. This indicates that environmental effects are particularly important early in development.

An interesting finding (i.e., negative correlation, r= -0.13) was the weak negative correlation between HG and live weight in Assaf sheep, considering that HG is normally positively correlated with body size. Because this study addressed both BCS and back-fat depth for Assaf sheep, the variation in live weight in Assaf sheep may be due to energy reserves versus skeletal dimensions. Cranston *et al*. (2017) also reported that BCS, back-fat depth, and kidney-fat depth are dimensions that relate to the energy status of the adult female sheep. Thus, the observed HG-weight relationship with Assaf sheep may be breed-specific or just measurement variability and requires further exploration.

Finally, the BCS of ewes and productivity (LBW and LWW) were positively related in this study (r= 0.10 and 0.09) and consistent with the results of Cranston *et al*. (2017), where ewes with a BCS of 2.5 to 3.0, classified as moderate to good BCS, at the time of weaning produced lambs more than 5 kg heavier than ewes with poorer BCS scores.

Traits Demonstrating Indirect Correlation with Lamb Birth Weight and Lamb Weaning Weight

The relationships among the body measurements that have been reported in Table 6 are in accordance with the principles of livestock growth and conformation. Lôbo *et al*. (2009) note that body weight traits shared a positive genetic correlation where growth traits are interrelated. It reveals that there is a strong association between the growth characteristics, indicating that larger animals will necessarily have larger morphological dimensions, that is, HG, CD, SW, RW, and PW. Such structural measurements are likely to be indirectly related to both birth and weaning weights, as the relationship would measure agreement with common growth trajectories. Sveinbjörnsson *et al*. (2021) determined that maternal body weight and BCS in gestation have very strong positive effects on LBW and, therefore, pre-weaning growth. This is again consistent with the strong positive relationships observed in Table 6 between BCS and morphometric traits (for example, EL, BL, and HAW).

Penn State Extension (2023) also documented a strong positive association between birth weight and later growth performance. This supports the trends shown in Table 6. Their research highlighted how environmental factors, especially maternal nutrition, affect BCS and offspring performance. This highlights the need to combine good management practices with genetic selection to improve lamb growth and productivity.

The ADM showed a strong positive correlation with LWW (r= 0.45, p<0.01). Although specific ADM correlation coefficients are not often found in the literature, the focus on maternal effects noted by Sveinbjörnsson *et al*. (2021) indirectly supports these findings.

The strong correlation between the number of lambs per birth and prolificacy (r= 0.79) matches genomic evidence showing a strong genetic link between these traits (Ziadi *et al*., 2025; genetic correlations ~0.75). Moderate correlations related to parity reflect observations of gradual reproductive maturation through successive cycles (Haldar *et al*., 2014; Salman *et al*., 2024a).

Traits Showing Significant Correlation with Lamb Birth Weight and Lamb Weaning Weight

The positive correlations between ADM and LBW (r= 0.36) and LWW (r= 0.45) in Assaf sheep are consistent with findings across multiple studies. Milk production by the mother is a key determinant for newborn and preweaning lamb growth rate. Lôbo *et al*. (2009) reported significant maternal effects on early growth traits, including LBW and LWW, in a multibreed population of meat sheep. Similarly, Sveinbjörnsson et al. (2021) identified ewe body weight and BCS during gestation as positively associated with LBW and preweaning growth, reflecting the ewe's capacity to support fetal development and postnatal nutrition.

Morphometric traits such as ear length, chest depth, rump width, pelvic width, and udder length were significantly correlated with LBW and LWW; such findings may be useful when implementing selection programs aimed at improving lamb production. For example, CD had a positive correlation (r= 0.25) with LBW and a slightly more positive correlation (r= 0.34) with LWW. Such results are consistent with Sveinbjörnsson *et al*. (2021), who reported positive relationships between ewe body weight, BCS, and lamb growth.

There was a negative correlation between HAW and LBW (r= -0.13) and between HG and LWW (-0.13). Despite being less common in research, the negative correlation could refer to nonlinear relationships in phenotypic development. Bunter *et al*. (2023) highlighted that selection for increased size in one dimension can lead to negative effects in another trait, illustrating that not all morphological traits equally influence lamb performance.

The number of lambs at birth (NLB) had a slightly negative insignificant correlation (r= -.04) with LBW, but a weak positive correlation (r= 0.10) with LWW. As a result, lambs born as twins may have lower weight at birth but can still achieve acceptable weaning weights. Sveinbjörnsson *et al*. (2021) found that single lambs were heavier at birth than twins or triplets.

CONCLUSION

The findings of this study demonstrate that some morphological (body shape) traits, such as pelvic width, chest depth, and maternal morphological traits, can impact both reproduction performance and growth of progeny in the Assaf sheep breed. Strong relationships have been established between prolificacy, number of lambs per lambing, body condition score, and milk yield, all performance indicators related to flock productivity, across the Assaf sheep breed. It is clear that sheep producers need to improve reproduction performance and lamb growth potential through the selection of specific traits as part of a genetic selection plan, along with improved management practices.

CONFLICT OF INTEREST

We certify that there is no conflict of interest with any financial, personal, or other relationships with other people or organizations related to the material discussed in the manuscript.

DECLARATION OF GENERATIVE AI AND AI-ASSISTED TECHNOLOGIES IN THE WRITING PROCESS

During the preparation of this work, the author(s) used [ChatGPT for Google] in order to language refinement, grammar correction, structural suggestions, and paraphrasing to improve clarity and readability. After using this tool/service, the author(s) reviewed and edited the content as needed and take full responsibility for the content of the publication.

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