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RESEARCH ARTICLE

Correlations Between Udder Morphometry and Body Measurements in Norduz Sheep and Saanen Goats

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ABSTRACT

Udder morphology and morphometry are critical for milk yield and health in small ruminant husbandry. This study aimed to determine the udder morphometric characteristics of Norduz sheep and Saanen goats and to comparatively evaluate their relationships with external body measurements. A total of 50 Norduz sheep and 50 Saanen goats were evaluated. In Norduz sheep, udder types were classified as Type-I, Type-II, Type-III, and Type-IV, with Type-IV being the most prevalent (38%, n=19). In Saanen goats, udders were categorized as Funnel, Cylindrical, and Bowl, with Bowl type being dominant (54%, n=27). Regarding teat shapes, Funnel type was predominant in sheep (84%, n=42), while cylindrical shape was most common in goats (44%, n=22). Most correlations between udder and body measurements were positive and statistically significant, though generally weak. A significant negative correlation was detected between Udder Teat Diameter (UTD) and Distance Between Udder Teats and Ground (DUTG) in Saanen goats (r = –0.365, P<0.05), and between Withers Height (WH) and Udder Width (UW) in Norduz sheep (r = –0.286, P<0.05). The findings provide valuable reference data for evaluating udder health, guiding clinical decisions, and supporting breeding programs aimed at improving productivity and suitability for mechanized milking systems in both breeds. In conclusion, the results highlight the differences in udder morphometry and its correlations with external body traits, which may serve as an important reference for veterinary practices, disease evaluation, and the development of selection programs and robotic milking systems in small ruminants.

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INTRODUCTION

Small ruminants are crucial for global food security, economic development, and environmental sustainability (Sobur *et al.*, 2025). In developing countries, particularly in regions with poor soil and harsh climates, they support the agricultural economy and help prevent rural migration by providing income (Amiridis and Cseh, 2012). In Türkiye, small ruminants represent a production model perfectly suited to the country's natural and economic conditions, making them a cornerstone of agriculture, especially in the eastern provinces (Semerci and Çelik, 2016).

This study focuses on two significant breeds. The first is the Norduz sheep, an indigenous Turkish breed from the Gürpınar district of Van. This versatile breed, vital for local breeders, provides meat, milk, and wool (Koca *et al.*, 2023). Its milk is essential for producing Van herbed cheese, a traditional product of growing economic importance (Yıldız and Aygün, 2021). Furthermore, Norduz sheep are distinguished by their high adaptability to severe cold, poor pasture conditions, and common diseases, making them a valuable regional genetic resource (Yılmaz *et al.*, 2006).

The second breed, the Saanen goat, is a globally renowned dairy breed known for its high milk yield, fertility, and adaptability (Ceyhan and Karadağ, 2009). Goat milk is a key raw material for various dairy products such as cheese, yogurt, and ice cream. Growing recognition of its nutritional value and digestibility has driven demand and stimulated investment in production (Kesenkaş *et al.*, 2010).

The udder's morphology is a critical factor influencing milk production. While the udder body, internal duct system, and teats are relatively less developed in sheep, they are more prominent in goats (Dyce *et al.*, 2010). The efficiency of modern milking systems is directly influenced by the anatomical and physiological characteristics of the udder (Kahraman and Yılmaz, 2024). These characteristics, which vary due to genetic and environmental factors, not only determine milk yield but also affect susceptibility to infections like mastitis, which is considered the most costly and serious disease of dairy animals (Khan and Khan, 2006; Zafar *et al.*, 2025), impairing milk quality and causing significant economic losses (Rovai *et al.*, 2008; De Cremoux *et al.*, 2018). In this context, the morphology of the teat and udder also plays an important role in the pathogenesis of mastitis (Hussain *et al.*, 2012). Therefore, understanding udder structure is vital for selection programs aimed at improving milk yield and udder health (Karakus, 2024).

The aim of this study was to determine the udder morphometric characteristics of Norduz sheep and Saanen goats and to compare their relationships with external body measurements. The findings are expected to provide useful reference data for breeding and selection programs to enhance milking productivity in both breeds.

MATERIALS AND METHODS

Animals: This study was conducted at a private enterprise in Van, Turkey, using 50 clinically healthy, lactating Norduz sheep and 50 Saanen goats aged 2-5 years. All procedures were approved by the Ethics Committee of Van Yüzüncü Yıl University (Protocol No: 2024/03-18).

Morphometric measurements of animals: External body measurements, including wither height, rump height, chest girth, and body weight, were taken following established anatomical points (Berberoğlu, 2022). Wither height, rump height, and chest girth were measured using a flexible measuring tape (accuracy: 0.1cm), and body weight was determined using a digital livestock scale (accuracy: 0.1kg). Udder and teat measurements were performed on the 60th day of lactation, two hours pre-milking (Dzidic *et al.*, 2004).

Firstly, the udder types of the ewes (Kukovics *et al.*, 2006) and the goats (James *et al.*, 2009) were determined with reference to the figures presented (Fig. 1-3). In the udder type classification, the shape and depth of the udder, as well as the position of the teats, were taken into consideration.

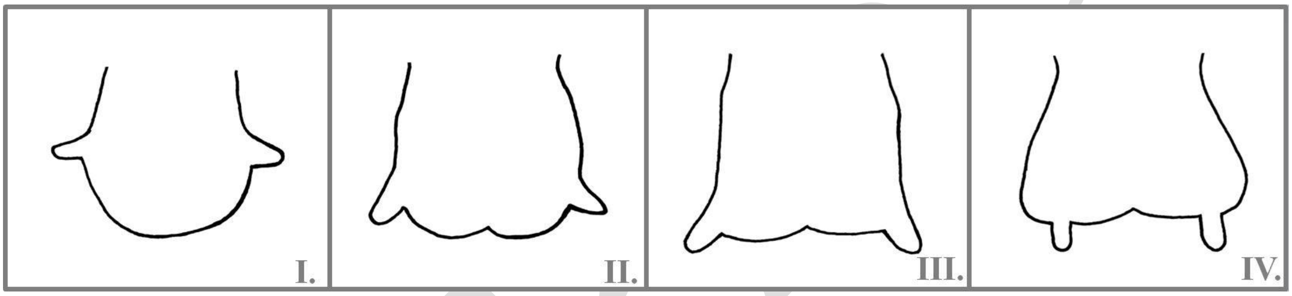

Fig. 1: Udder types (Modified based on Kukovics et al., 2006).

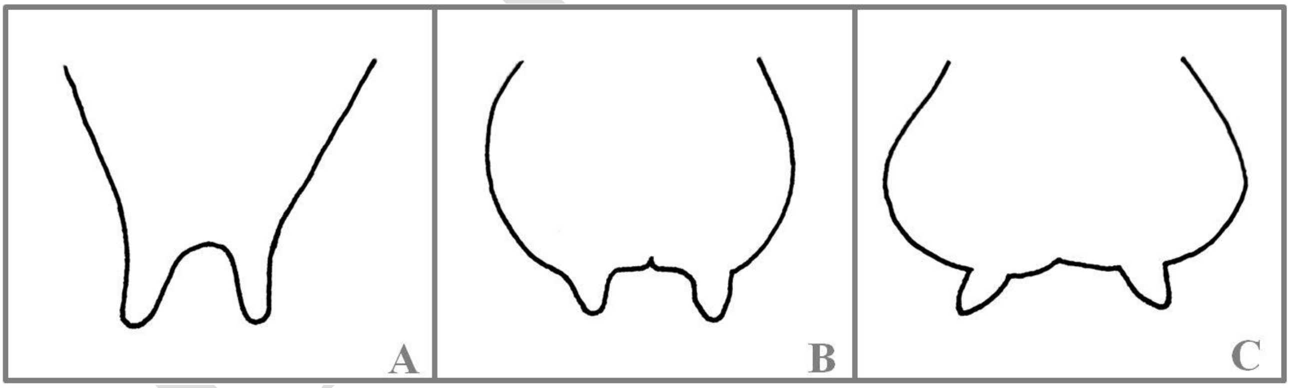

Fig. 2: Shapes of goat udders: A, Funnel; B, Cylindrical; C, Bowl (Modified based on James *et al.*, 2009).

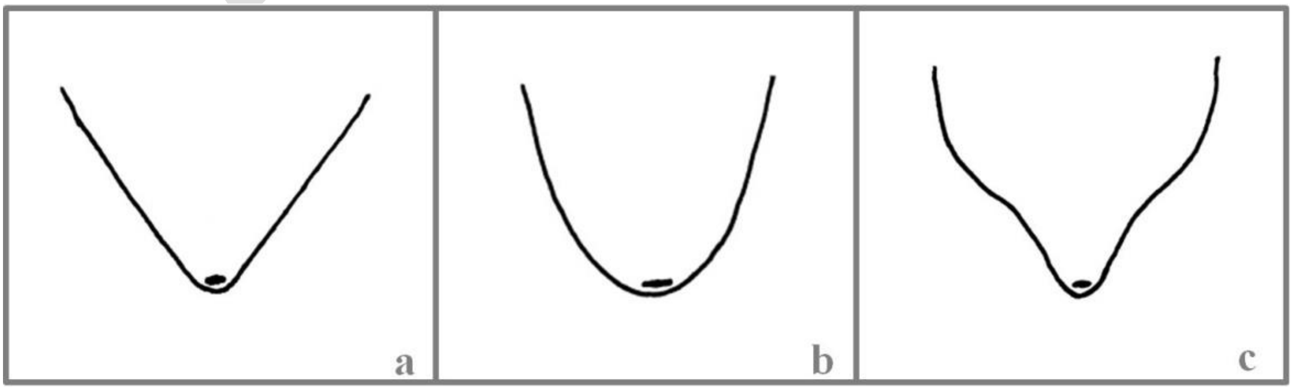

Fig. 3: Goat teat shapes: a, Funnel; b, Cylindrical; c, Bottle (Modified based on James et al., 2009).

According to this classification, udder types are divided into four groups:
Type I: Teats are positioned horizontally, and the mammary lobes are not distinctly separated.
Type II: Teats are nearly horizontal, and the mammary lobes are partially separated.
Type III: Teats are positioned between horizontal and vertical, with clearly separated mammary lobes.
Type IV: Teats are vertically or near-vertically oriented, and the mammary lobes are distinctly separated.

The udder types of the goats used in the study were divided into three groups as funnel, cylindrical, and bowl by considering the classifications in the literature. The teat shape was classified as funnel, cylindrical, or bottle (Kukovics *et al.*, 2006; James *et al.*, 2009).

In the linear morphometric measurements related to the udder in sheep and goats, parameters such as Udder Depth (cm), Udder Circumference (cm), Udder Width (cm), Udder Teat Length (cm), Udder Teat Diameter (cm), Distance Between Udder Teats (cm), and Distance Between Udder Teats and the Ground (cm) were measured, based on the methodologies outlined in the literature (Milerski *et al.*, 2006; Türkyılmaz *et al.*, 2018; Karakuş, 2024). Udder dimensions such as depth, circumference, width, and distance from the ground were measured using a flexible measuring tape (accuracy: 0.1cm), while teat length and diameter were measured with a digital vernier caliper (accuracy: 0.01mm).

The measurement points and abbreviations for the external body and udder morphometric measurements used in the study are presented in Table 1. Additionally, the measurement points used for udder morphometry are shown in Fig. 4. To ensure reliability, all parameters were measured three times by the same anatomist, and the average was used for analysis.

To ensure reliability, all parameters were measured three consecutive times by the same anatomist, and the average of the three readings was used for analysis. Measurement repeatability was further checked by calculating intra-observer variation, which remained below 5%. To minimize potential bias, the evaluator was blinded to the animal identification codes during measurement collection.

Statistical Analysis: All data were analyzed using IBM SPSS (version 26) with a significance level set at P<0.05. Normality was confirmed with Shapiro-Wilk and Skewness-Kurtosis tests, justifying the use of parametric methods. Descriptive statistics (mean, SD, n, %) were calculated. Independent variables, specifically udder teat shape and udder type, were reported as counts and percentages. Differences in dependent variables between groups were assessed using independent t-tests and One-Way Analysis of Variance (ANOVA), with Duncan's post-hoc test applied to identify pairwise group differences. Furthermore, Pearson correlation coefficients were calculated to examine the relationships between variables.

RESULTS

In this study, 13 morphometric parameters were analyzed from 50 Norduz sheep and 50 Saanen goats. Udder types in Norduz sheep were classified as Type-I, Type-II, Type-III, and Type-IV, while in Saanen goats, they were categorized as Funnel, Cylindrical, and Bowl. Teat shapes in both species were analyzed as Funnel, Cylindrical, and Bottle.

The classification of udder and teat types is presented in Fig. 5, with all other morphometric results detailed in Tables 2-6 and Figure. 6-7. Descriptive statistics for all measured parameters are provided in Table 2.

Table 1: Measurement points and abbreviations for external body measurements and udder morphometric measurements used in the study.

		Parameter	Abbreviation	Definition
Measurements	External Body	1	WH (cm)	Wither height: The vertical distance from the highest point of the withers (between the scapula) to the ground.
		2	RH (cm)	Rump Height: The highest point of the sacrum extending vertically to the ground.
		3	CG (cm)	Chest Girth: The circumference that passes over the withers and sternum just behind the humeral articulations, completely encircling the chest.
	Udder	4	UD (cm)	Udder Depth: The distance between the midpoint where the two udder lobes converge and the abdominal wall.
		5	UC (cm)	Udder Circumference: The circumference around the midpoint of the udder lobes.
		6	UW (cm)	Udder Width: The maximum width at the rear part of the udder.
		7	UTL (cm)	Udder Teat Length: The length between the proximal and distal ends of the teat.
		8	UTD (cm)	Udder Teat Diameter: The circumference around the midpoint of the teat.
		9	DUT (cm)	Distance Between Udder Teats: The distance between the two teats.
		10	DUTG (cm)	Distance Between Udder Teats and Ground: The distance between the teats and the ground.

Table 2: Mean measurement values for Saanen goats and Norduz sheep.

	Goat		Sheep	
	Mean±SD	Min.- Max.	Mean±SD	Min.- Max.
Age (years)	3.06±0.79	2.00-5.00	3.32±0.82	2.00-5.00
Parity (n)	2.24±0.80	1.00-5.00	2.40±0.90	1.00-5.00
W (kg)	30.90±3.37	25.00-38.00	50.92±3.25	45.00-55.00
WH (cm)	75.56±4.10	66.00-84.00	79.72±2.96	74.00-91.00
RH (cm)	72.20±3.14	65.00-78.00	76.78±2.96	73.00-86.00
CG (cm)	80.80±4.55	72.00-92.00	102.62±3.04	95.00-109.00
UD (cm)	13.61±1.01	11.66-15.34	12.72±1.62	10.10-16.42
UW (cm)	14.34±1.04	11.88-15.65	12.51±1.31	9.93-14.63
UC (cm)	44.50±3.51	36.00-51.00	34.89±3.55	27.00-43.00
UTL (cm)	4.49±0.52	3.11-5.56	2.83±0.44	1.95-3.95
UTD (cm)	2.15±0.26	1.62-2.99	1.70±0.32	1.21-2.77
DUT (cm)	12.93±1.07	11.24-15.24	14.00±1.46	10.05-17.23
DUTG (cm)	31.60±2.53	27.00-36.00	31.32±3.08	23.00-37.00

Independent sample T-test. W: Weight, WH: Withers Height, RH: Rump Height, CG: Chest Girth, UD: Udder Depth, UC: Udder Circumference, UW: Udder Width, UTL: Teat Length, UTD: Teat Diameter, DUT: Distance Between Two Teat Heads, DUTG: Distance Between Ground and Teat.

Table 3: Descriptive statistics of udder morphometry and external body measurements and comparisons between these measurements according to different udder types in Saanen goats.

	Funnel Mean±SD	Cylindrical Mean±SD	Bowl Mean±SD	p
Age (years)	2.57^{c}±0.53	2.88^{b}±0.96	3.30^{a}±0.67	0.048
Parity (n)	1.86±0.90	2.13±1.02	2.41±0.57	0.211
WH (cm)	73.71±5.12	75.62±3.93	76.00±3.95	0.429
W (kg)	29.43±3.87	30.50±3.25	31.52±3.29	0.297
RH (cm)	73.00±2.71	72.50±2.58	71.81±3.56	0.614
CG (cm)	81.00±4.04	81.63±5.41	80.26±4.18	0.640
UD (cm)	13.08±1.19	13.58±0.96	13.76±0.99	0.293
UW (cm)	14.49±1.02	14.48±0.94	14.21±1.11	0.661
UC (cm)	44.14±3.39	44.81±3.78	44.41±3.49	0.900
UTL (cm)	3.63^{b}±0.36	$4.58^{a\pm}$0.41	4.66^{a}±0.38	0.001
UTD (cm)	1.92^{b}±0.26	2.18^{a}±0.20	2.19^{a}±0.26	0.044
DUT (cm)	12.63±1.00	12.88±0.94	13.03±1.17	0.664
DUTG (cm)	31.71±2.36	30.94±2.57	31.96±2.56	0.444

*Significance levels according to one way ANOVA test; Different superscripts (a,b,c) within rows indicate significant differences (P<0.05, Duncan post-hoc test). W: Weight, WH: Withers Height, RH: Rump Height, CG: Chest Girth, UD: Udder Depth, UC: Udder Circumference, UW: Udder Width, UTL: Teat Length, UTD: Teat Diameter, DUT: Distance Between Two Teat Heads, DUTG: Distance Between Ground and Teat.

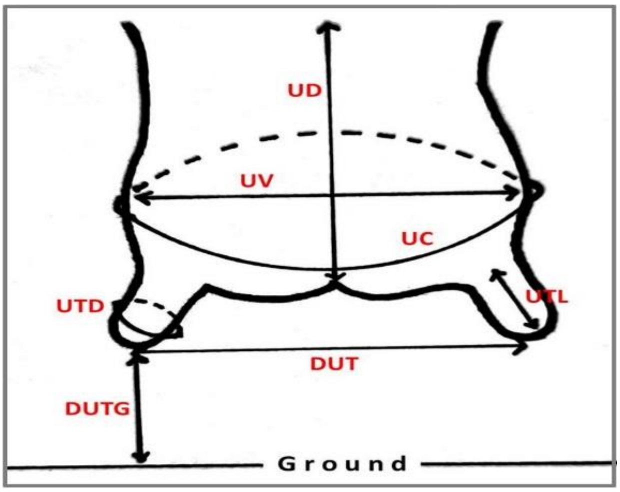

Fig. 4: Morphometric measurement points belonging to the udder.

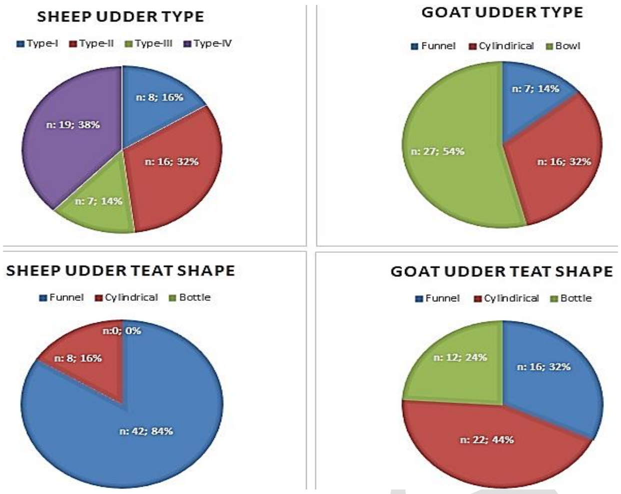

Fig. 5: Classification of udder types and teat shapes in Norduz sheep and Saanen goats.

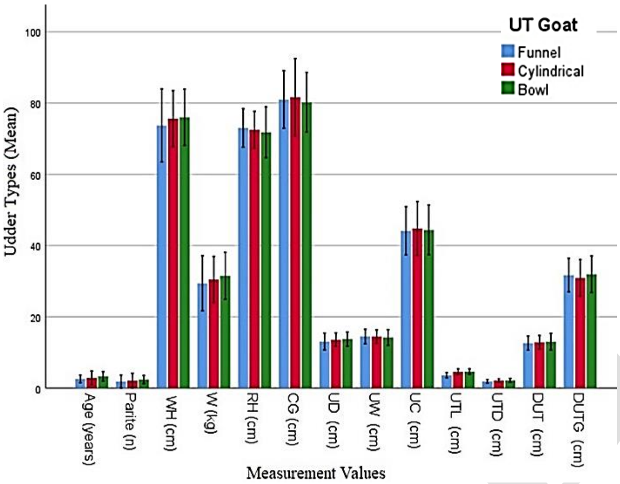

Fig. 6: Distribution of morphometric and external body measurement values according to udder types in Saanen goats.

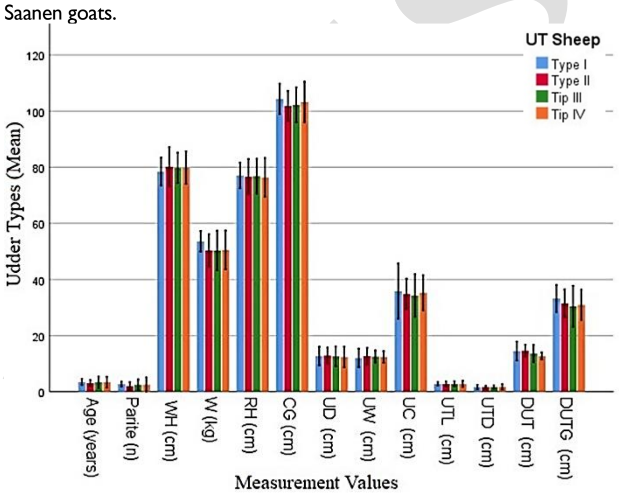

Fig. 7: Distribution of measurement values according to different udder types in Norduz sheep.

As shown in Fig. 5, the most prevalent udder type in Norduz sheep was Type-IV (38%, n=19), whereas in Saanen goats, the Bowl type was dominant (54%, n=27). For teat shapes, the Funnel type was predominant in sheep (84%, n=42) and the cylindrical type in goats (44%, n=22). No Bottle-type teats were observed in sheep.

Table 4: Descriptive statistics and comparison of udder morphometric and external body measurements according to udder types in Norduz sheep.

	Type-I Mean±SD	Type-II Mean±SD	Type-III Mean±SD	Type-IV Mean±SD	p
Age (years)	3.50±0.53	3.06±0.57	3.42±1.02	3.43±0.98	0.510
Parity (n)	2.75±0.46	2.00±0.73	2.53±0.96	2.57±1.27	0.175
WH (cm)	78.50±2.51	80.19±3.51	79.79±2.72	79.86±2.91	0.630
W (kg)	53.63±1.85	50.38±2.92	50.37±3.53	50.57±3.46	0.080
RH (cm)	77.13±2.30	76.69±3.14	76.84±3.10	76.43±3.46	0.974
CG (cm)	104.38±2.72	101.88±2.68	102.26±3.12	103.29±3.64	0.242
UD (cm)	12.73±1.68	12.93±1.44	12.64±1.76	12.40±1.84	0.914
UW (cm)	12.08±1.65	12.71±1.50	12.56±1.10	12.42±1.04	0.739
UC (cm)	35.88±4.94	34.91±2.72	34.32±3.82	35.29±3.15	0.765
UTL (cm)	2.86±0.31	2.81±0.46	2.84±0.45	2.84±0.57	0.995
UTD (cm)	1.69±0.40	1.67±0.26	1.70±0.29	1.76±0.48	0.937
DUT (cm)	14.50^{a}±1.70	14.67^{a}±1.06	13.69^{b}±1.55	12.76^{c}±0.64	0.013
DUTG (cm)	33.25±2.43	31.50±2.50	30.47±3.66	31.00±2.71	0.196

*Significance levels according to one way ANOVA test; Different superscripts (a,b,c) within rows indicate significant differences (P<0.05, Duncan post-hoc test). W: Weight, WH: Withers Height, RH: Rump Height, CG: Chest Girth, UD: Udder Depth, UC: Udder Circumference, UW: Udder Width, UTL: Teat Length, UTD: Teat Diameter, DUT: Distance Between Two Teat Heads, DUTG: Distance Between Ground and Teat.

Comparisons based on udder types in Saanen goats (Table 3) revealed a statistically significant age difference (P<0.05). Furthermore, Udder Teat Length (UTL) and Udder Teat Diameter (UTD) were significantly lower in goats with Funnel-type udders compared to the Cylindrical and Bowl groups (P<0.05). No other significant differences were found. Figure 6 graphically illustrates the distribution of all measured parameters across these udder types.

For Norduz sheep (Table 4), the Distance Between Udder Teats (DUT) showed significant differences among udder types (P<0.05). The mean DUT values for Type-I and Type-II udders were significantly higher than those for Type-III and Type-IV. Additionally, the DUT value for Type-III was significantly higher than for Type-IV. No other parameters showed significant differences across udder types (P>0.05). Figure 7 displays the distribution of these measurements.

In Saanen goats, correlation analysis (Table 5) revealed numerous significant positive correlations (P<0.05). These included relationships between Age and Parity (P), Weight (W), Withers Height (WH), Udder Depth (UD), Udder Width (UW), DUT, and Distance Between Udder Teats and Ground (DUTG); between UD and Udder Circumference (UC), UW, UTL, and UTD; and between UTL and UTD. However, a significant negative correlation was found between UTD and DUTG (P<0.05).

Table 5: Correlations between mean measurement values in Saanen goats

		Age	Parity	W	WH	RH	CG	UD	UW	UC	UTL	UTD	DUT
Parity (years)	r	0.849**	1										
	p.	0.001											
W (kg)	r	0.384**	0.245	1									
	p.	0.006	0.087										
WH (cm)	r	0.435**	0.370**	0.604**	1								
	p.	0.002	0.008	0.000									
RH (cm)	r	-0.193	-0.085	0.162	0.206	1							
	p.	0.179	0.558	0.261	0.150								
CG (cm)	r	0.139	0.183	0.320*	0.152	0.300*	1						
	p.	0.335	0.204	0.024	0.293	0.034							
UD (cm)	r	0.309*	0.139	0.215	0.046	0.022	-0.107	1					
	p.	.029	0.335	0.133	0.752	0.877	0.461						
UW (cm)	r	0.429**	0.370**	0.042	0.164	-0.183	0.091	0.367**	1				
	p.	0.002	0.008	0.774	0.255	0.203	0.530	0.009					
UC (cm)	r	0.275	0.073	0.225	0.192	0.224	-0.004	0.474**	0.314*	1			
	p.	0.053	0.614	0.116	0.183	0.118	0.979	0.001	0.027				
UTL (cm)	r	0.273	0.319*	0.249	0.140	0.033	0.121	0.328*	0.042	0.095	1		
	p.	0.055	0.024	0.081	0.331	0.818	0.402	0.020	0.770	0.514			
UTD (cm)	r	0.021	-0.014	-0.127	-0.087	-0.037	-0.156	0.327*	-0.097	0.128	0.566**	1	
	p.	0.884	0.921	0.380	0.547	0.799	0.279	0.020	0.502	0.377	0.000		
DUT (cm)	r	0.287*	0.158	0.527**	0.578**	0.167	0.315*	0.208	0.277	0.370**	-0.008	-0.103	1
	p.	0.044	0.274	0.000	0.000	0.248	0.026	0.147	0.052	0.008	0.954	0.475	
DUTG (cm)	r	0,337*	0,362**	0,206	0,181	-0,033	-0,078	0,142	0,210	0,186	-0,088	-0,365**	0,136
	p.	0,017	0,010	0,152	0,208	0,818	0,590	0,326	0,143	0,195	0,544	0,009	0,347

*. Correlation is significant at the P<0.05; **. Correlation is significant at the P<0.01; r: Pearson correlation W: Weight, WH: Withers Height, RH: Rump Height, CG: Chest Girth, UD: Udder Depth, UC: Udder Circumference, UW: Udder Width, UTL: Teat Length, UTD: Teat Diameter, DUT: Distance Between Two Teat Heads, DUTG: Distance Between Ground and Teat.

Table 6: Correlations between mean measurement values in Norduz sheep

		Age	Parity	W	WH	RH	CG	UD	UW	UC	UTL	UTD	DUT
Parity (years)	r	0.899**	1										
	p.	0.001											
W (kg)	r	0.194	0.150	1									
	p.	0.178	0.298										
WH (cm)	r	0.105	-0.011	0.208	1								
	p.	0.467	0.941	0.147									
RH (cm)	r	0.088	-0.020	0.280*	0.449**	1							
	p.	0.541	0.891	0.049	0.001								
CG (cm)	r	0.320*	0.287*	0.372**	0.058	0.047	1						
	p.	0.024	0.044	0.008	0.688	0.745							
UD (cm)	r	0.390**	0.339*	0.006	-0.032	0.118	0.101	1					
	p.	0.005	0.016	0.967	0.828	0.414	0.485						
UW (cm)	r	0.173	0.134	-0.085	-0.286*	-0.082	0.038	0.540**	1				
	p.	0.229	0.353	0.557	0.044	0.570	0.796	0.001					
UC (cm)	r	0.232	0.291*	0.081	0.064	0.150	0.138	0.520**	0.440**	1			
	p.	0.105	0.041	0.574	0.658	0.300	0.338	0.001	0.001				
UTL (cm)	r	0.008	0.093	-0.063	-0.115	0.163	0.145	0.302*	0.373**	0.383**	1		
	p.	0.959	0.519	0.663	0.426	0.259	0.315	0.033	0.008	0.006			
UTD (cm)	r	0.173	0.246	0.016	-0.110	-0.220	-0.053	0.277	0.273	0.371**	0.398**	1	
	p.	0.230	0.085	0.914	0.446	0.125	0.715	0.052	0.055	0.008	0.004		
DUT (cm)	r	0.116	0.074	0.185	-0.033	0.061	-0.076	0.557**	0.536**	0.585**	0.296*	0.266	1
	p.	0.424	0.609	0.198	0.819	0.673	0.601	0.001	0.001	0.001	0.037	0.062	
DUTG (cm)	r	-0.001	-0.054	0.390**	0.203	0.281*	0.159	0.005	0.018	-0.102	-0.154	-0.204	0.058
	p.	0.995	0.708	0.005	0.158	0.048	0.270	0.971	0.902	0.480	0.284	0.155	0.691

*. Correlation is significant at the P<0.05; **. Correlation is significant at the P<0.01; r: Pearson correlation. W: Weight, WH: Withers Height, RH: Rump Height, CG: Chest Girth, UD: Udder Depth, UC: Udder Circumference, UW: Udder Width, UTL: Teat Length, UTD: Teat Diameter, DUT: Distance Between Two Teat Heads, DUTG: Distance Between Ground and Teat.

In Norduz sheep (Table 6), significant positive correlations (P<0.05) were also prevalent. Key relationships were observed between UD and UC, UW, UTL, and DUT; between UC and UTL, UTD, and DUT; and between UTL, UTD, and DUT. Notably, a significant negative correlation was detected between Withers Height (WH) and Udder Width (UW) (P<0.05).

DISCUSSION

The morphological and physiological traits of sheep and goats, including age, parity, body weight, and udder structure, are of great clinical importance for milk production and animal health (Tilki Yılmaz and Keskin, 2021; Makamu *et al.*, 2023). Morphometric udder measurements are directly linked to both milk production capacity and udder health, with factors like udder symmetry and teat placement being critical for evaluating diseases such as mastitis (Gupta *et al.*, 2022; Marshall *et al.*, 2024; Salomone-Caballero *et al.*, 2024; Chambers *et al.*, 2025). This study analyzed these relationships in Norduz sheep and Saanen goats to provide a valuable guide for veterinarians, breeders, and milking system specialists, aiming to enhance milking efficiency and inform genetic breeding programs.

In small ruminants, udder and teat shape and dimensions are directly related to the longevity of productivity, especially in goats and sheep kept on pasture. Animals with deep (suspended) udders are more prone to mechanical injuries, which increase the risk of developing various udder-related pathological conditions, especially mastitis. Such conditions often reduce milk yield and may lead to early removal from the herd from the reproductive herd. (Vrdoljak *et al.*, 2020). When studies conducted to determine udder types and teat shapes were examined, Gupta *et al.* (2022) grouped udder types as Cylindrical and Bowl in Barbari goats, and teat shapes as Funnel, Cylindrical and Bottle. In Barbari goats, the number of those with Bowl-shaped udder was found to be higher than those with Cylindrical-shaped udder. In addition, it was observed in this study that Funnel-type teats were more common than Bottle and Cylindrical types. Similarly, James *et al.* (2009) reported that in West African Dwarf (Wad) goats, the number of goats with Bowl-shaped udder was more dominant than Funnel and Cylindrical udder shapes, with 57.20%. In the same study, Cylindrical teats were found to be more common than Funnel and Bottle teats, with a rate of 64.43%. In a more recent study focusing on the Nigerian West African Dwarf Goat population by Abiola *et al.* (2024), it was determined that the Pear-shaped udder type was more dominant than the Funnel and Cylindrical udder types, with a rate of 48.7%. This study also revealed that the Funnel-type teat was more dominant than the Cylindrical and Bottle types, with a rate of 44.0%. In addition, Amao *et al.* (2003) reported that in Red Skota goats, the udder types were Round (1.7%), Funnel (9.0%), Cylindrical (44.1%) and Bowl (45.2%); and the teat types were found to be Funnel (%50.9), Balloon (2.3%), Bottle (17.5%) and Cylindrical (29.4%). Margatho *et al.* (2020) reported that the teat types in Serana goats were Globular (40%), Pear-shaped (30%), and Cylindrical Pendulous (30%); and the teat types were Funnel (30%), Bottle (23.3%), and Balloon (26.7%). In this study, it was determined that the teat types in Saanen goats were Funnel (14%, n: 7), Cylindrical (32%, n: 16) and Bowl (54%, n: 27). In addition, it was found that the teat types in goats were Funnel (32%, n: 16), Cylindrical (44%, n: 22) and Bottle (24%, n: 12).

When examining studies conducted to classify udder types and teat shapes in sheep, various classification systems and findings have been reported across breeds. Karakuş (2024) categorized udder types from Type I to Type VI in Norduz sheep and found that 37% (n=15) of 41 sheep had Type II and 63% (n=26) had Type III udders. Denk (2022) classified udders in 50 Karakaş-type Akkaraman sheep as Type-I (26%, n=13), Type-II (28%, n=14), Type-III (28%, n=14), and Type-IV (18%, n=9). In Elit Ivesi sheep, Kaygısız and Dağ (2017) reported the distribution of udder types as Type-I (31%), Type-II (1%), Type-III (42%), Type-IV (3%), and Type-VI (23%). Similarly, Akdag *et al.* (2018) grouped udders in 32 Karakaya sheep into Type-I (n=11), Type-II (n=13), Type-III (n=4), and Type-IV (n=4). Türkyılmaz *et al.* (2018) evaluated Morkaraman (n=68), Tuj (n=64), and Awassi (n=26) sheep and found the prevalence of Type-I udders as 22.8%, 12.3%, and 33.3%; Type-II as 1.4%, 6.1%, and 0.0%; Type-III as 70%, 72.3%, and 66.6%; Type-IV as 2.8%, 9.2%, and 0.0%; and Type-VI as 2.8%, 0.0%, and 0.0%, respectively. Doğan *et al.* (2013) observed the distribution of udder types in Anatolian Merino sheep as Type-I (22.0%), Type-II (20.3%), Type-III (22.0%), Type-IV (16.9%), and Type-VI (18.6%). Additionally, James *et al.* (2009) reported that 83.92% of West African Dwarf (WAD) sheep (n=143) had bowl-shaped udders, and cylindrical teats were dominant with a rate of 83.91%. In the present study, the udder types observed in Norduz sheep were classified as Type-I (16%, n=8), Type-II (32%, n=16), Type-III (14%, n=7), and Type-IV (38%, n=19). Regarding teat shapes, Funnel type (84%, n=42) and Cylindrical type (16%, n=8) were identified, while Bottle-shaped teats were not observed. Overall, the differences in udder and teat types observed across studies and breeds are thought to be influenced by factors such as breed characteristics, lactation stage, and milk production traits.

In our study, linear morphometric measurements of the udder such as Udder Depth (UD), Udder Circumference (UC), Udder Width (UW), Udder Teat Length (UTL), Udder Teat Diameter (UTD), Distance Between Udder Teats (DUT) and Distance Between Udder Teats and Ground (DUTG) were obtained in different goat and sheep breeds in previous studies. In goats, these measurements were measured in West African Dwarf goats (James *et al.*, 2009; Abu *et al.*, 2013), Kilis goats (Yılmaz Tilki and Keskin, 2021), Akkeçi goats (Keskin *et al.*, 2005), Bedouin goats (Kouri *et al.*, 2019), Damascus Goats (Yılmaz and Can, 2022), Barbari Goats (Gupta *et al.*, 2022), Black and Meriz goats (Merkhan and Alkass, 2011), Honamlı goats (Akbaş *et al.*, 2019), local goats from the Rohilkhand Region of India (Upadhyay *et al.*, 2014), Serrana Goats (Margatho *et al.*, 2020), Tunisian Local Goats (Ahlem *et al.*, 2023), and Saanen Goats in It has been stated in many studies such as a semi-intensive system (Erduran, 2022). In sheep, Norduz Sheep (Karakus, 2024), Karakaş Type Akkaraman Sheep (Denk, 2022), Dairy sheep (Milerski *et al.*, 2006; Marshall *et al.*, 2024), New Zealand Dairy Ewes (Chambers *et al.*, 2025), Karakaya Sheep (Akdag *et al.*, 2018), Kivircik, Tahirova, and Karacabey Merino Ewes (Altınçekiç and Koyuncu, 2011), Morkaraman, Tuj and Awassi Sheep (Özyürek *et al.*, 2018), Pelibuey Ewes (Arcos-Álvarez *et al.*, 2020), Tuj Ewes (Sarı *et al.*, 2015), Spanish Assaf Sheep (Ángeles Pérez-Cabal *et al.*, 2013), and Morkaraman and Awassi Sheep has been included in many studies (Özyürek, 2020). In our study, the mean values for goats were: UD: 13.606 ± 1.012cm, UC: 44.500 ± 3.507cm, UW: 14.335 ± 1.035cm, UTL: 4.487 ± 0.520cm, UTD: 2.146 ± 0.257cm, DUT: 12.926 ± 1.068cm, and DUTG: 31.600 ± 2.53 cm. For sheep: UD: 12.718 ± 1.619cm, UC: 34.890 ± 3.552cm, UW: 12.511 ± 1.306cm, UTL: 2.834 ± 0.439cm, UTD: 1.697 ± 0.323cm, DUT: 14.001 ± 1.458cm, and DUTG: 31.320 ± 3.080cm. Although consistent with the literature, minor discrepancies may arise due to factors such as breed, age, body weight, measurement techniques, and stage of lactation.

In sheep and goats, body weight and external body measurements are widely recognized as indirect indicators of udder health and milk production potential (Ángeles Pérez-Cabal *et al.*, 2013; Kouri *et al.*, 2019; Tilki Yılmaz and Keskin, 2021; Shettima *et al.*, 2022; Makamu *et al.*, 2023). Tilki Yılmaz and Keskin (2021) found correlations in Kilis goats between body size and udder traits and milk yield. Shettima *et al.* (2022) showed strong positive correlations between body weight and udder traits in three

Nigerian sheep breeds. Similarly, Makamu *et al.* (2023) identified such correlations in Saanen goats, though they recommended larger sample sizes for future work. In this study, Saanen goats showed significant positive correlations between body weight and WH (r = 0.604, P<0.01), CG (r = 0.320, P<0.05), DUT (r = 0.527, P<0.01); WH and DUT (r = 0.578, P<0.01); RH and CG (r = 0.300, P<0.05); CG and DUT (r = 0.315, P<0.05). In Norduz sheep, body weight was positively correlated with RH (r = 0.280, P<0.05), CG (r = 0.372, P<0.01), and DUTG (r = 0.390, P<0.01); WH correlated with RH (r = 0.449, P<0.01) and UW (r = –0.286, P<0.05); RH correlated with DUTG (r = 0.281, P<0.05). These findings highlight the potential use of external body metrics as indirect indicators in breeding programs.

Age and parity play critical roles in mammary gland development and milk production in small ruminants. Studies have confirmed that as age and parity increase, anatomical and functional changes occur in the mammary gland (Kausar *et al.*, 2001; James *et al.*, 2009; Merkhan and Alkass, 2011; Özyürek *et al.*, 2018; Tilki Yılmaz and Keskin, 2021; Erduran, 2022; Ahlem *et al.*, 2023; Marshall *et al.*, 2023; Karakuş, 2024; Salomone-Caballero *et al.*, 2024; Chambers *et al.*, 2025). Although some studies have reported negative correlations between mammary morphological traits and linear udder measurements in goats (Keskin *et al.*, 2005; James *et al.*, 2009; Merkhan and Alkass, 2011; Upadhyay *et al.*, 2014; Tilki Yılmaz and Keskin, 2021; Gupta *et al.*, 2022; Yılmaz and Can, 2022; Ahlem *et al.*, 2023) and sheep (Altınçekiç and Koyuncu, 2011; Özyürek *et al.*, 2018; Arcos-Álvarez *et al.*, 2020; Özyürek, 2020; Shettima *et al.*, 2022; Makamu *et al.*, 2023; Karakus, 2024), the majority of findings indicate positive and significant correlations. In our study, significant positive correlations were found between age and various parameters in Saanen goats, including parity, body weight, wither height (WH), udder depth (UD), udder width (UW), distance between teats (DUT), and distance between teats and the ground (DUTG). Additionally, parity was positively and significantly correlated with WH, UW, udder teat length (UTL), and DUTG (P<0.05). While some negative associations were noted, the majority were significant and positive. These metrics may serve as valuable indicators for clinical evaluations of udder health and selection strategies in breeding programs aimed at improving milking productivity, milk production, and reproductive performance.

Conclusions: This study demonstrated significant relationships between udder morphometric traits and external body measurements in Norduz sheep and Saanen goats. The findings provide practical, non-invasive indicators for clinicians to assess udder health, predict milk production potential, and identify animals at risk of udder disorders such as mastitis, thereby supporting more informed herd management and clinical decision-making. At the same time, these results contribute to the academic understanding of breed-specific udder characteristics and highlight their potential application in genetic selection and breeding programs aimed at improving productivity, reproductive performance, and udder health in small ruminants. Overall, this study offers both practical guidance for veterinary practice and a foundation for future research in small ruminant production systems.

Ethical Statement: The study was conducted in accordance with the ethical guidelines approved by the Ethics Committee of Van Yüzüncü Yıl University (Protocol No: 2024/03-18).

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