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Influence of environmental factors on ponderal performance and morphometric characteristics of lambs of different genetic groups from birth to weaning

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ABSTRACT - The objectives of this work were to evaluate the environmental effects (age of dam, type of birth and sex of lamb) and genetic groups (Hampshire Down and Ile de France, ½ and ¾ Hampshire Down, Ile de France and Suffolk, and ½ Texel) on performance and morphometric characteristics (height, length and heart girth) of lambs; to test regressions to predict live weight of lambs from body measurements; and to describe the growth type of the measurements as function of the weight. Weights and measurements were collected from birth to weaning, every 14 days. For evaluations of performance in relation to environmental effects and genetic groups, only data from birth and from weaning were used; for type of growth all collected data were used. Lambs from younger ewes (2 teeth) presented smaller average for weight at birth, heart girth and height at weaning. Single-birth lambs presented greater averages than twins. Genetic group influenced all traits evaluated, except heart girth at birth and average heart girth gain. Means for birth weight were higher in ¾ Ile de France (3.93±0.16 kg) and lower in ½ Texel lambs (3.04±0.24 kg), and for weaning, they were higher in ½ Texel (14.86±0.87 kg) and lower in Ile de France lambs (11.66±0.83 kg). Year of birth influenced all traits. Heart girth and length showed a negative allometric growth in relation to weight, while between weight and height the relation was positive allometric. The factors that most influenced the performance of lambs from birth to weaning are the type of birth, genetic group and year of birth. Correlations between body weight and morphometric measurements are significant, so it is possible to predict one from the other.

Key Words: allometric growth, body morphometry, body weight, sheep

Introduction

Sheep farming has been developing in Brazil, mainly due to the growth of production and consumption of high-quality sheep meat (Souza, 2008), which is considered an attractive source of income to farmers.

In order to be a viable economical activity, sheep farming needs to provide the lambs with conditions to externalize the most of their genetic potential. Therefore, it is important to know the components that affect the proper development of the animals and consequently their production (Landim et al., 2007).

The factors that may influence the development of lambs in the pre-weaning period are the year and type of birth, sex of the lamb, quantity and quality of the feed available to the ewe during the periods of pregnancy and lactation and the maternal effects (Rashidi et al., 2008).

Morphometric measurements are easily obtained, and have been used to evaluate performance, to characterize genetic groups and as a way of selection for animal breeding (Sowand & Sobola, 2008). According to Araújo Filho et al. (2007), the phenotypic characterization of a particular genetic group is important for an animal breeding process and can be accomplished through morphometric measurements.

The development of morphometric measurements can be better assessed by allometric equations, which compare the growth of body parts with the total growth, determining whether they present a differential growth or not. According to Carvalho et al. (2007), body parts do not grow at the same speed as the total mass, causing changes in the shapes, anatomical structures, body composition, and consequently in the development of the animals.

The objective of this study was to investigate the influence of the year of birth, type of birth, sex of the offspring, genetic group and age of dam at lambing in relation to the weight and morphometric characteristics of the lambs at birth and at weaning (70 days of age); to test linear and allometric regressions to predict live weight by means of the morphometric measurements; and to describe the type of growth of the body measurements within the study period.

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Material and Methods

The data came from the sheep-raising sector of Universidade Estadual de Londrina (UEL). The experimental unit is located at latitude and longitude 23° 23' S and 51° 11' W, respectively. The analized data came from records of the herd of sheep collected throughout seven years, from 1996 to 2002.

Data from 337 lambs of different genetic groups were analized. Lambs were purebred and crossbred Hampshire Down (HD) and Ile de France (IF) (½ HD and ¾ HD, ½ IF and ¾ IF), crossbred Suffolk (SUF) (½ SUF and ¾ SUF) and Texel (TEX) (½ TEX). Crossbred lambs were offspring of ewes without defined breed.

The evaluated ewes and lambs were kept on a Coastcross (*Cynodon dactylon* (L.) Pers.) pasture, with mineralized salt available in suitable troughs, receiving supplementation of sorghum silage and concentrate based on corn and soybean meal during winter periods. The sanitary management was performed as usual on the property, and parasite control was carried out according to results of faecal examination. Lambs were weaned at 70 days of age.

Only weights and morphometric measurements taken at birth and at weaning were used to evaluate effects of environment and genetic groups. To determine the type of growth (allometric or isometric) of heart girth, body length and height compared with body weight, we used measurements taken from birth to weaning every 14 days, totalling six measurements per feature.

Morphometric measurements were performed with the help of a tape measure, with the animal standing correctly on its feet and legs, in agreement with the methodology described by Costa Júnior et al. (2006). The following morphometric measurements were recorded: height, measured between the highest point of the interscapular region (withers) and the ground; body length, measured from wither to the tail insertion; and heart girth, measured on the external circumference of the thoracic cavity, on the axillae.

The studied traits were subjected to an analysis of variance, using the GLM procedure of the computer system SAS (Statistical Analysis System, version 8.2), taking as independent variables the genetic group, type of birth (single or twin), sex of the lamb (male or female), age of dam at lambing (two, four, six or eight permanent incisors) and year of birth of the lamb.

Interactions between the independent variables were not considered in the final analysis because they did not present significance (P>0.05). Averages for genetic group, age of dam at lambing and year of birth were compared by the Tukey test and the others by the F test. The linear model used for the analysis of weights and morphometric measurements was:

$$Y_{ijklm} = \mu + I_i + S_j + G_k + T_l + A_m + \varepsilon_{ijklm}$$

in which Y_{ijklm}= dependent variables (weights or body measurements); μ = overall mean; I_i = effect of the age of the dam at lambing, where I = two, four, six or eight teeth; S_j = effect of the sex of the lamb, where j = male or female; G_k = effect of the genetic group, where k = HD, ½ HD, ¾ HD, IF, ½ IF, ¾ IF, ½ SUF, ¾ SUF or ½ TEX; T_l = effect of the type of birth, where l = single or twin; A_m = effect of the year of birth of the lamb, where m = 1996, 1997, 1998, 1999, 2000, 2001 or 2002; ε_{ijklm} = random error associated with each observation.

Linear and allometric regressions were tested to predict live weight of lambs from body measurements from birth to weaning by the REG procedure of SAS. In the multiple linear regression equations, using more than one feature to predict the weight, the gradual elimination procedure REG stepwise of SAS was used. The following models were used:

$$- Y = a + bX \text{ (Linear)}$$

$$- Y = a + b_1X_1 + ... + b_nX_n \text{ (Multiple linear)}$$

$$- Y = aX^b \text{ (Allometric)}$$

in which Y = live weight; a = intercept; X = morphometric measurements; b = regression coefficient of Y on X; n = number of morphometric measurements. The adhesion of the model was evaluated throught the coefficient of determination (R^2) of the equations.

To determine the type of growth of the morphometric measurements, an allometric equation "$Y = aX^b$" of Huxley (1932) was used, by means of the logarithmic transformation in a simple linear regression: "lnY=lna+b(lnX)", where "Y" was considered the weight of the animal; "X", the size of the body parts of the animal; "a", the interception of the logarithm of the linear regression of "Y" (antilogarithm of "a"); and "b", the relative growth coefficient, or the allometric coefficient, which is the growth relative speed of "Y" related to "X".

Analyses to obtain the allometric coefficients were performed using SAS. To test the hypothesis "b = 3.0", Student's t-test was performed at 1% level of significance. In the relationship between traits of different units of measurement, if "b = 3.0", the growth was termed isometric, indicating that the growth rate of "X" and "Y" were similar; if "b ≠ 3.0", the growth was considered allometric, which means that the growth of one trait is different from the other (Rocha et al., 2002).

Results and Discution

Age of the dam at lambing influenced weight at birth, heart girth, height at weaning and average daily height gain (P<0.05), in which lambs from young ewes (two teeth) presented lower means (Table 1).

According to Souza et al. (2003) young growing females produce lighter offspring, due to less development of reproductive organs and minor irrigation in the uterus, with possible competition between the dam and fetus for nutrients. Furthermore, ewes at up to three years of age, because of reduced milk production, compromise the ponderal performance of lambs until weaning (Ribeiro et al., 2008; Mohammadi et al., 2010).

Lambs born from single births presented higher averages than the twin-birth lambs for all the evaluated traits (P<0.05), weights and morphometric measurements from birth to weaning (Table 2).

According to Barros et al. (2005) and Santello (2008), twins present lighter weights at birth because of an intra-uterine competition. Lighter weights at weaning are probably due to the availability of milk, as the dams which give birth to twins produce higher quantity of milk, although they do not reach twice as much the production (Santello, 2008).

There was no effect of sex on the evaluated traits (P>0.05), except for height at weaning, in which males were higher than females (P<0.05) (Table 2). These results agree with those obtained by Moura Filho et al. (2005) and Rocha et al. (2009), who did not find any differences between weight of males and females at weaning.

The lack of sexual dimorphism may be related to the age of the evaluated animals. Costa Júnior et al. (2006) reported that the differences between males and females increase as the lambs reach maturity. However, Rashidi et al. (2008) and Mohammadi et al. (2010) reported that males are heavier than females during the pre-weaning period.

Year of birth influenced all traits evaluated from birth to weaning (P<0.05) (Table 3). Several studies reported that the year of birth is an important source of variation, which

Table 1 - Body measurements from birth to weaning, according to the age of dam at lambing

Traits	Age of dam at lambing (number of teeth)			
	Two	Four	Six	Eight
Number of observations	54	45	37	90
Weight at birth, kg	2.80±0.14b	3.11±0.14ab	3.20±0.15a	3.23±0.10a
Weight at weaning, kg	12.53±0.48	13.94±0.52	14.16±0.53	13.26±0.36
Weight gain, kg/day	0.14±0.01	0.15±0.01	0.16±0.01	0.14±0.00
Heart girth at birth, cm	33.78±0.54	34.05±0.58	34.72±0.59	34.79±0.41
Heart girth at weaning, cm	56.59±0.88b	58.82±0.94ab	59.92±0.96a	57.89±0.65ab
Heart girth gain, cm/day	0.33±0.01	0.35±0.01	0.36±0.01	0.33±0.01
Length at birth, cm	25.91±0.40	26.44±0.43	26.90±0.44	26.61±0.30
Length at weaning, cm	45.15±0.55	46.63±0.59	46.82±0.61	45.85±0.41
Length gain, cm/day	0.27±0.01	0.29±0.01	0.28±0.01	0.27±0.01
Height at birth, cm	33.44±0.53	34.57±0.56	34.03±0.58	34.35±0.40
Height at weaning, cm	47.40±0.55b	48.76±0.59a	50.03±0.61a	49.00±0.42a
Height gain, cm/day	0.20±0.01b	0.20±0.01b	0.23±0.01a	0.21±0.01ab

Means followed by different letters in the row differ significantly (P<0.05).

Table 2 - Body measurements from birth to weaning, according to the type of birth and sex of lamb

Traits	Type of birth		Sex of lamb	
	Single	Twin	Female	Male
Number of observations	238	99	174	163
Weight at birth, kg	3.53±0.15a	2.65±0.20b	3.01±0.10	3.17±0.10
Weight at weaning, kg	15.87±0.32a	11.07±0.42b	13.28±0.34	13.67±0.35
Weight gain, kg/day	0.18±0.00a	0.12±0.01b	0.15±0.00	0.15±0.00
Heart girth at birth, cm	35.38±0.36a	33.29±0.47b	34.15±0.39	34.52±0.40
Heart girth at weaning, cm	61.84±0.35a	54.77±0.77b	58.14±0.63	58.47±0.64
Heart girth gain, cm/day	0.38±0.01a	0.31±0.01b	0.34±0.01	0.34±0.01
Length at birth, cm	27.44±0.27a	25.50±0.35b	26.29±0.29	26.64±0.30
Length at weaning, cm	48.30±0.37a	43.92±0.48b	46.13±0.39	46.10±0.40
Length gain, cm/day	0.30±0.01a	0.26±0.01b	0.28±0.01	0.28±0.01
Height at birth, cm	34.80±0.35a	33.40±0.46b	33.75±0.38	34.45±0.39
Height at weaning, cm	51.61±0.37a	45.98±0.48b	48.14±0.39a	49.45±0.41b
Height gain, cm/day	0.24±0.01a	0.18±0.01b	0.21±0.01	0.21±0.01

Means followed by different letters in the row differ significantly (P<0.05).

occurs by several factors, such as climate (temperature, rainfall, humidity, etc.), management practices and quality and quantity of the available feed for the animals (Silva et al., 2008; Mohammadi et al., 2010).

Weights and morphometric measurements were influenced by genetic group (P<0.05) (Tables 4 and 5). The ¾ Ile de France (3.93±0.16 kg) and ¾ Hampshire Down (3.86±0.16 kg) lambs showed the highest weight values at birth. Three-quarter lambs probably have higher maternal heterozygosity attributable to the use of crossbred females, which may provide an improvement in the intrauterine environment and consequently higher weights at birth. Leymaster (2002) and Barbosa Neto (2008) reported the existence of maternal heterosis on weight at birth of small ruminants.

Weight at weaning and average daily weight gains until weaning varied from 11.66±0.83 and 0.13±0.01 kg in pure Ile de France lambs to 14.86±0.87 and 0.17±0.01 kg in ½ Texel lambs. Ribeiro et al. (2008) found differences among the genetic groups Ile de France, Suffolk and Hampshire Down for weight at weaning and for average daily weight gain until weaning.

Differences in heart girth were significant (P<0.05) among the studied genetic groups only at weaning, in which the ½ Texel animals presented the highest average (61.56±1.57). Lambs that had Sulffolk in their composition presented the highest length and height from birth to weaning. These results were expected and are probably due to the additive effects of the Texel breed, which is known to have greater heart girth, and the Suffolk, which have greater body lengths and heights.

Table 3 - Body measurements from birth to weaning, according to the year of birth

Traits	Year of birth						
	1996	1997	1998	1999	2000	2001	2002
Number of observations	8	28	49	60	73	60	59
WB (kg)	2.28±0.35c	2.86±0.18bc	2.89±0.16bc	3.04±0.17bc	3.10±0.13b	3.79±0.15a	3.66±0.15a
WW (kg)	15.67±0.26a	14.12±0.65a	11.58±0.58b	11.87±0.59b	10.88±0.48b	15.45±0.54a	14.75±0.44a
WG (kg/day)	0.19±0.02a	0.16±0.01a	0.12±0.01b	0.13±0.01b	0.11±0.01b	0.17±0.01a	0.16±0.01a
HGB (cm)	31.78±1.40c	33.90±0.72bc	33.81±0.65c	34.48±0.66bc	33.53±0.54c	37.26±0.60a	35.60±0.49b
HGW (cm)	61.34±2.28ab	61.08±1.17ab	55.67±1.05cd	56.29±1.08bcd	54.10±0.87d	62.12±0.98a	57.54±0.80bc
HGG (cm/day)	0.42±0.03a	0.39±0.02ab	0.31±0.01c	0.31±0.01c	0.29±0.01c	0.36±0.01b	0.31±0.01c
LB (cm)	23.61±1.05c	25.51±0.54bc	26.06±0.48b	26.25±0.50b	26.54±0.40b	29.06±0.45a	28.22±0.37a
LW (cm)	49.12±1.43a	44.43±0.74b	44.52±0.66b	43.66±0.68c	44.05±0.55b	48.68±0.61a	48.33±0.50a
LG (cm/day)	0.36±0.01a	0.27±0.01bc	0.26±0.01bc	0.25±0.01c	0.25±0.01c	0.28±0.01b	0.29±0.01b
HB (cm)	32.62±1.37b	32.66±0.71b	33.23±0.63b	34.08±0.65b	34.03±0.52b	36.40±0.59a	35.68±0.48a
HW (cm)	49.40±1.44abc	49.35±0.74bc	46.21±0.66d	47.66±0.68cd	46.97±0.55cd	51.61±0.61a	50.37±0.50ab
HG (cm/day)	0.24±0.02a	0.24±0.01a	0.19±0.01c	0.19±0.01bc	0.18±0.01c	0.22±0.01a	0.20±0.01ab

WB, HGB, LB, HB - weight, heart girth, length and height at birth; WW, HGW, LW, HW - weight, heart girth, length and height at weaning; WG, HGG, LG, HG - average daily weight, heart girth, length and height gains, respectively.
Means followed by different letters in the row differ significantly (P<0.05).

Table 4 - Body measurements from birth to weaning, according to the genetic group

Traits	Genetic group				
	Hampshire Down	1/2 Hampshire Down	3/4 Hampshire Down	Ile de France	1/2 Ile de France
Number of observations	92	27	55	15	50
Weight at birth, kg	3.33±0.15d	3.13±0.20d	3.86±0.16a	3.54±0.23c	3.19±0.15d
Weight at weaning, kg	13.71±0.52ab	13.48±0.72abc	11.89±0.59c	11.66±0.83c	14.29±0.54a
Weight gain, kg/day	0.15±0.01ab	0.15±0.01ab	0.13±0.01b	0.13±0.01b	0.16±0.01a
Heart girth at birth, cm	34.40±0.59	34.40±0.80	34.60±0.66	32.55±0.92	34.42±0.60
Heart girth at weaning, cm	58.21±0.95abc	59.07±1.30abc	56.40±1.07c	55.01±1.50c	58.69±0.98abc
Heart girth gain, cm/day	0.34±0.01	0.35±0.01	0.31±0.01	0.32±0.02	0.35±0.01

Traits	Genetic group			
	3/4 Ile de France	1/2 Suffolk	3/4 Suffolk	1/2 Texel
Number of observations	32	29	17	20
Weight at birth, kg	3.93±0.16a	3.63±0.20b	3.13±0.25d	3.04±0.24d
Weight at weaning, kg	12.55±0.55bc	14.15±0.72a	14.67±0.90a	14.86±0.87a
Weight gain, kg/day	0.13±0.01b	0.15±0.01ab	0.16±0.01a	0.17±0.01a
Heart girth at birth, cm	34.16±0.62	35.54±0.81	34.35±1.00	34.71±0.97
Heart girth at weaning, cm	56.45±1.01bc	60.10±1.31a	59.25±1.63ab	61.56±1.57a
Heart girth gain, cm/day	0.32±0.01	0.35±0.02	0.36±0.02	0.38±0.02

Means followed by different letters in the row differ significantly (P<0.05).

Phenotypical correlations were analyzed between the evaluated traits within each genetic group; however, since they were similar to each other, they were represented by general correlations including all the genetic groups (Table 6). The correlations between all variables were positive and highly significant (P<0.01).

The knowledge of the conformation of the individuals that constitute each genetic group contributes to the establishment of the link between conformation and functionality of the animal (Araujo Filho et al., 2007). Therefore, further studies should be conducted in order to characterize the genetic groups according to the morphometric measurements.

The morphometric measurement that presented the highest correlations with the body weight was heart girth, which occurred at birth (0.76) and at weaning (0.85) (Table 6). Considering that the body of lambs has a similar shape to a cylinder, this result was expected because heart girth, along with body length, is directly related to the body volume, so it is expected that the higher the volume, the higher the weight and vice versa.

Average daily weight gain presented the highest correlations with measurements at weaning, especially with weight at weaning (0.98). These results agree with those of Costa Júnior et al. (2006), Fajemilehin & Salako (2008) and Sowand & Sobola (2008).

According to Fajemilehin & Salako (2008) due to the high correlations between weights and morphometric measurements, it is possible to predict one from another through regression equations. Three types of regression equations were tested in this study: simple linear (Table 7), multiple linear (Table 8) and allometric (Table 7), in order to determine which equation and which body measurement is more efficient to estimate weights from birth to weaning.

According to the coefficients of determination (R^2) of the regression equations (Table 7), the simple linear showed to be a little better than the allometric ones to predict weights at birth and at weaning with most of the morphometric measurements. These results differed from those obtained by Sowand & Sobola (2008); however, these differences may be related to the ages of the evaluated animals. In

Table 5 - Length and height at birth and at weaning, and average daily gain for these traits from birth to weaning, according to the genetic group

Traits	Genetic group				
	Hampshire Down	1/2 Hampshire Down	3/4 Hampshire Down	Ile de France	1/2 Ile de France
Number of observations	92	27	55	15	50
Length at birth, cm	28.27±0.60a	27.72±0.75ab	25.89±0.72cd	27.02±0.44abc	26.28±0.60bcd
Length at weaning, cm	48.34±0.82ab	49.41±1.03a	45.72±0.99cd	46.38±0.60c	45.90±0.82cd
Length gain, cm/day	0.29±0.01abc	0.31±0.02a	0.28±0.02abcd	0.28±0.01abcd	0.28±0.01abcd
Height at birth, cm	36.16±0.79a	34.47±0.98ab	33.86±0.95bc	34.48±0.57ab	33.98±0.78bc
Height at weaning, cm	51.52±0.82a	52.18±1.03a	49.53±0.99ab	48.51±0.60b	47.99±0.82bc
Height gain, cm/day	0.22±0.01ab	0.25±0.01a	0.22±0.01ab	0.20±0.01bcd	0.20±0.01bcd

Traits	Genetic group			
	3/4 Ile de France	1/2 Suffolk	3/4 Suffolk	1/2 Texel
Number of observations	32	29	17	20
Length at birth, cm	25.99±0.49cd	25.21±0.69d	25.97±0.45cd	25.83±0.46d
Length at weaning, cm	45.12±0.67cd	43.55±0.94d	46.82±0.62bc	43.78±0.63d
Length gain, cm/day	0.27±0.01bcd	0.26±0.01cd	0.30±0.01ab	0.26±0.01d
Height at birth, cm	33.77±0.64bc	31.80±0.90c	34.09±0.60b	34.30±0.59b
Height at weaning, cm	46.54±0.67c	47.05±0.95bc	48.04±0.62bc	47.80±0.63bc
Height gain, cm/day	0.18±0.01d	0.22±0.01abc	0.20±0.01bcd	0.19±0.01cd

Means followed by different letters in the row differ significantly (P<0.05).

Table 6 - Phenotypic correlations between body measurements and weights of lambs at birth and weaning

	WW	LB	LW	HGB	HGW	HB	HW	WG
WB	0.61**	0.76**	0.54**	0.76**	0.51**	0.76**	0.67**	0.42**
WW	-	0.45**	0.83**	0.49**	0.85**	0.44**	0.83**	0.98**
LB	-	-	0.50**	0.68**	0.38**	0.64**	0.58**	0.31**
LW	-	-	-	0.39**	0.72**	0.42**	0.76**	0.80**
HGB	-	-	-	-	0.54**	0.70**	0.56**	0.35**
HGW	-	-	-	-	-	0.37**	0.70**	0.83**
HB	-	-	-	-	-	-	0.59**	0.29**
HW	-	-	-	-	-	-	-	0.76**

WG - average daily weight gain; WB, HGB, LB, HB - weight, heart girth, length and height at birth; WW, HGW, LW, HW - weight, heart girth, length and height at weaning, respectively.
**P<0.01.

this study, the animals were very young and probably with constant growth rates, while in the work of Sowand & Sobola (2008), the evaluation period was longer and the age of the animals ranged between 13 and 16 months.

Morphometric measurements at birth partly explained the live weight at birth and were not successful in predicting the live weight at weaning. However, measurements at weaning explained well the live weight at weaning. The most efficient morphometric measurement to estimate the weight, i.e., the one that presented the best coefficients of determination (R^2) was the heart girth, for showing high correlations with weight.

The multiple linear regressions (Table 8) showed better coefficients of determination than the simple linear regressions, meaning that equations using more than one morphometric measurement are more efficient to estimate live weight than equations using only one measurement, which agrees with results obtained by Reis et al. (2008) and Sowand & Sobola (2008). In the same way of what was observed in the correlations, equations for prediction of weight at weaning are better when using morphometric data of weaning.

According to these results, it is possible to use the multiple equations to estimate live weight of the animals in the absence of a scale, especially at weaning.

According to Carvalho et al. (2007) the allometry or isometry enables an appropriate quantitative description of the growth of regions in relation to the body as a whole.

Table 7 - Parameters of linear and allometric regressions to estimate live weight from body measurements of lambs at birth and at weaning

Measurements	Intercept	Regression coefficient	Coefficient of determination (R^2)	Standard deviation
Linear regression parameters to estimate live weight at birth				
Heart girth at birth, cm	-3.70194	0.20335	0.57	0.84
Length at birth, cm	-3.59246	0.25850	0.58	0.84
Height at birth, cm	-4.32008	0.22271	0.58	0.84
Linear regression parameters to estimate live weight at weaning				
Heart girth at birth, cm	-4.88814	0.53935	0.24	3.06
Heart girth at weaning, cm	-15.55018	0.50340	0.72	3.60
Length at birth, cm	-3.21540	0.63523	0.21	3.02
Length at weaning, cm	-20.91476	0.74857	0.69	3.58
Height at birth, cm	-4.31877	0.52779	0.19	3.00
Height at weaning, cm	-22.77080	0.74466	0.68	3.56
Measurements	Antilogarithm "a"	Regression coefficient	Coefficient of determination (R^2)	Standard deviation
Allometric regression parameters to estimate live weight at birth				
Heart girth at birth, cm	0.00299	1.97351	0.54	0.82
Length at birth, cm	0.00338	2.08803	0.61	0.85
Height at birth, cm	0.00144	2.18294	0.57	0.82
Allometric regression parameters to estimate live weight at weaning				
Heart girth at birth, cm	0.17169	1.22901	0.20	3.00
Heart girth at weaning, cm	0.00295	2.07203	0.68	3.55
Length at birth, cm	0.29865	1.15650	0.18	2.99
Length at weaning, cm	0.00098	2.48237	0.65	3.58
Height at birth, cm	0.17919	1.21968	0.16	2.96
Height at weaning, cm	0.00044	2.65408	0.66	3.60

Table 8 - Multiple linear regressions to estimate live weight from body measurements of lambs at birth and at weaning

Prediction equations	Coefficient of determination (R^2)	Standard deviation
WB = -5.6079 + 0.1580LB + 0.1359HB	0.70	0.88
WB = -5.95349 + 0.0748HGB + 0.1202LB + 0.0998HB	0.74	0.88
WW = -7.5494 + 0.3681HGB + 0.3180LB	0.27	3.09
WW = -9.0538 + 0.2972HGB + 0.2625LB + 0.1578HB	0.28	3.10
WW = -24.6584 + 0.3145HGW + 0.4083HW	0.82	3.71
WW = -26.6974 + 0.2495HGW + 0.2700LW + 0.2717HW	0.85	3.74

WB, HGB, LB, HB - weight, heart girth, length and height at birth; WW, HGW, LW, HW - weight, heart girth, length and height at weaning, respectively.

Table 9 - Antilog "a" values (lna), coefficient of allometry (b), coefficient of determination (R^2) and type of growth of body measurements in relation to weight in lambs from birth to weaning

	Number of observations	lna	b	R^2	Type of growth
Length	2578	-7.08489	2.52039	0.91	Negative allometric**
Heart girth	2578	-7.78283	2.54539	0.91	Negative allometric**
Height	2578	-10.95381	3.46785	0.87	Positive allometric**

** P<0.01.

In the present study, allometric regression equations were determined to estimate the type of development of the measurements from the body weight.

Equations for each studied genetic group were estimated. However, because they were similar to each other, general equations including all the genetic groups were presented (Table 9), making it possible to conclude that the development of the measurements is independent of the genetic group.

The relation between weight and height showed positive allometric growth (P<0.01) with the regression coefficient (b) equal to 3.47; this result indicates that weight increased proportionally more than the height at the pre-weaning period. The relation between weight and length, and weight and heart girth presented negative allometric growth (P<0.01), with b = 2.52 and b = 2.55, respectively, indicating that the body length and heart girth increased proportionally more than the weight during the study period (Table 9).

Conclusions

It is important to consider the different environmental factors, as they affect the performance of lambs and consequently their production. In the absence of a scale, it is possible to predict the weight according to the morphometric measurements. Weights and body measurements present different (allometric) growth from birth to weaning in all the evaluated genetic groups.

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