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Prediction of live weight from body measurements using stepwise regression models in Karacabey Merino lambs

Adem Kabasakal

Susurluk Agriculture and Forest Vocational School, Bandırma Onyedi Eylül University, Balıkesir, Türkiye.

Correspondence: *Adem Kabasakal (akabasakal@bandirma.edu.tr)*

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ABSTRACT

Objectives: The aim of this study was to determine regression models that can be used to estimate live weight from body measurements in Karacabey Merino lambs of different ages (6th, 8th and 12th months).

Material and Methods: The animal material for the study consisted of 200 Karacabey Merino lambs. Some body measurements were taken from all lambs and live weights were also recorded. For live weight prediction equations with multiple linear regression analysis using some measurements according to age groups. stepwise multiple regression procedure was used in SAS (1999). DUNCAN test. one of the tests for multiple comparisons, was used to detect the differences between groups.

Results: The least squares mean for body length (BL), withers height (HW), back height (BH), rump height (RH), breast depth (CD), breast width (CW), rump width (RW), and live weight (LW) were 71.28 cm, 69.91 cm, 70.50 cm, 71.57 cm, 30.05 cm, 87.25 cm, 21.50 cm, 23.32 cm, and 51.05 kg, as the average of all lambs, respectively. High positive phenotypic correlation coefficients were found between body measurements and live weight in the different age groups. It is noteworthy that the live weight estimation models for three different age groups using stepwise regression analysis (second, third, and fourth models) can be recommended for the 6-month ages (R^2:0.82), 8-month ages (R^2:0.71), and 12th (R^2:0.79) months of life. The variables that can be used in the equations to estimate body weight for this breed. at these ages are HW, CW, RW, CG, CD, and BL.

Conclusion: Finally. it has been demonstrated that the live weights of Karacabey Merino lambs can be estimated with high accuracy using the stepwise regression method based on body measurements.

Keywords: *Body measurements, Extensive, Karacabey Merino sheep, Regression models*

INTRODUCTION

It can be said that studies on sheep breeding in Turkey began with the establishment of the Republic. Within the framework of these studies. the initial focus was on "merinoization" studies to improve the wool quality of Turkish sheep breeds (Kaymakçı and Taskin, 2008; Sezenler and Özder, 2009). Later. efforts were made to improve the meat and milk yield of indigenous breeds in Turkey (Kaymakçı, 2006; Sönmez et al., 2009). For this purpose. crosses of German Meat Fleece Merino x Kıvırcık were performed on Karacabey farm. As a result of this study. Karacabey Merino was developed for wool and meat performance (Özcan, 1990). Karacabey Merino bred mainly in the Marmara region of Turkey, has become an important breed with medium size, high quality fleece and carcass. (Sezenler et al., 2013; Yilmaz et al., 2014; Yilmaz et al., 2015; Ambarcioglu et al. 2017).

Breeding objectives in livestock include the determination of traits of economic importance. In this context. body measurements and live weight control. which can be considered the most important of these measures. are important criteria that are widely used for both scientific research and selection procedures (Yilmaz et al., 2013; Siddiqui et al., 2015; Kumar et al., 2018; Jawasreh et al., 2018; Hamadani et al., 2019; Sabbioni et al., 2020). Growth characteristics and live weights of sheep are economically important characteristics for breeding farms. Therefore. the accuracy of the measurements required to monitor the development of sheep is extremely significant. (Hossein-Zadeh, 2012; Abdel-Mageed and Ghanem, 2013; Eteqadi et al., 2014; Jafari and Hashemi, 2014; Mulyono et al., 2018) Livestock has a balance between body measurements and live weight in livestock. Studies on this topic have found significant phenotypic correlation values between live weight and body measurements. Many studies on this subject show a phenotypic correlation (Yilmaz et al., 2013; Ghotbaldini et al., 2019; Ibrahim et al., 2021; Panda et al., 2021). Research on body measurements is very important for describing breeds.

Since sheep breeding in Turkey is mainly carried out under extensive conditions. there is often not enough infrastructure available to perform live weight checks. Which is an important selection criterion (Yilmaz et al., 2013; Inan and Aygun. 2019). This important selection criterion cannot be adequately be used on some sheep farms. Estimation of liveweight of animals with different statistical approaches using some body measures is particularly important to more effectively include farms that do not have sufficient infrastructure in breeding programs. Several studies have found high and positive phenotypic correlation coefficients between body weight and body measurements. Scientific studies have shown that live weight can be estimated from various body measurements with a high degree of accuracy (Yilmaz et al., 2013; Sun et al., 2020; Esen and Elmaci, 2021; Kumar et al., 2021). Due to inadequate infrastructure on some sheep farms, estimation of live weight using body measurements will provide more practical and rapid results and will also make an important contribute to breeding programs. In the present study, the objective was to predict the live weight of Karacabey Merino lambs of different age groups from body measurements using stepwise regression models.

MATERIALS and METHODS

The animal material for the study consisted of 200 Karacabey Merino lambs. The Karacabey Merino lambs were divided into three groups according to age. The birth dates of the lambs are registered. There are male and female lambs in every age group. At the sheep farm where the study was conducted. controlled mating of sheep is practiced. leading to synchronized births. While there may be differences in individual birth dates in days. there is no age difference among the lambs within each group. All lambs were measured on the same day. The number of animals in each age group is shown in Table 1.

Table 1. Distribution of animal material by age groups.

Age Group (Months)	n
6th	54
8th	35
12th	111
Total	**200**

The live weights of the animals were determined using an electronic balance with a sensitivity of 50 g. Of the body measurements defined in the study. body length (BL). withers height (HW). back height (BH). rump height (RH). chest depth (CD). chest width (CW). and rump width (RW) were measured with a measuring stick. and chest girth (CG) was measured with a tape measure (Figure 1).

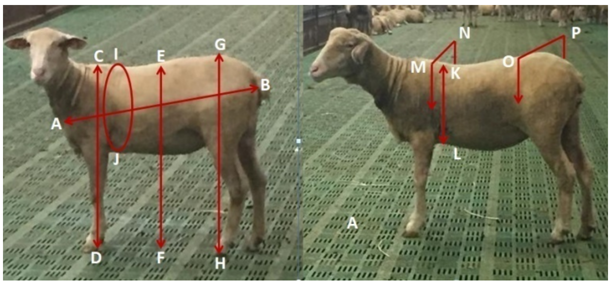

Figure 1. Karacabey Merino ewe showing the exact points at which the body measurements were taken.

To check the normality of the data, the procedure UNIVARIATE of the statistical programme SAS (1999) was used. The result of this analysis showed that the data were normally distributed for all measured characteristics. Subsequently, the general linear model (GLM) procedure of the same software was used to perform an analysis of variance and obtain least squares means for the studied traits. Phenotypic correlations between variables were also obtained using the procedures PROC CORR in SAS (1999). DUNCAN test, one of the tests for multiple comparisons, was used to show the differences between groups.

The mathematical models used for the analysis of variance are presented below:

Model used for live weight:

$\gamma_{ijk} = \mu + a_i + b_j + e_{ij}$

Model used for body measurement

$\gamma_{ijk} = \mu + a_i + b_j + \beta_k(X_i - \bar{X}) + e_{ijk}$

where:

Y_{ijk}= Observations for body measurement and weight

μ= Overall mean of the trait

a_i= Fixed effect of age group (i=6th. 8th and 12th months)

b_j= Fixed effect of gender (j= male and female)

β_1= Coefficient of regression of live weight

$\bar{X}$= Mean live weight

X_i= Live weight

e_{ijk} and e_{ijk} =Random errors with the assumption of N (0. σ^2)

Estimation equations of live weights with multiple linear regression analysis using some measurements according to age groups were obtained by using stepwise multiple regression procedure in SAS (1999).

Multiple linear regression model given below was used for estimation equations.

$\hat{\boldsymbol{\gamma}}_{\boldsymbol{i}} = \hat{\beta}_0 + \hat{\beta}_1 x_{1+}\hat{\beta}_2 x_{2+}\hat{\beta}_3 x_{3+}\hat{\beta}_4 x_{4+}\hat{\beta}_5 x_{5+}\hat{\beta}_6 x_{6+}$ei

$\hat{\boldsymbol{\beta}}_{\boldsymbol{0}}$=Constant

$\hat{\boldsymbol{\beta}}_{\boldsymbol{i}}$=Regression coefficient

$\boldsymbol{x_i}$=Body measurements

$\boldsymbol{x_1}$= Height at withers (HW)

$\boldsymbol{x_2}$=Chest width (CW)

$\boldsymbol{x_3}$= Rump width (RW)

$\boldsymbol{x_4}$=Chest Girth (CG)

$\boldsymbol{x_5}$= Chest depth (CD)

$\boldsymbol{x_6}$=Body length (BL)

Afterwards. the obtained estimates were compared with the actual live weights.

RESULTS

Descriptive statistics obtained for the characteristics addressed in the study are shown in Table 2. When examining the descriptive statistics. it was noticeable that the coefficients of variation for CW, RW, and LW were relatively high compared to other traits.

The least squares means and standard errors are shown in Table 3. The general mean values for BL, HW, BH, RH, CD, CG, CW, RW and LW were 71.28 cm, 69.91 cm, 70.50 cm, 71.57 cm, 30.05 cm, 87.25 cm, 21.50 cm, 23.32 cm and 51.05 kg as the average of all lambs, respectively. The analysis results showed that there was a statistically highly significant difference between the age groups in the present study in terms of HW, BH, RH RW and LW ($p<0.01$).

To estimate body weight considering body measurements, separate models were developed for different age groups using the stepwise regression model. The developed models and standard error values of coefficients of determination (R^2) are shown in Table 4. The independent variables of the final models selected for each age group analyzed were as follows: HW, CW, RW and CG for 6 months; HW, CW, RW and CG for 8 months; HW, CW, RW, CG and CD for 12 months. In the 8-month group, the independent variable CG (2.04) and in the 12-month group, CD (2.03) are observed to have a higher impact on the dependent variable.

When the determination coefficients (R^2) obtained for the developed models were evaluated, the lowest value was achieved in the first model developed for the 8th-month age group, while the highest value was obtained in the second model developed for the 6th-month age group. Additionally, all obtained regression models were found to be statistically significant.

The ANOVA significance tests for models II, III, and IV for these age groups and the t-test for regression coefficients were conducted according to the results presented in Table 4 in order to determine the best model with the stepwise regression method. The root means square error values (S) obtained for these models are lower than the other models in their age group, and the R^2 values are higher. In addition, since the Durbin-Watson (DW) test statistic values obtained are close to 2, there is no autocorrelation problem in these models. The fact that the Variance Inflation Factor (VIF) values obtained for each coefficient are less than 10 indicates that there is no multicollinearity problem.

Phenotypic correlation coefficients between body measurements and live weights for the age groups included in the study are shown in Table 5.

In general, high positive phenotypic correlation coefficients between body measurements and live weight were obtained for all age groups. Among the age groups, the highest phenotypic correlation coefficients between body measurements and live weight were obtained in the 6-month-old age group, with the exception of CD and CG.

Table 2. Basic statistics on body measurements and live weight.

Variable	Age	n	Mean	SD	CV	Min	Max
	6	54	39.90	7.59	19.03	26.50	59.00
LW	8	35	48.29	8.67	17.96	33.50	63.50
	12	111	56.07	9.75	17.38	35.00	89.00
	6	54	67.07	4.24	6.32	59.00	77.00
BL	8	35	73.13	3.24	4.44	65.00	79.00
	12	111	73.26	4.38	5.98	63.50	85.00
	6	54	65.93	3.52	5.33	60.00	75.00
HW	8	35	70.81	2.12	3.00	68.00	**76.50**
	12	111	71.22	3.37	4.73	64.00	81.00
	6	54	66.25	3.32	5.01	60.00	74.00
BH	8	35	71.29	1.82	2.56	68.50	77.00
	12	111	72.15	3.46	4.80	66.00	82.00
	6	54	67.03	3.33	4.96	60.00	75.00
RH	8	35	72.20	1.87	2.59	69.00	78.00
	12	111	73.59	3.32	4.50	66.50	83.00
	6	54	26.07	1.81	6.94	21.00	30.00
CD	8	35	27.69	1.62	5.85	24.00	30.00
	12	111	29.19	2.04	7.00	21.00	35.00
	6	54	80.58	5.30	6.57	72.00	94.00
CG	8	35	87.16	5.79	6.64	75.00	102.00
	12	111	91.51	6.70	7.32	78.00	109.00
	6	54	19.35	1.80	9.30	15.00	23.00
CW	8	35	21.20	2.43	11.44	16.00	27.00
	12	111	22.99	2.41	10.47	19.00	31.00
	6	54	21.67	1.97	9.09	18.00	28.00
RW	8	35	22.44	2.26	10.08	17.00	28.00
	12	111	24.62	2.41	9.78	18.00	31.00

BL:body length. HW:withers height. BH:back height. RH:rump height .CD: chest depth. CG: chest girth. CW: chest width. RW: rump width. LW: live weight. CV: coefficient of variation

Table 3. Least squares means and standard errors for body measurements and live weight belonging to Karacabey Merino lambs

Factors	n	BL	HW	BH	RH	CD	CG	CW	RW	LW
Age Group		p=0.546	p=0.000	p=0.000	p=0.000	p=0.498	p=0.419	p=0.843	p=0.043	p=0.000
6th months	54	70.84±0.962	67.81±0.461^{a}	68.04±0.456^{a}	68.90±0.424^{a}	29.75±2.495	85.88±1.284	21.57±0.269	23.36±0.299^{a}	39.90±0.817^{a}
8th months	35	72.04±0.921	71.25±0.441^{b}	71.72±0.436^{b}	72.65±0.406^{b}	28.12±2.389	88.18±1.229	21.58±0.258	22.79±0.287^{b}	48.29±1.016^{b}
12th months	111	70.95±1.032	70.68±0.494^{b}	71.76±0.489^{b}	73.17±0.455^{b}	32.29±2.677	87.69±1.377	21.35±0.289	23.81±0.321^{c}	56.07±0.710^{c}
Gender		p=0.709	p=0.103	p=0.051	p=0.029	p=0.059	p=0.869	p=0.017	p=0.552	p=0.000
Male	50	71.01±0.977	70.48±0.468	71.18±0.463	72.28±0.431	33.64±2.534	87.09±1.304	21.01±0.273	23.45±0.304	59.47±0.860
Female	150	71.55±0.728	69.34±0.348	69.83±0.344	70.87±0.321	26.47±1.887	87.41±0.971	21.99±0.204	23.18±0.226	42.63±0.585
Reg (Linear)		p=0.000	p=0.000	p=0.000	p=0.000	p=0.812	p=0.000	p=0.000	p=0.000	
Live weight		0.365±0.065	0.174±0.031	0.164±0.031	0.172±0.029	-0.04±0.168	0.509±0.086	0.217±0.018	0.160±0.020	
Overall	**200**	71.28±0.463	69.91±0.222	70.50±0.219	71.57±0.204	30.05±1.2	87.25±0.618	21.50±0.129	23.32±0.144	51.05±0.509

BL:body length. **HW:**withers height. **BH:**back height. **RH:**rump height. **CD:** chest depth. **CG:** chest girth. **CW:** chest width.**RW:** rump width. **LW:** live weight

Table 4. Live weight estimation models for three different age groups using stepwise regression analysis

Age Groups	Models		$\hat{\beta}_0$	β_1	β_2	β_3	β_4	DW	S	R^2	P
6th months	I	**βi**	86.51	1.92							
		S.E. Coeff.	9.11	0.14							
		t-value	-9.49	13.89				2.21	3.53	0.78	<0.001*
		VIF		1							
		P	<0.001*	<0.001*							
	II	**βi**	-82.86	1.55	1.06						
		S.E. Coeff.	8.5	0.17	0.34						
		t-value	-9.74	8.97	3.14			2.35	3.26	0.82	<0.001*
		VIF		1.84	1.84						
		P	<0.001*	<0.001*	0.003*						
8th months	I	**βi**	-17.64	2.94							
		S.E. Coeff.	9.68	0.43							
		t-value	-1.82	6.85				1.86	5.65	0.57	<0.001*
		VIF		1							
		P	0.077	<0.001*							
	II	**βi**	-49.8	2.13	0.58						
		S.E. Coeff.	13	0.45	0.18						
		t-value	-3.84	4.72	3.28			1.52	4.97	0.67	<0.001*
		VIF		1.43	1.43						
		P	0.001*	<0.001*	0.002*						
	III	**βi**	-69.2	1.57	0.43	1.6					
		S.E. Coeff.	14.9	0.49	0.18	0.7					
		t-value	-4.65	3.22	2.44	2.28		1.73	4.67	0.71	<0.001*
		VIF		1.9	1.64	2.02					
		P	<0.001*	0.003*	0.02*	0.03*					
12th months	I	**βi**	16.8	3.17							
		S.E. Coeff.	5.58	0.24							
		t-value	-3.01	13.13				1.73	6.09	0.61	<0.001*
		VIF		1							
		P	0.003*	<0.001*							
	II	**βi**	-62.46	1.88	1.03						
		S.E. Coeff.	8.34	0.28	0.15						
		t-value	-7.49	6.69	6.64			2.05	5.16	0.72	<0.001*
		VIF		1.9	1.9						
		P	<0.001*	<0.001*	<0.001*						
	III	**βi**	-76.14	1.61	1.3	0.78					
		S.E. Coeff.	8.16	0.26	0.28	0.15					
		t-value	-9.33	6.1	4.7	5.2		2.04	4.72	0.77	<0.001*
		VIF		2	1.57	2.15					
		P	<0.001*	<0.001*	<0.001*	<0.001*					
	IV	**βi**	-80.52	1.43	0.16	1.22	0.73				
		S.E. Coeff.	7.9	0.26	0.05	0.26	0.14				
		t-value	-10.19	5.55	3.38	4.64	5.08	2.03	4.5	0.79	<0.001*
		VIF		2.08	1.23	1.58	2.17				
		P	<0.001*	<0.001*	0.001*	<0.001*	<0.001*				

* The test is important at the 0.05 significance level. $\hat{\beta}_0$=constant. β_i=regression coefficient. **R^2**=adjusted estimation power **S.E. Coeff.:** Standard error values of coefficients **VIF:** Variance Inflation Factor **DW:** Durbin-Watson test **S:** Root Mean Square Error value of model

Table 5. Phenotypic correlation coefficients between weight and body measurements according to age group.

	Age Group	LW	BL	HW	BH	RH	CD	CG	CW
BL	6^{th} months	0.812***							
	8^{th}months	0.148ns							
	12^{th} months	0.782***							
HW	6^{th} months	0.888***	0.817***						
	8^{th}months	0.341*	-0.109ns						
	12^{th} months	0.537***	0.603***						
BH	6^{th} months	0.862***	0.823***	0.968***					
	8^{th}months	0.332ns	-0.120ns	0.934***					
	12^{th} months	0.548***	0.560***	0.888***					
RH	6^{th} months	0.859***	0.818***	0.958***	0.983***				
	8^{th}months	0.434**	-0.002ns	0.913***	0.941***				
	12^{th} months	0.598***	0.595***	0.878***	0.924***				
CD	6^{th} months	0.123ns	0.194ns	0.136ns	0.126ns	0.134ns			
	8^{th}months	0.739***	0.145ns	0.257ns	0.295ns	0.377ns			
	12^{th} months	0.683***	0.575***	0.510***	0.494***	0.530***			
CG	6^{th} months	0.559***	0.567***	0.477***	0.443**	0.393**	0.076ns		
	8^{th}months	0.690***	-0.037ns	0.243ns	0.231ns	0.329ns	0.586***		
	12^{th} months	0.512***	0.372***	0.222*	0.217*	0.252**	0.310**		
CW	6^{th} months	0.736***	0.680***	0.675***	0.668***	0.667***	0.017ns	0.690***	
	8^{th}months	0.573***	0.094ns	0.207ns	0.208ns	0.173ns	0.458**	0.401*	
	12^{th}months	0.783***	0.688***	0.445***	0.430***	0.490***	0.527***	0.410***	
RW	6^{th} months	0.770***	0.692***	0.738***	0.745***	0.707***	0.071ns	0.548***	0.749***
	8^{th}months	0.766***	0.056ns	**0.298ns**	0.316ns	0.327ns	0.658***	0.548**	0.572***
	12^{th} months	0.619***	0.493***	0.391***	0.427***	0.450***	0.526***	0.187*	0.668***

BL:body length. HW:wither height. BH:back height. RH:rump height. CD: chest depth.CG: chest girth. CW: chest width. RW: rump width. LW: live weight. ns:non-significant.*: $p<0.05$.**: $p<0.01$.***: $p<0.001$

Table 6. Average live weight for age groups. live weight estimations and hit rates (%) according to models

Age Groups	LW	Models							
		I		II		III		IV	
			%		%		%		%
6^{th} months	39.90	40.07	99.996	39.84	99.998				
8^{th} months	48.29	48.34	99.999	48.54	99.995	47.79	99.990		
12^{th} months	56.07	56.07	100	56.21	99.998	55.96	99.998	55.96	99.998

Average live weights for age groups. live weight estimates and hit rates according to models are given in Table 6. The lowest hit rate was found to be 99.990% in model III in the 8^{th}-month age group. The highest hit rate was found to be 100% in model I in the 12^{th}-month age group. In this case, it has been revealed that live weight estimation can be made with high accuracy from the body measurements subject to the models.

DISCUSSION

The average body weight values obtained in the present study were lower than those obtained in studies of native Turkish and foreign breeds in different countries (Yilmaz et al., 2004; Sezenleret al., 2011; Yilmaz et al. 2013; Jafari and Hashemi, 2014; Zishiriet al., 2014). These differences, which have emerged in the literature, are due to the differences in breeds and breeding systems. The study found a high positive phenotypic correlation coefficient between body measurements and live weight. This result is also consistent with the studies conducted in different breeds on this subject (Yilmaz et al., 2013; Lakew et al., 2018; Gul et al., 2019; Sabbioni et al., 2020; Canul-Solis et al., 2020; Panda et al., 2021).

In addition to BL, CG, and CW, other body measurements and live weight values were higher in males. The regression between live weights proved statistically highly significant ($p<0.01$) when all body characteristics except CD were measured. The effect of gender on RH and CW and live weight values was statistically significant. Regression between live weights in the measurement of all body characteristics was found to be statistically significant. The difference between the genders is an expected finding, and numerous literatures supports this (Sabbioni et al., 2020; Esen and Elmaci, 2021). The genders of the lambs used in the study are not equal. Therefore, the main focus of the study is to develop models for different age groups.

As can be seen from the models presented for estimating live weight by age, the addition of more than one body feature to the model results in an increase in the R^2 value. However, it is well known that taking a minimal number of measurements in field studies not only saves time, but also allows for practical application. For this reason, it is useful to make sure that the models to be created contain, few features and have a high R^2 value. Consistent with this information, it is noteworthy that the second, third, and fourth models can be recommended for the 6th, 8th, and 12th months of age, respectively. The R^2 values of these models were relatively high compared with the other models. The body measures that can be used in the equations to estimate body weight for this breed and these age groups are HW, CW, RW, CG, CD and BL. Sun et al. (2000) determined by stepwise multiple regression analysis according to age that the most appropriate equation with the highest R2 value was HW, RH, BL, CD, RW, and the parameter that best predicted body weight and BW. Yilmaz et al. (2013) in their study on Karya sheep, CG and BL showed the most significant effects on BW according to multiple linear regression models. In their study on 4 sheep, Esen and Elmacı (2021) found a high correlation between LW and such body measurements (e.g. HW and CG). They stated that these two traits could be used instead of BL and BH in Karacabey Merino and Ramlıç lambs. Ambarcıoğlu et al. (2017) stated that the body size with the highest direct effect on live weight was determined to be CG. and CD and RW had an indirect effect.

CONCLUSION

Live weight measurement in animal husbandry is an important application for both breeding and commercial sheep farms. However, due to the difficulty and time involved in weighing. especially in commercial sheep farms operating under intense conditions, it cannot always be done exactly. Due to both physical and financial difficulties. weighing is not possible at some sheep farms.

The study revealed that live weight determination from body measurements can be achieved successfully. Particularly in extensive conditions and in enterprises that do not have sufficient infrastructure, it is absolutely necessary to know the live weight data in order to be integrated into animal breeding programs. In this case, live weight estimation models can be used by using some measurements to determine the live weights in sheep farms that do not have sufficient infrastructure. In this way, even if there is a deviation in the weight. the condition of the flock can be followed with the estimated weights according to the body measurements, and it can guide the breeding programs.

Consequently, the live weights of Karacabey Merino lambs can be successfully predicted from body measurements using stepwise regression models. Live weight and body measurements are directly related. However, it is well known that it varies according to species, breed, nutritional status, age and body size. For this reason, the models created for live weight estimation may differ for each breed. Considering this situation, live weight estimation from body measurements can be successfully performed in other sheep breeds.

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