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# A Study on Live Weight Estimation Using Body Measurements in Hair Goats

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**ABSTRACT**

This study aimed to estimate the body weight of hair goats of various ages during the mating period using body measurements. Age-based regression prediction models were developed using the stepwise regression method. The study involved 205 hair goats from four farms under extensive conditions. The least squares mean values for withers height, back height, rump height, chest girth, chest depth, body length, and live weight were 81.05 cm, 77.24 cm, 79.84 cm, 88.74 cm, 32.71 cm, 83.56 cm, and 58.61 kg, respectively. Given that the goats differed in age, four distinct age groups were established (2, 3, 4, and ≥5 years), and separate regression models were defined for each group. High positive phenotypic correlation coefficients of 0.917, 0.834, 0.883, 0.817, and 0.817 were observed for the 2, 3, 4, and ≥5 age groups, respectively. Among the prediction equations, the highest level of accuracy ($R^2$ = 0.87) was achieved with the second regression equation for the 2-year age group, while the lowest accuracy ($R^2$ = 0.67) was found in the regression equation designed for the 5-year age group This study demonstrated that body weight estimation based on body measurements in hair goats can be performed using regression models.

# Kıl Keçilerinde Vücut Ölçüleri Kullanılarak Canlı Ağırlık Tahmini Üzerine Bir Çalışma

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**ÖZ**

Çalışmanın amacı, farklı yaşlardaki kıl keçilerinin çiftleşme dönemindeki canlı ağırlıklarının vücut ölçümleri kullanılarak tahmin edilmesidir. Bu çalışmada, aşamalı regresyon yöntemi kullanılarak yaşa dayalı regresyon tahmin modelleri geliştirilmiştir. Çalışmanın hayvan materyalini, ekstansif koşullar altında yetiştiricilik yapan 4 işletmedeki toplam 205 baş kıl keçi oluşturmuştur. Cidago yüksekliği, sırt yüksekliği, sağrı yüksekliği, göğüs çevresi, göğüs derinliği, vücut uzunluğu ve canlı ağırlık değerlerinin en küçük kareler ortalamaları sırasıyla 81.05 cm, 77.24 cm, 79.84 cm, 88.74 cm, 32.71 cm, 83.56 cm ve 58.61 kg olmuştur. Hayvan materyalini oluşturan hayvanlar yaş bakımından farklılık gösterdiğinden, dört farklı yaş grubu (2, 3, 4, ve ≥5) oluşturulmuş ve her yaş grubu için farklı regresyon modelleri tanımlanmıştır. Çeşitli yaş gruplarında özellikle vücut ölçülerinden göğüs çevresi ile canlı ağırlık arasında 2, 3, 4 ve ≥5 yaş grupları için

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sırasıyla 0.917, 0.834, 0.883 ve 0.817 gibi yüksek pozitif fenotipik korelasyon katsayıları bulunmuştur. Oluşturulan tahmin denklemlerinden en yüksek isabet derecesi ($R^2$ = 0.87) 2 yaş için oluşturulan ikinci regresyon denkleminden elde edilirken en düşük isabet düzeyi ($R^2$ = 0.67) 5 yaş için tasarlanan regresyon denkleminden elde edilmiştir. Bu çalışma, kıl keçilerde vücut ölçümlerine dayalı vücut ağırlığı tahmininin regresyon modelleri kullanılarak yapılabileceğini ortaya koymuştur.

## Introduction

In addition to Türkiye's economic and geographical conditions, its rich cultural heritage provides a significant foundation for animal production. Especially, sheep and goat breeding hold a unique position in this area (Tolunay et al., 2016; Cedden et al., 2020; Gül et al., 2020). Hair goats, which are widely bred in almost every region of Türkiye, constitute approximately 98% of the 11 577 000 goats in Türkiye (TÜİK, 2023) . Goat breeding in Türkiye is carried out under extensive conditions, generally in the mountainous parts of the country (Daskiran et al., 2018). The National Genetic Improvement Project for Small Ruminants at Breeders' Conditions, supported by the General Directorate of Agricultural Research and Policies of the Ministry of Agriculture and Forestry, encompasses numerous sub-projects focusing on various species and breeds of livestock across Türkiye. Initiated in 2005, the project has achieved a significant milestone by establishing a registration system for Hair goats, similar to other indigenous breeds (Daskiran and Ayhan, 2013; Daşkıran et al., 2015).

In Hair goat breeding, which is traditionally carried out in Türkiye, the growth characteristics of Hair goat kids are of primary importance (Toplu and Altinel, 2008; Tolunay et al., 2016; Cedden et al., 2020; Varol and Demirhan, 2022). Especially in goat breeding programs focusing on growth characteristics, it is important to collect live weight parameters such as birth weight and weaning weight. By obtaining these parameters accurately, some important measures such as feed conversion and growth rate can be easily monitored (Meza-Herrera et al., 2019; Liotta et al., 2020; Sheriff et al., 2020; Şen et al., 2021; Varol and Demirhan, 2022; Ergül and Hızlı, 2023).

It is not possible to measure some basic parameters on hair goat farms where breeding activities are primarily conducted under extensive conditions, especially in mountainous areas, due to inadequate infrastructure. Although scales are used to determine live weights most accurately, it is neither practical nor economical to suggest using scales to record live weights for each farm. In developed countries, tables have been created to estimate live weight from body measurements obtained using measuring tapes, allowing for some deviations in the recorded parameters (Anonymous, 2017). These tables enable breeders to estimate live weight values with high accuracy without using any weighing instruments.

There is a balanced relationship between body measurements and body weight in farm animals. In related studies, significant phenotypic correlation values have been reported between body measurements and body weight, leading to the development of body weight estimation equations using various statistical approaches (Sowande and Sobola, 2008; Yilmaz et al., 2013; Moaeen-Ud-Din et al., 2018; Canul-Solis et al., 2020; Sabbioni et al., 2020; Faraz et al., 2021).

In Türkiye, the number of studies on estimating live weight from body measurements for Hair goats is quite limited (Sağır Akyürek and Akkol, 2024). The present study aimed to develop equations for estimating live weight based on body measurements in Hair goats. These goats are raised extensively throughout Türkiye, where infrastructure for live weight measurements is relatively limited compared to other livestock breeding areas.

## Materials and Methods

### *Animal Material*

The animal material for the study comprised 205 female hair goats raised on four different farms. Farms with similar animal care and feeding practices were selected for the study. The age distribution of the animals, whose body weights and body measurements were taken, is presented in Table 1.

Table 1. Distribution of animal material according to ages
*Tablo 1. Hayvan materyalinin yaşlara göre dağılımı*

| Farms | Age Groups | | | | N |
|---|---|---|---|---|---|
| | 2 | 3 | 4 | ≥5 | |
| Farm-1 | 4 | 21 | 10 | 19 | 54 |
| Farm-2 | 17 | 5 | 9 | 14 | 45 |
| Farm-3 | 4 | 9 | 12 | 28 | 53 |
| Farm-4 | 13 | 7 | 22 | 11 | 53 |
| Total | 38 | 42 | 53 | 72 | 205 |

### *Live weight and body measurements*

Body weights of the animals were determined using an electronic weighing scale with a precision of 50 g. Body measurements, including height at withers (HW), body length (BL), rump height (RH), chest depth (CD), and back height (BH), were taken with a measuring stick, while chest girth (CG) was measured using a tape measure. Body weight and body measurements were taken before the mating period. The points where body measurements were taken in the study on Hair goats are provided in Figure 1 (Karaca et al., 2014).

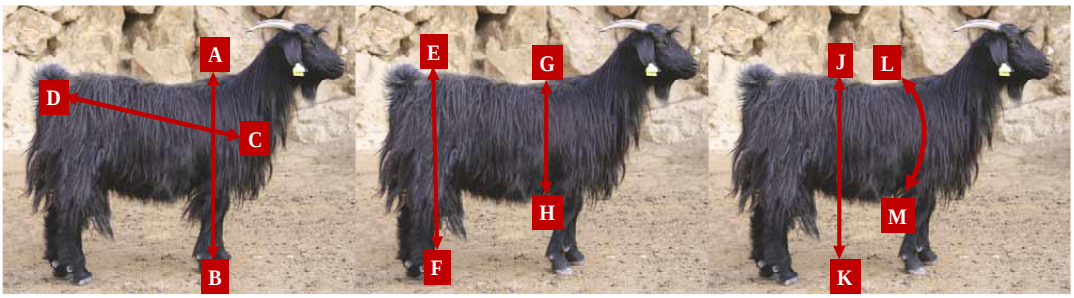


Figure 1. Points where body measurements are taken in Hair goat (A-B: height at withers, C-D: body lenght, E-F: rump height, G-H: chest depth, J-K: back height, L-M: chest girth)
*Şekil 1. Kıl keçisinde vücut ölçülerinin alındığı noktalar (A-B: cidago yüksekliği, C-D: vücut uzunluğu, E-F: sağrı yüksekliği, G-H: göğüs derinliği, J-K: sırt yüksekliği, L-M: göğüs çevresi)*

***Statistical analysis***

The conformity of the data to a normal distribution was tested using the SAS (1999) statistical program. The GLM procedure in the SAS (1999) statistical package program was used for analysis of variance and least squares mean, while the PROC CORR procedure was utilized for phenotypic correlations. Duncan was used as a multiple comparison test to determine the differences between the groups. The mathematical models used for the analysis of variance are presented below.

Mathematical model used for live weight,

$$Y_{ijk} = \mu + a_i + b_j + e_{ijk} \quad (1)$$

Mathematical model for body measurements,

$$Y_{ijkl} = \mu + a_i + b_j + \beta_1(X_i - \bar{X}) + e_{ijkl} \quad (2)$$

Where;

$Y_{ijkl}$= Observations for body measurement and weight

$\mu$= Overall mean of the trait

$a_i$= Fixed effect of farms ($i$=Farm-1, Farm-2, Farm-3, and Farm-4 )

$b_j$= Fixed effect of age (j= 2, 3, 4 and, 5)

$\beta_1$= Coefficient of regression of live weight

$\bar{X}$= Mean live weight

$X_i$= Live weight

$e_{ijk}$ and $e_{ijkl}$ =Random errors with the assumption of N (0. $\sigma^2$)

The estimation equations for body weights based on body measurements were derived using stepwise regression procedure in SAS (1999). Since the study included broodstock of different age groups, the prediction equations were obtained based on the age groups outlined in Table 2. The following linear regression model was used for the prediction equations.

$$\hat{y}_i = \hat{\beta}_0 + \hat{\beta}_i x_i \quad (3)$$

$\hat{\beta}_0$=constant

$\hat{\beta}_i$=regression coefficient

$\boldsymbol{x_i}$=body measurements

$\boldsymbol{x_1}$= chest girth (CG)

$\boldsymbol{x_2}$= height at withers (HW)

$\boldsymbol{x_3}$= body lenght (BL)

$\boldsymbol{x_4}$= back height (BH)

$\boldsymbol{x_5}$= rump height (RH)

$\boldsymbol{x_6}$= chest depth (CD)

**Results**

The descriptive statistics obtained for the characteristics analyzed in the study are presented in Table 2.

The mean values obtained for HW, BH, RH, CG, CD, and BL were 81.25, 77.40, 79.93, 88.82, 32.84, and 84.09 cm, respectively. The average live weight of the Hair goats was 86.90 kg, which fell within a range of 43.10 kg (minimum) to 86.90 kg (maximum).It is noteworthy

that the variation of the body measurements considered in the study is within acceptable limits, while the body weight parameter has a higher coefficient of variation than the body measurements.

Table 2. Descriptive statistics on body measurements (cm) and live weight (kg)
*Tablo 2. Vücut ölçüleri (cm) ve canlı ağırlığa (kg) ilişkin tanımlayıcı istatistikler*

| Variable | N | Mean±SD | CV(%) | Min | Max |
|---|---|---|---|---|---|
| HW | 205 | 81.25±3.478 | 4.28 | 69.10 | 90.70 |
| BH | 205 | 77.40±3.384 | 4.37 | 65.20 | 85.60 |
| RH | 205 | 79.93±3.313 | 4.14 | 69.10 | 88.70 |
| CG | 205 | 88.82±4.484 | 5.05 | 76.00 | 104.00 |
| CD | 205 | 32.84±2.170 | 6.61 | 28.75 | 48.10 |
| BL | 205 | 84.09±4.281 | 5.09 | 55.00 | 94.50 |
| LW | 205 | 58.48±6.850 | 11.71 | 43.10 | 86.90 |

HW: height at withers, BH: back height, RH: rump height, CG: chest girth, CD: chest depth, BL: body length, LW: live weight, CV: coefficient of variation

The mean values obtained for HW, BH, RH, CG, CD, and BL were 81.25, 77.40, 79.93, 88.82, 32.84, and 84.09 cm, respectively. The average live weight of the Hair goats was 86.90 kg, which fell within a range of 43.10 kg (minimum) to 86.90 kg (maximum).It is noteworthy that the variation of the body measurements considered in the study is within acceptable limits, while the body weight parameter has a higher coefficient of variation than the body measurements.

Analysis of variance was applied to the dataset obtained from the study, and the least squares means and standard errors associated with this analysis are presented in Table 3. The average values for HW, BH, RH, CG, CD, BL, and LW were 81.05 cm, 77.24 cm, 79.84 cm, 88.74 cm, 32.71 cm, 83.56 cm, and 58.61 kg, respectively.

While there was a statistically significant difference between farms in terms of all traits, the effect of animal age on BH, RH, and LW was statistically insignificant. The effect of live weight, treated as a continuous variable for body measurements, was determined to be statistically significant for all body measurements.

Phenotypic correlation coefficients between body measurements and live weights of the age groups included in the study are provided in Table 4.

Table 3. Least squares means and standard errors for body measurements (cm) and live weight (kg) in Hair goat

*Tablo 3. Kıl keçisinde vücut ölçüleri (cm) ve canlı ağırlığa (kg) ait en küçük kareler ortalamaları ve standart hataları*

| Factors | N | HW | BH | RH | CG | CD | BL | LW |
|---|---|---|---|---|---|---|---|---|
| Farms | | P=0.003 | P=0.001 | P=0.014 | P=0.000 | P=0.023 | P=0.039 | P=0.005 |
| Farm-1 | 54 | 81.64±0.480$^{a}$ | 78.18±0.469$^{a}$ | 80.86±0.466$^{a}$ | 89.46±0.309$^{a}$ | 33.24±0.272$^{a}$ | 81.69±0.892$^{b}$ | 60.87±0.949$^{a}$ |
| Farm-2 | 45 | 79.45±0.509$^{b}$ | 75.48±0.497$^{b}$ | 78.83±0.494$^{b}$ | 89.47±0.327$^{a}$ | 32.82±0.288$^{ab}$ | 84.05±0.945$^{b}$ | 59.67±1.018$^{ab}$ |
| Farm-3 | 53 | 81.21±0.484$^{a}$ | 77.44±0.473$^{a}$ | 79.42±0.470$^{b}$ | 87.71±0.311$^{b}$ | 32.07±0.274$^{b}$ | 83.14±0.900$^{ab}$ | 57.16±0.967$^{b}$ |
| Farm-4 | 53 | 81.90±0.471$^{a}$ | 77.86±0.460$^{a}$ | 80.25±0.457$^{ab}$ | 88.33±0.303$^{b}$ | 32.71±0.267$^{b}$ | 85.36±0.876$^{a}$ | 56.76±0.938$^{b}$ |
| Age | | P=0.030 | P=0.251 | P=0.892 | P=0.014 | P=0.002 | P=0.047 | P=0.181 |
| 2 | 38 | 81.13±0.560$^{ab}$ | 77.29±0.546 | 79.73±0.543 | 88.07±0.360$^{b}$ | 32.20±0.317$^{b}$ | 83.27±1.040$^{ab}$ | 58.53±1.123 |
| 3 | 42 | 80.08±0.533$^{b}$ | 76.79±0.520 | 79.62±0.517 | 88.40±0.342$^{ab}$ | 32.35±0.302$^{ab}$ | 83.29±0.989$^{ab}$ | 58.52±1.069 |
| 4 | 53 | 80.96±0.469$^{ab}$ | 76.94±0.458 | 79.94±0.455 | 89.35±0.302$^{a}$ | 32.78±0.266$^{ab}$ | 82.26±0.871$^{b}$ | 60.08±0.934 |
| ≥5 | 72 | 82.04±0.403$^{a}$ | 77.93±0.393 | 80.07±0.391 | 89.15±0.259$^{a}$ | 33.52±0.228$^{a}$ | 85.42±0.749$^{a}$ | 57.32±0.804 |
| Reg. Linear | | P=0.013 | P=0.044 | P=0.019 | P=0.000 | P=0.000 | P=0.000 | |
| LW | | 0.089±0.035 | 0.070±0.035 | 0.081±0.034 | 0.542±0.023 | 0.133±0.020 | 0.437±0.066 | |
| Generall | 205 | 81.05±0.24 | 77.24±0.234 | 79.84±0.232 | 88.74±0.154 | 32.71±0.136 | 83.56±0.445 | 58.61±0.481 |

HW: height at withers, BH: back height, RH: rump height, CG: chest girth, CD: chest depth, BL: body length, LW: live weight, $^{a,b}$: Different letters as superscripts mean significant differences ($p < 0.05$)

Table 4. Phenotypic correlation coefficients between weight and body measurements according to age group

*Tablo 4. Yaş gruplarına göre ağırlık ve vücut ölçüleri arasındaki fenotipik korelasyon katsayıları*

| Age groups | BM | LW | HW | BH | RH | CG | CD |
|---|---|---|---|---|---|---|---|
| 2 | HW | $0.263^{ns}$ | | | | | |
| | BH | $0.187^{ns}$ | $0.891^{***}$ | | | | |
| | RH | $0.174^{ns}$ | $0.782^{***}$ | $0.842^{***}$ | | | |
| | CG | $0.917^{***}$ | $0.092^{ns}$ | $0.034^{ns}$ | $0.049^{ns}$ | | |
| | CD | $0.729^{***}$ | $0.018^{ns}$ | $0.074^{ns}$ | $0.001^{ns}$ | $0.771^{***}$ | |
| | BL | $0.632^{***}$ | $0.272^{ns}$ | $0.230^{ns}$ | $0.013^{ns}$ | $0.597^{***}$ | $0.567^{***}$ |
| 3 | HW | $0.285^{ns}$ | | | | | |
| | BH | $0.291^{ns}$ | $0.895^{***}$ | | | | |
| | RH | $0.289^{ns}$ | $0.927^{***}$ | $0.902^{***}$ | | | |
| | CG | $0.834^{***}$ | $0.220^{ns}$ | $0.209^{ns}$ | $0.268^{ns}$ | | |
| | CD | $0.649^{***}$ | $0.330^{*}$ | $0.304^{ns}$ | $0.351^{*}$ | $0.765^{***}$ | |
| | BL | $0.647^{***}$ | $0.193^{ns}$ | $0.172^{ns}$ | $0.184^{ns}$ | $0.583^{***}$ | $0.454^{**}$ |
| 4 | HW | $0.043^{ns}$ | | | | | |
| | BH | $0.062^{ns}$ | $0.806^{***}$ | | | | |
| | RH | $0.125^{ns}$ | $0.813^{***}$ | $0.801^{***}$ | | | |
| | CG | $0.883^{***}$ | $0.086^{ns}$ | $0.161^{ns}$ | $0.203^{ns}$ | | |
| | CD | $0.407^{**}$ | $0.053^{ns}$ | $0.167^{ns}$ | $0.150^{ns}$ | $0.565^{***}$ | |
| | BL | $0.242^{ns}$ | $0.224^{ns}$ | $0.268^{ns}$ | $0.294^{*}$ | $0.402^{**}$ | $0.278^{*}$ |
| ≥5 | HW | $0.045^{ns}$ | | | | | |
| | BH | $0.042^{ns}$ | $0.891^{***}$ | | | | |
| | RH | $0.163^{ns}$ | $0.834^{***}$ | $0.914^{***}$ | | | |
| | CG | $0.817^{***}$ | $0.113^{ns}$ | $0.060^{ns}$ | $0.140^{ns}$ | | |
| | CD | $0.289^{*}$ | $0.264^{*}$ | $0.289^{*}$ | $0.372^{**}$ | $0.357^{**}$ | |
| | BL | $0.585^{***}$ | $0.016^{ns}$ | $0.035^{ns}$ | $0.053^{ns}$ | $0.667^{***}$ | $0.225^{ns}$ |

BM: body measurments, HW: height at withers, BH: back height, RH: rump height, CG: chest girth, CD: chest depth, BL: body length, LW: live weight, *:p<0.05, **:p<0.01, ***:p<0.001, ns: non-significant

In general, high positive phenotypic correlation coefficients were obtained between body measurements and body weight. In all age groups, the phenotypic correlation coefficients between chest circumference, chest depth, body length, and live weight were significantly higher than the coefficients between other body measurements and live weight. In general, the highest phenotypic correlation coefficients between body measurements and body weight were obtained in 2- and 3-year-old animals.

Separate models were developed for different age groups using the stepwise regression method to predict body weight based on body measurements. The developed models and coefficients of determination ($R^2$) are presented in Table 5.

Table 5. Live weight estimation models for four different age groups using stepwise regression analysis

*Tablo 5. Aşamalı regresyon analizi kullanılarak dört farklı yaş grubu için elde edilen canlı ağırlık tahmin modelleri*

| **Age Groups** | **Regression Models** | $\beta_i$ | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | $\hat{\beta}_0$ | $\beta_1$ | $\beta_2$ | $\beta_3$ | $\beta_4$ | $\beta_5$ | $\beta_6$ | $R^2$ | P |
| **2** | $\hat{\gamma}_1 = \hat{\beta}_0 + \hat{\beta}_1 x_1$ | -68.73 | 1.44 | | | | | | 0.84 | 0.000 |
| | $\hat{\gamma}_1 = \hat{\beta}_0 + \hat{\beta}_1 x_1 + \hat{\beta}_2 x_2$ | -99.61 | 1.42 | 0.41 | | | | | 0.87 | 0.000 |
| **3** | $\hat{\gamma}_1 = \hat{\beta}_0 + \hat{\beta}_1 x_1$ | -43.73 | 1.16 | | | | | | 0.70 | 0.000 |
| | $\hat{\gamma}_1 = \hat{\beta}_0 + \hat{\beta}_1 x_1 + \hat{\beta}_2 x_3$ | -69.72 | 0.96 | 0.53 | | | | | 0.73 | 0.000 |
| **4** | $\hat{\gamma}_1 = \hat{\beta}_0 + \hat{\beta}_1 x_1$ | -65.98 | 1.40 | | | | | | 0.78 | 0.000 |
| **≥ 5** | $\hat{\gamma}_1 = \hat{\beta}_0 + \hat{\beta}_1 x_1$ | -53.23 | 1.25 | | | | | | 0.67 | 0.000 |

$x_1$= chest girth (CG), $x_2$= height at withers (HW), $x_3$= body lenght (BL), $x_4$= back height (BH), $x_5$= rump height (RH), $x_6$= chest depth (CD), $\hat{\beta}_0$=constant, $\beta_i$=coefficient of regression, $R^2$=adjusted coefficients of determination

As can be seen from Table 5, two prediction models were obtained for the 2- and 3-year-old age groups, while one prediction model was obtained for the 4- and 5-year-old age groups. When the coefficients of determination ($R^2$) obtained for the developed models were evaluated, the lowest value was observed in the model developed for the 5 age group, and the highest value was observed in the second model obtained for the 2 age group. Using the enter regression procedure, the coefficient of determination of the regression model including all body measurements was obtained as 0.74. All regression models obtained were statistically significant.

## Discussion and Conclusion

Morphometric traits are crucial for identifying populations and classifying breeds (Rodero et al., 2015; Saleh et al., 2021). Numerous studies have been conducted on determining morphometric traits and estimating live weight based on these traits in livestock (Yilmaz et al., 2013; Eyduran et al., 2017; Wangchuk et al., 2018; Dakhlan et al., 2021).

When analyzing the descriptive statistics, it is evident that the coefficients of variation fall within acceptable limits; however, there is a significant disparity between the minimum and maximum values. This observation can primarily be attributed to the relatively low number of animals represented by the minimum values in the data set.

The average live weight values obtained in this study were higher than the values reported in some studies conducted on domestic and foreign breeds (Khargharia et al., 2015; Karakuş, 2016; Gezer, 2018; Yılmaz and Daşkıran, 2018; Manirakiza et al., 2020; Dakhlan et al., 2021) and lower than othersr (Bingöl et al., 2012; Varol, 2014; Karadağ and Soysal, 2018; Tyasi and Tada, 2023). These differences in the literature are due to variations in breeds and breeding systems.

Studies show that live weight and body measurements are influenced by factors such as breed, age, sex, management, and breeding type (Varol, 2014; Gezer, 2018; Karna et al., 2020; Varol and Demirhan, 2022; Tyasi and Tada, 2023). In the present study, management and age factors had statistically significant effects on body weight and body measurements. This situation aligns with the relevant literature.

It is noteworthy that all body measurements change with age. As a matter of fact, similar situations have been identified in some previous studies conducted on farm animals (Yilmaz et al., 2013; Karna et al., 2020). Similarly, it has been observed that live weight values increase slightly with age but tend to decrease in animals aged five years and older. Comparable findings have been reported in various breeds (Alizadehasl, 2011; Yılmaz and Daşkıran, 2018). This trend indicates potential issues such as decreased metabolic efficiency and loss of muscle mass in older animals.

In this study, high positive phenotypic correlation coefficients were obtained between body measurements and body weight. This result is consistent with the related studies (Karakuş, 2016; Eyduran et al., 2017; Dakhlan et al., 2021). Although body weight was positively correlated with many body measurements, the strongest relationships were observed between body weight and chest girth, body weight and body length, and body weight and height at withers. This indicates that one or a combination of these body measurements could be used in regression models for estimating body weight.

In most studies on the subject, it is noteworthy that chest girth has a stronger linear relationship with body weight than other body measurements. This measurement is widely utilized in body weight estimation equations (Yilmaz et al., 2013; Moaeen-Ud-Din et al., 2018; Karna et al., 2020; Sabbioni et al., 2020). In this study, the chest girth parameter is included in all models obtained for estimating body weight, in line with the literature.

As can be seen from the models presented for body weight estimation by age, the parameters of chest girth, height at withers, and body length are crucial in estimating body weight in Hair goats. In addition, incorporating more than one body trait into the model leads to a relative increase in $R^2$ values. The utilization of the model with higher $R^2$ values for animals in the $2^{nd}$, $3^{rd}$, and $4^{th}$ age groups in the study will enable more precise live weight estimates to be generated. The $R^2$ value of the stepwise regression model obtained for the age group of 5 years and older was lower than the $R^2$ value determined for the model obtained using the enter regression procedure, where all body characteristics were added to the model. In the 2 to 3 age groups, the inclusion of additional variables in the model enhanced prediction accuracy. However, in the age group of 5 years and older, the addition of extra variables did not positively impact the model's predictive power. The variation in $R^2$ values between age groups may be attributed to differences in growth processes and metabolism. Therefore, it would be more meaningful to use the general regression model for this age group. However, it should not be ignored that taking a minimum number of measurements in field studies saves time and enables practical application.

As a result, measuring chest girth, height at withers, and body length, which are considered in the regression models for estimating body weight, is relatively easier to perform than determining body weight under field conditions. The use of live weight estimation models, based on body measurements instead of live weight measurements that cannot be taken due to inadequate infrastructure conditions in the field, will save labor and time. In younger animals (2 to 4 years), live weight can be predicted with greater accuracy, whereas prediction accuracy diminishes in older animals. It was determined that employing multivariate models is particularly beneficial for younger animals. Conversely, in the age group of 5 years and older, simpler models that utilize only chest circumference may suffice. This approach will also enable highly accurate predictions to be made. Considering that live weight varies according to species, breed, nutritional status, age, and body size, it should not be overlooked that these regression models for live weight estimation in hair goats may not be applied with the same success in other species and breeds.

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