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Estimation of Body Weight from Heart Girth in Sardi and Timahdite Sheep Using Different Models

Research Article

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ABSTRACT

The objective of this study was to determine the relationship between body weight (BW) and heart girth (HG) in Sardi and Timahdite sheep in order to develop a prediction equation of BW from HG. The data used for this study included 476 records on BW and HG (227 in Sardi and 249 in Timahdite) collected on males and females of different ages in 33 private farms. The BW and the HG averaged 34.8 ± 21.2 kg and 74.0 ± 16.3 cm, respectively in Sardi and 39.2 ± 22.7 kg and 78.4 ± 16.4 cm, respectively in Timahdite. Correlation coefficients between BW and HG were 0.958 in Sardi and 0.944 in Timahdite indicating a strong relationship between the two variables. Six predictive models for BW were fitted to the data; simple linear regression, polynomial quadratic and cubic regressions and three non-linear regressions (Gompertz, allometric and Mitscherlich). These models were used for the pooled data (regardless of breed and sex), separately for all the animals of a breed regardless of sex (breed-specific) and separately for males and females irrespective of breed (sex-specific). To determine the best fitted regression model, coefficient of determination (R^2 or Pseudo-R^2), residual mean square (MSE) and Akaike information criterion (AIC) were used. The six models fitted the dataset well since their R^2 or Pseudo- R^2 varied from 0.892 to 0.969. Nevertheless, based on the previous selection criteria, it seemed that the polynomial cubic model was the best and the allometric model should be discarded. Extreme observations of the three best models were checked using studentized residuals and an absolute value greater than two standard deviations implies considerable deviation. Once the outliers discarded, the best models were run on the clean dataset and compared. Thus, for the pooled data, Sardi breed and females, the Mitscherlich model was appropriate, whereas for Timahdite breed and males, cubic and Gompertz models, respectively were the best. Therefore, a tape measure was developed for each animal category in order to assist livestock farmers in managing their sheep better.

KEY WORDS body weight, heart girth, Morocco, prediction equation, regression, sheep.

INTRODUCTION

Body weight is a very important aspect of sheep production. Knowledge of an animal's body weight is necessary for determining its food maintenance and growth requirement, administering the correct amount of medication, choosing replacement males and females and estimating its weight at market. Often, farmers rely on visual assessment to determine the animal's body weight, which is not an accurate method for good sheep management. Thus, the easiest way to assess an animal's body weight is to weigh the animal using a weighing scale. However, because of its prohibitive price, the weighing scale is often not available to most of rural livestock farmers. Therefore, there is a need to estimate sheep body weight from simple and easily measurable variables such as linear body measurements.

Many body measurements (e.g., heart girth, wither height, body length…) have been used to estimate body weight of sheep (Baffour-Awuah *et al.* 2000; Afolayan *et al.* 2006; Kunene *et al.* 2009; Mohammad *et al.* 2012; Melesse *et al.* 2013; Ravimurugan *et al.* 2013; Shirzeyli *et al.* 2013). The heart girth is generally accepted as the most suitable single variable (Sarti *et al.* 2003; Olatunji-Akioye *et al.* 2009; Mahieu *et al.* 2011; Birteeb and Ozoje, 2012; Musa *et al.* 2012; Melesse *et al.* 2013), because of its high correlation with body weight 0.83-0.98; (Baffour-Awuah *et al.* 2000; Afolayan *et al.* 2006; Ravimurugan *et al.* 2013; Shirzeyli *et al.* 2013) and its easiness to measure using a simple measuring tape. Moreover, the importance of heart girth in weight estimation could be a result from the fact that muscle and some fat along with bone structure contribute towards its formation (Kurnianto *et al.* 2013). Thus, regressions were fitted to obtain prediction equations of body weight from heart girth using simple linear, polynomial and / or non-linear functions (Sarti *et al.* 2003; Mahieu *et al.* 2011). No reports have yet been published on body weight and heart girth relationships in the Moroccan sheep. Therefore, knowledge of these relationships is essential for sheep breeding and management. However, different models might be needed to predict body weight in different environmental conditions, body conditions and breeds (Enevoldsen and Kristensen, 1997). The objective of this study was to predict body weight based on heart girth in Sardi and Timahdite sheep using different regression models in order to provide a practical method to determine body weight of sheep for those farmers who are not able to purchase their own weighing scales.

MATERIALS AND METHODS

Breeds studied

The Sardi breed has animals with white heads and black spots around the nose, mouth and eyes; is thin-tailed and the rams have strong spiral horns. The body fleece is white and the legs are bare. Adult rams and ewes generally have height at withers of 80-90 cm and 60-70 cm, respectively. The Sardi is an excellent meat breed and is highly desired for the religious celebrations of the Aïd Al Adha. Its population number was estimated to 2154194 sheep (Boujenane, 1999; Boujenane, 2005). Timahdite have brown faces, white, coarse fleece, and white legs. The tail is thin and horns are present in rams, but ewes are polled. Adult rams and ewes generally have respective height at withers of 70-80 cm and 55-65 cm. The Timahdite breed is valued for high milk production, good conformation, ease of fattening and a high carcass yield, along with excellent adaptation. The population number of Timahdite breed was estimated to 1910881 sheep (Boujenane, 1999; Boujenane, 2005).

Data collection

Data were collected from 476 sheep of Sardi (227 records) and Timahdite (249 records) local breeds in 33 private flocks located in the breeding area of each breed. In each flock, animals of both sexes and of different weights / ages were measured. Measurements were restricted to animals not weighing less than 10 kg, because weight of lighter lambs is not very necessary as they are still suckling, and not weighing more than 100 kg, because heavier animals are scarce, especially in Timahdite breed. Additionally, pregnant ewes were excluded from sampling since pregnancy in its different stages has an effect on body weight (Kunene *et al.* 2007). Measurements recorded were live body weight and heart girth. Body weights of sheep were taken early in the morning with an overnight fasting and before their release for feeding using an electronic scale (Gallagher Group LTD Private Bag W610, 3026 Hamilton, New Zealand). Heart girth measurement was the circumference of the chest taken just behind the withers from the right side of the animal by the same operator, using the measuring tape (with records taken to the nearest cm) after restraining and holding the animal on a flat surface. Also recorded were sex and age of each animal. The age of animals was estimated from teeth inspection by counting the number of permanent incisors.

Statistical analyses

Statistical analyses were carried out using the SAS (2002). Descriptive statistics for body weight and hearth girth were obtained using PROC MEANS. The PROC CORR was also used to compute the Pearson correlation. The least-squares analysis of variance was conducted using the GLM procedure. The model fitted included the fixed effects of breed (2 levels: Sardi and Timahdite), sex (2 levels: male and female), age (4 levels: milk set of teeth, one pair, two pairs and three or four pairs of permanent incisors) and the significant 1^{st} order interactions between them.

Prediction models

Simple linear, polynomial and non linear regressions were fitted to obtain prediction equations of body weight from heart girth using REG and NLIN procedures (SAS, 2002). The REG procedure was used to determine the simple linear and polynomial quadratic and cubic regressions and NLIN procedure was used to determine the non-linear regressions. The non-linear functions used were Gompertz, allometric and Mitscherlich. Thus, the six models studied were:

Simple: $BW = a + b_1 \times HG$ (Model 1)
Quadratic: $BW = a + b_1 \times HG + b_2 \times HG^2$ (Model 2)
Cubic: $BW = a + b_1 \times HG + b_2 \times HG^2 + b_3 \times HG^3$ (Model 3)

Gompertz: BW= A × exp(-B×exp(-K×HG)) (Model 4)
Allometric: BW= A × HG^B (Model 5)
Mitscherlich: BW= A + B × exp(K×HG) (Model 6)

Where:
BW: body weight (kg).
HG: heart girth (cm).
a, b_1, b_2, b_3, A, B and K: constants.

As in the study of Benyi (1997) on goats, these models were used separately for the pooled data (regardless of breed and sex), for all the animals of a breed regardless of sex (breed-specific) and separately for males and females irrespective of breed (sex-specific).

Criteria for model selection

To determine the best fitted regression model, we used:
Coefficient of determination, R^2= 1 – (residual sum of squares/corrected total sum of squares)
Residual mean square, MSE= (residual sum of squares/n-p)
Akaike information criterion, AIC= n × log(residual sum of squares/n) + 2p

Where:
n: number of records.
p: number of parameters in the model.

However, since R^2 definition requires the presence of an intercept, R^2 is unfortunately not readily defined in non-linear regressions that fit Gompertz and Allometric functions. Nevertheless, the Pseudo- R^2, a measure relatively closely corresponding to R^2 in the non-linear case, was computed:

Pseudo – R^2= 1 – (residual sum of squares/uncorrected total sum of squares-$n\bar{y}^2$)

Where:
$\bar{y}$: average body weight.

Moreover, Ratkowsky (1990) reported that the R^2 is no longer useful in non-linear regression. He advocated the use of:
R^2_{adj}= R^2 – |(p-1)/(n-p)×(1-R^2)|.

However, since in this study both R^2 and R^2_{adj} were very similar due to the large number of observations present, R^2 was used. Additionally, for simple linear and polynomial quadratic and cubic regressions, the AIC was given by the REG procedure, whereas for non-linear regressions; it was computed using the formula above. Thus, models resulting in higher R^2 or Pseudo- R^2, smaller MSE and smaller AIC were considered to be superior.

Extreme observations of the best models were checked to determine their validity. The approach used was to express residuals as studentized residuals, that is (residual/√MSE), and an absolute value greater than two standard deviations implies considerable deviation (Kaps and Lamberson, 2004). The extreme values may be due to errors in the measurement and recording process. INFLUENCE and R options of REG procedure were used to compute studentized residuals. Once the outliers discarded, the best models were run on the clean dataset and compared based on the previous criteria. Thus, for each animal category, the model resulting in higher R^2 or Pseudo- R^2, smaller MSE and smaller AIC was retained for the final parameter calculation, and the regression equation was selected to predict body weight of sheep from heart girth.

RESULTS AND DISCUSSION

Arithmetic and least-squares means

The descriptive statistics for body weight and heart girth are shown in Table 1. Body weight and heart girth averaged 37.1 kg and 76.3 cm, respectively. Body weight ranged from 10.2 to 100.0 kg in Sardi and from 10.4 to 99.5 kg in Timahdite sheep, whereas heart girth varied from 48.0 to 112.0 cm and from 49.0 to 110.0 cm, respectively. Coefficients of variation for body weight were higher than those for heart girth. Also, those of Sardi were greater than those of Timahdite for both traits. Likewise, coefficients of variation of males were higher than those of females. This may be due to the great variability of weights observed in Sardi and in male sheep.

The least-squares analysis of variance showed that body weight and heart girth were influenced by sex and age of sheep (P<0.001), but not by the breed (P>0.05). Body weight and heart girth of males were 28.4 kg and 12.1 cm, respectively greater than those of females (results not presented). This is expected as sheep have been shown to exhibit sexual dimorphism in body weight right from birth. These differences between male and female sheep were similar to those reported by Baffour-Awuah *et al.* (2000) and Afolayan *et al.* (2006). As expected, sheep having 3 or 4 pairs of permanent incisors had the highest body weight and heart girth and those with a milk set of teeth had the lowest measurements. The effect of age on body weight and heart girth is in agreement with those of Birteeb and Ozoje (2012) and Musa *et al.* (2012), who reported that mature animals had higher mean values for all body measurements than young animals.

Prediction equations

The relationship between body weight and heart girth is high (0.950) with a curvilinear tendency (Figure 1).

Table 1 Number of records, arithmetic means, coefficients of variation (CV) and ranges for body weight and heart girth, and pearson correlation coefficients between them in sheep

Breed/Sex	Number of records	Body weight (kg)			Heart girth (cm)			Coefficient of correlation
		Arithmetic mean	CV (%)	Range	Arithmetic mean	CV (%)	Range	
Pooled data	476	37.1	59.5	10.2-100.0	76.3	21.6	48-112	0.950
Sardi	227	34.8	60.9	10.2-100.0	74.0	22.1	48-112	0.958
Timahdite	249	39.2	58.0	10.4-99.5	78.4	20.9	49-110	0.944
Females	264	33.8	47.5	10.2-92.5	75.8	19.1	48-109	0.954
Males	212	41.2	66.3	10.4-100.0	76.9	24.3	50-112	0.975

However, this association decreased with the increase of sheep age. In agreement with Kunene *et al.* (2009), this may be explained by the fact that at maturity, body weight and heart girth are essentially a constant. The correlation coefficient was slightly higher in Sardi (0.958) than in Timahdite (0.944) and in males (0.975) than in females (0.954) (Table 1).

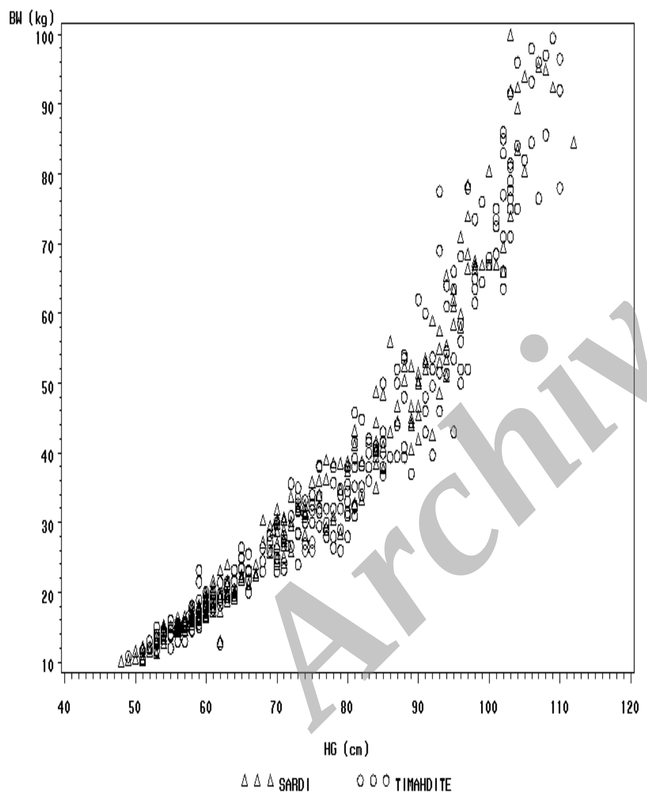

Figure 1 Relationship between body weight (BW) and heart girth (HG) in Sardi and Timahdite sheep

The highest correlation coefficient reported in this study is similar to those of several authors (Baffour-Awuah *et al.* 2000; Afolayan *et al.* 2006).

Therefore, positive and highly significant (P<0.001) correlation between body weight and heart girth indicates high predictability.

This conclusion is in agreement with those of numerous researchers (Afolayan *et al.* 2006; Kunene *et al.* 2009; Melesse *et al.* 2013), who concluded that heart girth can be used as a sole predictor of body weight. Prediction of body weight in sheep from heart girth was realised using different regression models. The six models fitted the pooled data well, since their R^2 or Pseudo- R^2 varied from 0.892 to 0.969. Regressions found in this study with R^2 higher than 0.892 closely resembled work done elsewhere, with regard to the relationship between heart girth measurement and body weight. Based on R^2 or Pseudo- R^2, MSE and AIC, it seemed that among linear and polynomial models, the polynomial cubic model was the best, and among the non-linear models, the allometric model should be discarded, because it seemed to fit the corresponding values less accurately. Thus for the pooled data (regardless of breed and sex), the polynomial cubic model estimated live weight more accurately (R^2=0.954; MSE=22.8; AIC=1492.1), followed by Mitscherlich and Gompertz non-linear models, which were similar (Table 2). Kunene *et al.* (2009) reported that the coefficient of determination R^2 based on the use of linear heart girth was 0.71 but the third degree polynomial of heart girth increased R^2 to 0.76. Also, Birteeb and Ozoje (2012) found that the R^2_{adj} values associated with the quadratic models of the yearling Wall sheep were generally higher than those associated with the simple linear models. In the present study, the simple linear regression, reported by Cam *et al.* (2010) and Musa *et al.* (2012) as the best model for predicting body weight from heart girth, was the less accurate model, since its R^2 was the lowest and its MSE and AIC were the highest.

When sheep were grouped by breed, the selection criteria showed that the six prediction models were better in Sardi than in Timahdite sheep. Focusing on the Sardi breed, the polynomial cubic model was the best (R^2=0.961; MSE=17.8; AIC=657.0) and next better were the Gompertz and Mitscherlich models that had similar R^2 or Pseudo- R^2, but the Mitscherlich model had lower MSE and AIC (Table 3). For Timahdite sheep, the Gompertz model did not converge. The polynomial cubic and Mitscherlich models were the best since their R^2 were the highest, but the cubic model had lower MSE and AIC (Table 3).

Table 2 Linear and non-linear regression equations for estimating body weight from heart girth in sheep for the pooled data[a]

Model	Regression equations	R^2 or Pseudo- R^2	MSE	AIC
Model 1	BW= -59953 + 1.272 × HG	0.903	47.6	1840.3
Model 2	BW= 54.423 + 1.788 × HG + 0.019 × HG^2	0.951	24.1	1518.4
Model 3	BW= -85.269 + 3.812 × HG -0.053 × HG^2 + 0.0003 × HG^3	0.954	22.8	1492.1
Model 4	BW= 13364052 × exp(-15.875×exp(-0.003×HG))	0.953	23.1	1496.7
Model 5	BW= 0.00015 × $HG^{2.838}$	0.948	25.2	1538.0
Model 6	BW= -3.494 + 3.324 × exp(0.031×HG)	0.953	23.0	1496.4

[a] BW: body weight and HG: heart girth.
R^2: coefficient of determination; MSE: residual mean square and AIC: akaike information criteri.

Table 3 Linear and non-linear regression equations for estimating body weight from heart girth in Sardi and Timahdite sheep regardless of sex[a]

Breed/model	Regression equations	R^2 or Pseudo- R^2	MSE	AIC
Sardi				
Model 1	BW= -57.126 + 1.242 × HG	0.917	37.3	823.2
Model 2	BW= 46.173 - 1.569 × HG + 0.018 × HG^2	0.958	19.1	672.7
Model 3	BW= -86.480 + 3.798 × HG -0.052 × HG^2 + 0.0003 × HG^3	0.961	17.8	657.0
Model 4	BW= 179082 × exp(-11.729×exp(-0.004×HG))	0.960	18.1	660.1
Model 5	BW= 0.0002 × $HG^{2.782}$	0.957	19.6	679.0
Model 6	BW= -5.725 + 4.075 × exp(0.029×HG)	0.960	18.0	659.4
Timahdite				
Model 1	BW= -63.354 + 1.308 × HG	0.892	56.1	1004.6
Model 2	BW= 61.644 - 1.980 × HG + 0.021 × HG^2	0.945	28.4	836.0
Model 3	BW= -88.369 + 3.991 × HG -0.056 × HG^2 + 0.0003 × HG^3	0.948	27.1	825.6
Model 4	Did not converge	-	-	-
Model 5	BW= 0.0001 × $HG^{2.901}$	0.942	29.8	847.6
Model 6	BW= -1.717 + 2.765 × exp(0.033×HG)	0.948	27.3	826.1

[a] BW: body weight and HG: heart girth.
R^2: coefficient of determination; MSE: residual mean square and AIC: akaike information criteri.

Again, for Sardi and Timahdite sheep, the simple linear regression was the less accurate among the six models. Kunene *et al.* (2009) reported that although the coefficients of determination were slightly higher for the polynomial than those of the simple linear regression models, the differences were minimal, and hence both types of equations can be used to best estimate the live body weight of Zulu sheep aged 22 months and below.

When sheep were grouped by sex, prediction models of males were more accurate than those of females on the basis of R^2 or Pseudo- R^2 and AIC, but not on the basis of MSE (Table 4). The fact that higher R^2 were realized in males than in females may be explained by the likely difference of the fat deposition in the two sexes as reported by Bassano *et al.* (2003). Furthermore, the best prediction equation for predicting the body weight from heart girth in females was given by the cubic model, since it had the highest R^2 (0.945) and the lowest MSE (14.2) and AIC (705.2) followed by Gompertz and Mitscherlich models that were similar with a small advantage for the latter model (Table 4). In males, Gompertz and quadratic models (since quadratic and cubic models were practically the same because the last coefficient of the cubic model did not differ significantly from zero) were the best, with a small advantage for the former model (R^2=0.969; MSE=23.5; AIC=672.7), whereas the Mitscherlich and the simple linear models were the worst.

Mahieu *et al.* (2011) reported that the best models for predicting body weight from heart girth in goats were the quadratic and Gompertz models. However, Birteeb and Ozoje (2012) reported that among the two years old wall sheep, liveweight prediction is easier and better done with the use of simple linear models than quadratic models irrespective of the linear body measurement (trait) used as the regressor.

The optimum model

From the first analysis, the cubic, Gompertz and Mitscherlich models were considered to be the best for predicting body weight from heart girth in studied sheep and therefore they were used for further analyses. Thus, extreme observations from these models were checked using studentized residuals, and outliers were discarded. The percentage of discarded records was 8.96%. Once the outliers discarded, the three models were run on clean datasets and compared based on R^2 or Pseudo- R^2, MSE and AIC criteria. Analyses indicated that the exclusion of outliers resulted in significant improvements in selection criteria, e.g. R^2 or Pseudo-R^2 varied from 0.953 to 0.983 and hence in the accuracy of prediction. Moreover, for the pooled data (regardless of breed and sex), the prediction equation using Mitscherlich function was found to be the best for estimating the body weight (Pseudo-R^2=0.971; MSE=12.0; AIC=1113.0) (Table 5).

Table 4 Linear and non-linear regression equations for estimating body weight from heart girth in females and males sheep regardless of breed[a]

Sex/model	Regression equations	R^2 or Pseudo- R^2	MSE	AIC
Females				
Model 1	BW= -46.242 + 1.055 × HG	0.909	23.4	834.6
Model 2	BW= 35.066 + 1.195 × HG + 0.015 × HG^2	0.942	15.0	717.8
Model 3	BW= -85.546 + 3.769 × HG -0.051 × HG^2 + 0.0003 × HG^3	0.945	14.2	705.2
Model 4	BW= 607663 × exp(-12.791×exp(-0.003×HG))	0.944	14.4	708.1
Model 5	BW= 0.0004 × $HG^{2.624}$	0.940	15.3	722.2
Model 6	BW= -4.852 + 4.011 × exp(0.029×HG)	0.945	14.4	706.9
Males				
Model 1	BW= -68.255 + 1.423 × HG	0.950	37.5	770.3
Model 2	BW= 23.064 + 0.978 × HG + 0.015 × HG^2	0.969	23.6	673.3
Model 3	BW= 23.064 - 0.978 × HG + 0.051 × HG^2	0.969	23.6	673.3
Model 4	BW= 510.300 × exp(-7.660×exp(-0.014×HG))	0.969	23.5	672.7
Model 5	BW= 0.0002 × $HG^{2.750}$	0.968	23.6	672.5
Model 6	BW= -25.139 + 12.517 × exp(0.021×HG)	0.968	24.1	677.4

[a] BW: body weight and HG: heart girth.
R^2: coefficient of determination; MSE: residual mean square and AIC: akaike information criteri.

Table 5 The best regression equations for estimating body weight from heart girth in sheep[a]

Group of animals	Regression equations	Number of records	R^2 or Pseudo- R^2	MSE	AIC
Pooled data	BW= -2.339 + 3.024 × exp(0.0318×HG)	447	0.971	12.0	1113.0
Sardi	BW= -6.746 + 4.577 × exp(0.0282×HG)	212	0.977	8.05	445.2
Timahdite	BW= -125.431 + 5.505 × HG -0.076 × HG^2 + 0.0004 × HG^3	233	0.969	14.6	628.0
Females	BW= -3.566 + 3.542 × exp(0.0299×HG)	248	0.964	9.03	548.8
Males	BW= 1099.200 × exp(-7.676×exp(-0.0105×HG))	198	0.983	11.6	488.5

[a] BW: body weight and HG: heart girth.
R^2: coefficient of determination; MSE: residual mean square and AIC: akaike information criteri.

The same function was also the good fit for estimating the body weight in Sardi breed (regardless of sex) (Pseudo-R^2=0.977; MSE=8.05; AIC=445.2) and in females (regardless of breed) (Pseudo-R^2=0.964; MSE=9.03; AIC=548.8). However, the polynomial cubic model fits well the data in Timahdite breed (regardless of sex) (R^2=0.969; MSE=14.6; AIC=628.0) and the Gompertz function is the best for estimating the body weight in males (regardless of breed) (Pseudo-R^2=0.983; MSE=11.6; AIC=488.5). Lawrence and Fowler (1997) reported that the relationship between live weight and heart girth is curvilinear for animals growing over a wide weight range.

Atta and El Khidir (2004) also reported an increased coefficient of determination based on curvilinear functions when estimating the live weight using heart girth of 2-8-month-old Nilotic sheep.

Goe *et al.* (2001) suggested that higher order polynomial equations are more appropriate for predicting the weight of growing animals. Sarti *et al.* (2003) found that the quadratic model was considered the most suitable one to predict the weight from the chest girth in two Italian meat sheep breeds (Appenninica and Merinizzata italiana), whereas Mahieu *et al.* (2011) concluded that using Creole of Guadeloupe goats, the best fit was obtained with a Gompertz model.

Regression equations with the best fit according to previous criteria were selected to predict body weight for all sheep, for each separate breed and for each separate sex.

Thus, charts that convert the heart girth measure to body weight were set up, and tape measures graduated in cm and in corresponding kg for each sheep group were developed (Table 6).

As an example, for a sheep (regardless of breed and sex) with a heart girth of 75 cm, the predicted body weight is 30.5 kg. Corresponding weights for a male animal and a female animal (regardless of breed) are 33.4 kg and 29.8 kg, respectively.

The corresponding weight for a Sardi animal regardless of the sex is 31.2 kg and the one for a Timahdite animal is 30.3 kg.

Therefore, this tool that allows body weight estimation using heart girth alone will be very useful under field conditions.

Moreover, when the best prediction model for each group of animals (pooled data, breed-specific and sex-specific) was applied using the average values of the observed weights that fell in each 1 cm class of heart girth, the same predicted weights (with few differences in the first decimal) as those reported in Table 6 were obtained.

Table 6 Prediction of body weight (kg) corresponding to heart girth measures (cm) for all sheep (regardless of breed and sex) (Pooled), separately for all the animals of a breed regardless of sex (S and T) and separately for males and females irrespective of breed (F and M)[a]

HG	Pooled	S	T	F	M	HG	Pooled	S	T	F	M
48	11.6	11.0	8.1	11.3	10.6	81	37.4	38.2	36.6	36.3	41.4
49	12.0	11.5	9.1	11.8	11.2	82	38.7	39.5	37.7	37.6	42.8
50	12.5	12.0	10.1	12.2	11.7	83	40.0	40.8	39.0	38.8	44.3
51	13.0	12.5	11.0	12.7	12.3	84	41.4	42.2	40.3	40.1	45.8
52	13.5	13.1	11.9	13.2	12.9	85	42.8	43.6	41.6	41.4	47.4
53	14.0	13.7	12.7	13.7	13.5	86	44.3	45.0	43.0	42.8	48.9
54	14.5	14.2	13.6	14.2	14.1	87	45.8	46.5	44.5	44.2	50.6
55	15.0	14.8	14.4	14.8	14.8	88	47.3	48.0	46.0	45.6	52.2
56	15.6	15.5	15.2	15.3	15.5	89	48.9	49.6	47.6	47.1	53.9
57	16.2	16.1	16.0	15.9	16.2	90	50.6	51.2	49.2	48.7	55.6
58	16.8	16.7	16.8	16.5	16.9	91	52.3	52.8	50.9	50.3	57.4
59	17.4	17.4	17.5	17.1	17.7	92	54.1	54.5	52.7	51.9	59.2
60	18.0	18.1	18.3	17.7	18.4	93	55.9	56.3	54.5	53.6	61.0
61	18.7	18.8	19.0	18.4	19.2	94	57.8	58.1	56.5	55.3	62.9
62	19.4	19.5	19.8	19.0	20.1	95	59.7	59.9	58.5	57.1	64.8
63	20.1	20.3	20.5	19.7	20.9	96	61.7	61.8	60.6	58.9	66.7
64	20.8	21.1	21.3	20.4	21.8	97	63.8	63.8	62.7	60.8	68.7
65	21.6	21.9	22.0	21.2	22.7	98	65.9	65.8	65.0	62.8	70.7
66	22.3	22.7	22.8	21.9	23.7	99	68.1	67.9	67.3	64.8	72.8
67	23.1	23.5	23.5	22.7	24.6	100	70.4	70.0	69.7	66.9	74.9
68	23.9	24.4	24.3	23.5	25.6	101	72.7	72.2	72.3	69.0	77.0
69	24.8	25.3	25.1	24.3	26.6	102	75.2	74.5	74.9	71.2	79.2
70	25.7	26.2	25.9	25.2	27.7	103	77.7	76.8	77.6	73.5	81.4
71	26.6	27.1	26.7	26.0	28.8	104	80.3	79.2	80.4	75.8	83.6
72	27.5	28.1	27.6	26.9	29.9	105	82.9	81.7	83.3	78.2	85.9
73	28.5	29.1	28.5	27.9	31.1	106	85.7	84.2	86.3	80.7	88.2
74	29.5	30.1	29.4	28.8	32.2	107	88.5	86.8	89.4	83.3	90.6
75	30.5	31.2	30.3	29.8	33.4	108	91.5	89.5	92.7	85.9	93.0
76	31.6	32.3	31.2	30.8	34.7	109	94.5	92.2	96.0	88.6	95.4
77	32.7	33.4	32.2	31.8	36.0	110	97.6	95.1	99.5	91.4	97.9
78	33.8	34.5	33.2	32.9	37.3	111	100.8	98.0	103.0	94.3	100.4
79	35.0	35.7	34.3	34.0	38.6	112	104.2	101.0	106.7	97.3	102.9
80	36.2	36.9	35.4	35.2	40.0	-	-	-	-	-	-

[a] HG: heart girth; S: Sardi; T: Timahdite; F: females and M: males.

For these analyses, data sets used consisted of 63, 60, 57, 56 and 54 girth classes with their corresponding mean weights for pooled data, Sardi, Timahdite, female and male sheep, respectively.

CONCLUSION

The body weight and heart girth were highly correlated. This high correlation indicates that body weight could be predicted fairly accurately from heart girth in Sardi and Timahdite sheep and a tape measure can therefore be developed to assist livestock farmers in managing their sheep better. Such a tool would be cheaper and easier to implement than the various different weighing equipment currently in use.

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