

Original Research Paper

## Statistical models based on morphometric traits for body weight prediction in four dog breeds raised in Algeria

Haddam HY.<sup>1\*</sup>, Mennani A.<sup>2</sup> – R. Belala<sup>3</sup> – W. Hamel<sup>1</sup> – S. Mokrani<sup>1</sup> – C. Saad<sup>1</sup> – H. Abdelbari<sup>1</sup> – MEA. Benhamadi<sup>1</sup> – SBS. Gaouar<sup>1</sup>

<sup>1</sup>Applied genetic in agriculture, ecology and public health laboratory, Department of Biology, Faculty of Natural Sciences and Life and Earth Sciences and the Universe, University of Tlemcen, Algeria

<sup>2</sup>Department of Agronomic Sciences, Faculty of Sciences, University of M'sila, Algeria

<sup>3</sup>Carnivore Reproductive Biotechnologies Platform, University of Blida1, Algeria

**\*Corresponding Author:** Hadi Youssouf Haddam, Laboratory of Applied genetic in agriculture, ecology and public health, Biology Department, Faculty SNV/STU, University of Tlemcen, Algeria; Email: [hyh.genetics@gmail.com](mailto:hyh.genetics@gmail.com)

**Article history:** Received: June 18, 2024, revised: July 16, 2024, Accepted: July 19, 2024

### Abstract

The present study aims to evaluate the morphological differences between genders in four dog breeds: Belgian Shepherd Malinois, Siberian Husky, Algerian Sloughi, and German Shepherd. Additionally, we aim to determine the correlation between live weight and body measurements according to breeds and gender. A total of 292 dogs belonging to these four breeds were used: Belgian Shepherd Malinois (36 females and 44 males), Siberian Husky (31 females and 33 males), Algerian Sloughi (40 females and 40 males), and German Shepherd (32 females and 36 males). Eleven body measurements and live weight were recorded. Multiple linear regression models were proposed using some body measurements to predict the live weight of the dogs. Among the multiple regression models formed, the highest coefficients of determination ( $R^2$ ) were obtained from the models for male German Shepherds using Height at Withers (HW), Head Width (HEW), Muzzle Length (ML), and Chest Girth (CG), with a coefficient of determination ( $R^2 = 0.996$ ) and Lin's concordance correlation coefficient ( $CCC = 0.998$ ). This study demonstrates that the live weight of the four dog breeds can be estimated with a high degree of accuracy using certain body measurements and statistical methods, after checking the variance inflation factor to eliminate error rates.

**Keywords:** Body measurements, breed, concordance, dog, live weight, prediction.

### ملخص

تهدف الدراسة الحالية إلى تقييم الفرق المورفولوجي بين الجنسين في أربع سلالات من الكلاب: الراعي البلجيكي المالينوي، الهاسكي السيبيري، السلوقي الجزائري، والراعي الألماني. ومن ناحية أخرى، فإننا نهدف إلى تحديد العلاقة بين الوزن الحي وقياسات الجسم حسب السلالة والسلالة والجنس. تم استخدام 292 كلباً ينتمون إلى أربع سلالات مختلفة وهي: الراعي البلجيكي مالينوي (36 أنثى و44 ذكر)، الهاسكي السيبيري (31 أنثى و33 ذكر)، سلوقي الجزائري (41 أنثى و59 ذكر)، والراعي الألماني (32 أنثى و36 ذكر). تم استخدام أحد عشر قياساً للجسم والوزن الحي. تم اقتراح نماذج الانحدار الخطي المتعددة باستخدام بعض قياسات الجسم للتنبؤ بالوزن الحي للكلاب. من بين نماذج الانحدار المتعددة التي تم تشكيلها تم الحصول على أعلى معاملات التحديد من النماذج في ذكور الراعي الألماني باستخدام الارتفاع عند الذراعين (ا ذ) وعرض الرأس (ع ر) وطول الكمامة (م ك) ومحيط الصدر (م ص) معاً مع معامل التحديد ( $R^2 = 0.996$ ) ومعامل ارتباط توفاق لين ( $CCC = 0.998$ ). لقد أثبتنا في هذه الدراسة أنه يمكن تقدير الوزن الحي لسلالات الكلاب الأربعة بدرجة عالية من الدقة باستخدام بعض قياسات الجسم والطرق الإحصائية بعد التحقق من عامل تضخم التباين لإزالة معدل الخطأ.

**الكلمات المفتاحية:** قياسات الجسم، سلالة، توافق، كلب، الوزن الحي، التنبؤ.

### Introduction

Algeria is the largest country in Africa, renowned for its biological resources and diverse geographical regions. From 2017 to 2019, according to statistics from The International Cynological Federation (FCI) available on their official website ([www.fci.be](http://www.fci.be)) and information from some dog breeders, there has been a significant increase in the number of dogs in Algeria, including breeds such as the Belgian Shepherd Malinois, German Shepherd, and Siberian Husky, which have become particularly fashionable. One of the most ancestral dog breeds present for several centuries in Algeria is the Sloughi. It is considered an emblematic breed of the country, having withstood the test of time. According to local Algerian breeders, male individuals, especially those of the Belgian Shepherd Malinois (BSM), German Shepherd (GS),

and Siberian Husky (SH) breeds, are most favored for breeding as watchdogs and defense dogs. Due to their developed traits and weight, both males and females of the Sloughi (SLG) breed are used for hunting and racing.

Several methods are used to analyze data in various breeding contexts to predict the weight of the animal, which is considered an important trait for selection (Çelik & Yilmaz, 2018). The methods used in the present study, based on morphometric analysis, are the same as those applied to other dog breeds and domestic species such as sheep, goats, donkeys, and camels (Traoré et al., 2008; González et al., 2011; Yilmaz et al., 2013; McCarthy et al., 2018; Urosevic et al., 2020a; Meghelli et al., 2020; Haddam et al., 2021; Djaout et al., 2022; Urosevic et al., 2022; Deabold et al., 2023; Haddam et al., 2024a; Haddam et al., 2024b).

For body weight estimation using certain body measurements, the method employed is based on multiple linear regression, as utilized in other dog breeds, including Zağar, Zerdava, and Çatalburun dogs raised in Turkey (Özkul et al., 2021), and in other animal species such as camels and sheep (Yilmaz et al., 2013; Meghelli et al., 2020; Haddam et al., 2024b). The aim of this study is to develop mathematical models that will allow for the prediction of live body weight in dogs according to breed and gender.

## Material and Methods

The study samples consisted of 292 dogs: 80 Belgian Shepherd Malinois (36 females and 44 males), 64 Siberian Huskies (31 females and 33 males), 80 Algerian Sloughis (40 females and 40 males), and 68 German Shepherds (32 females and 36 males). All the studied dogs were adults, aged between 24 and 27 months. None of these dogs were in the reproductive period (both males and females), nor were they in gestation or the lactation period for females. The dogs were weighed on a digital scale with a precision of 100 grams. Eleven body measurements and live body weight were recorded in this study. The body measurements included: height at withers (HW) and height at rump (HR), measured using a measuring rod; body length (BL), head length (HL), muzzle length (ML), ears length (EL), head girth (HG), chest girth (CG), wrist girth (WG), and abdominal girth (AG), measured using a measuring tape; and head width (HEW), measured using a caliper.



**Figure 1.** Examples of the studied breeds, from left to right and top to bottom: Belgian Shepherd Malinois, Siberian Husky, Algerian Sloughi, and German Shepherd (original photos).

This work was carried out over three months with the participation of the Algerian Cynological Association (ACA) in a dog selection program based on their utility. All activities were performed in accordance with Algerian laws and regulations. No ethical conflicts exist in the execution of this work. All analyses in this study were performed using R version 4.3.1 for Windows. First, the normality of the data was assessed using the Kolmogorov-Smirnov (KS) test. The results of this analysis indicated that the data for all measured characteristics were normally distributed. A t-test was then used to evaluate the differences between males and females in each breed. Backward stepwise multiple linear regression, using several packages in R, was employed to estimate the live weights of the dogs based on some body measurements. The estimation equations for live weights were obtained through multiple linear regression analysis according to breed-sex groups (separated models) and stepwise multiple regression. Subsequently, the Durbin-Watson test was used to detect the presence of autocorrelation in the residuals (prediction errors) from the regression analysis. Tolerance and the variance inflation factor (VIF) were

checked for each model. Finally, Lin's Concordance Correlation Coefficient was used to assess the accuracy of each predictive model.

An example of each breed is represented in (Figure 1); from left to right and top to bottom, we see a male Belgian Shepherd Malinois, two male Siberian Huskies, a female and a male Algerian Sloughi, and finally a male German Shepherd.

## Results and Discussion

Means, standard deviations, and the results of the Student's t-test according to gender in each breed are presented in (Table 1). Body measurements are in cm, and live weight is in kg.

**Table 1.** Means, standard deviations, and t-tests according to gender among the four studied breeds.

| Traits | BSM<br>(N=80) |         | SH<br>(N=64) |         | SLG<br>(N=80) |         | GS<br>(N=68) |         |
|--------|---------------|---------|--------------|---------|---------------|---------|--------------|---------|
|        | Mean±SD       | P-value | Mean±SD      | P-value | Mean±SD       | P-value | Mean±SD      | P-value |
| HW     | 60.29±2.69    | <0.001  | 57.42±3.90   | <0.001  | 71.16±4.98    | <0.001  | 60.29±4.34   | <0.001  |
| HR     | 59.74±2.57    | <0.001  | 56.84±3.95   | <0.001  | 69.91±4.94    | <0.001  | 54.29±4.24   | <0.001  |
| BL     | 60.96±2.90    | <0.01   | 59.81±3.75   | <0.001  | 69.31±4.43    | <0.001  | 66.16±4.76   | <0.001  |
| HL     | 24.32±1.64    | <0.001  | 24.18±1.37   | <0.01   | 24.75±1.76    | <0.001  | 24.43±1.36   | <0.001  |
| HEW    | 12.52±0.82    | <0.001  | 12.85±0.98   | >0.05   | 12.83±0.89    | <0.001  | 12.53±0.83   | <0.001  |
| ML     | 12.48±0.83    | <0.001  | 11.80±0.98   | <0.001  | 10.84±1.11    | <0.001  | 13.03±0.94   | <0.001  |
| HG     | 42.90±2.48    | <0.001  | 44.18±2.34   | <0.001  | 32.64±2.43    | <0.001  | 43.40±1.69   | <0.001  |
| EL     | 11.24±1.14    | <0.001  | 10.29±1.17   | <0.05   | 12.81±1.25    | <0.001  | 12.48±0.87   | <0.001  |
| CG     | 60.73±2.22    | <0.001  | 60.24±3.68   | >0.05   | 70.81±4.39    | <0.001  | 61.66±3.10   | <0.001  |
| WG     | 11.64±1.31    | <0.001  | 12.29±0.83   | <0.01   | 10.83±1.07    | <0.001  | 12.02±0.83   | <0.01   |
| AG     | 45.48±4.33    | <0.001  | 51.51±3.47   | <0.001  | 45.36±5.46    | <0.001  | 48.18±3.57   | <0.001  |
| LW     | 25.96±2.66    | <0.001  | 23.58±3.36   | <0.001  | 22.46±2.52    | <0.001  | 31.33±6.76   | <0.001  |

HW: height at withers, HR: height at rump, BL: body length, HL: head length, HEW: head width, ML: muzzle length, HG: head girth, EL: ears length, CG: chest girth, WG: wrist girth, AG: abdominal girth, LW: live weight, BSM: Belgian Shepherd Malinois, SH: Siberian Husky, SLG: Algerian Sloughi, GS: German Shepherd, SD: Standard deviation, CV: coefficient of variation, P: probability value, ns: not significant.

The descriptive statistics results (Table 1) show the means and standard deviations of all studied traits in each dog breed. According to the t-test results, sexual dimorphism was evident in the four studied breeds for both body measurements and live weight, with males exhibiting more developed traits than females.

In Belgian Shepherd Malinois (BSM), the difference between males and females was very highly significant for all traits ( $p < 0.001$ ) and highly significant for body length (BL) ( $p < 0.01$ ), with males consistently showing more developed traits than females.

In Siberian Huskies (SH), the difference was very highly significant for height at withers (HW), height at rump (HR), body length (BL), muzzle length (ML), head girth (HG), abdominal girth (AG), and live weight (LW) ( $p < 0.001$ ). For head length (HL) and wrist girth (WG), the difference was highly significant ( $p < 0.01$ ), and for ears length (EL), it was significant ( $p < 0.05$ ). For all the cited traits, males were consistently more developed than females. The difference was not significant for head width (HEW) and chest girth (CG) ( $p > 0.05$ ).

In Algerian Sloughi (SLG), males exhibited more developed traits than females for all studied traits, with a very high significant difference ( $p < 0.001$ ).

In German Shepherds (GS), males were more developed than females for all studied traits, with a very high significant difference ( $p < 0.001$ ), except for wrist girth (WG), where the difference was highly significant ( $p < 0.01$ ), always in favor of males.

According to various official standards from organizations such as the FCI (Fédération Cynologique Internationale) and the AKC (American Kennel Club), as well as numerous studies on different dog breeds, sexual dimorphism is common across various breeds. For example, a study on Labrador Retrievers demonstrated differences between males and females in terms of height at withers (HW) and body length (BL) (Thuller et al., 2015). Similarly, research on the Italian pointing dog (Bracco Italiano)

found that males generally exhibit larger measurements than females across several metrics, including HW, chest girth (CG), BL, height at rump (HR), and head length (HL) (Cecchi et al., 2015). In the Turkish Tazi sighthound, males were observed to have greater dimensions than females in HW, HR, CG, HL, and BL (Urosevic et al., 2020a). The Tarsus Çatalburun breed of Turkish hunting dogs also showed male predominance in HW, HR, BL, CG, and HL (Oğrak et al., 2014). Furthermore, studies on Turkish Tazi dogs indicated that males typically have more developed HW, HR, CG, and BL measurements, along with greater body weight compared to females (Yilmaz & Ertuğrul, 2011). Similarly, in Akbash Turkish Shepherd dogs, males were found to have larger measurements for HW, HL, and back height compared to females (Urosevic et al., 2020b).

Separate models were developed for each breed group to estimate weight from body measurements, as shown in (Table 2).

**Table 2.** Final Regression Models for Estimating Body Weight in the Four Studied Breeds from Body Measurements.

| Breed | Independent variable | RC±SE           | P-value | Tol   | VIF   | DWS   | P-value | R2    |
|-------|----------------------|-----------------|---------|-------|-------|-------|---------|-------|
| BSM   | Intercept            | -28.359 ± 3.523 | <0.001  | --    | --    |       |         |       |
|       | HW                   | 0.828 ± 0.049   | <0.01   | 0.690 | 1.447 | 1.922 | >0.05   | 0.865 |
|       | AG                   | 0.096 ± 0.030   | <0.001  | 0.690 | 1.447 |       |         |       |
| SH    | Intercept            | -34.311 ± 3.329 | <0.001  | --    | --    |       |         |       |
|       | BL                   | 0.557 ± 0.052   | <0.001  | 0.785 | 1.272 | 1.676 | >0.05   | 0.829 |
|       | ML                   | 1.038 ± 0.192   | <0.001  | 0.857 | 1.166 |       |         |       |
|       | WG                   | 1.002 ± 0.239   | <0.001  | 0.767 | 1.302 |       |         |       |
| SLG   | Intercept            | -8.796 ± 2.043  | <0.001  | --    | --    | 1.733 | >0.05   | 0.747 |
|       | HW                   | 0.439 ± 0.028   | <0.001  | --    | --    |       |         |       |
| GS    | Intercept            | -70.086 ± 3.160 | <0.001  | --    | --    |       |         |       |
|       | HW                   | 1.153 ± 0.085   | <0.001  | 0.160 | 6.220 | 2.169 | >0.05   | 0.967 |
|       | HEW                  | 1.392 ± 0.369   | <0.001  | 0.237 | 4.212 |       |         |       |
|       | CG                   | 0.234 ± 0.085   | <0.01   | 0.316 | 3.154 |       |         |       |

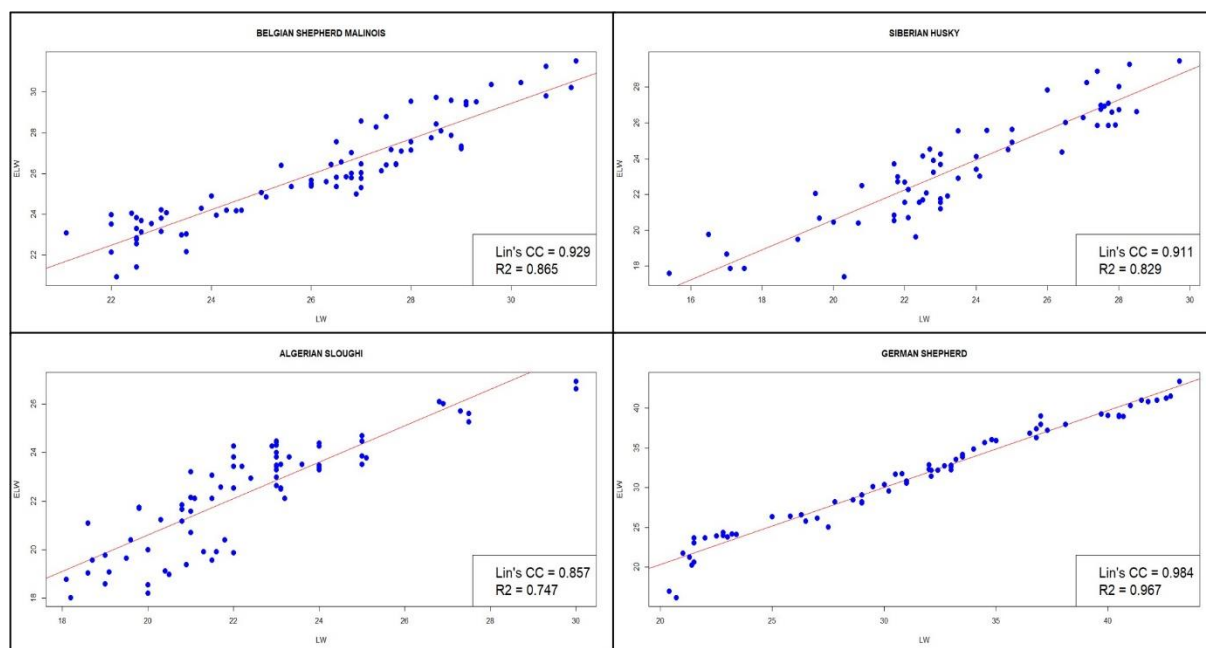
RC: regression coefficient, SE: standard error, Tol: tolerance, VIF: variance inflation factor, DWS: Durbin-Watson statistics, R2: coefficient of determination, BSM: Belgian Shepherd Malinois, SH: Siberian Husky, SLG: Algerian Sloughi, GS: German Shepherd.

The regression analysis resulted in prediction equations for body weight based on different sets of independent variables for each breed (Table 2). For Belgian Shepherd Malinois, body weight could be adequately predicted using height at withers and abdominal girth. In Siberian Husky, body length, muzzle length, and wrist girth were the effective predictors of body weight. For Algerian Sloughi, height at withers was the principal and only predictive variable of body weight. In German Shepherd, body weight could be adequately predicted using height at withers, head width, and chest girth. These equations explained 86.5%, 82.9%, 74.7%, and 96.7% of the total variance in body weight for each breed, respectively. The tolerance statistics, variance inflation factors, and Durbin-Watson statistics for these final models indicate that there were no issues with multicollinearity. Height at withers was identified as a universal predictive variable for Belgian Shepherd Malinois, Algerian Sloughi, and German Shepherd, as it was included in the models for these breeds.

To assess the accuracy of the linear regression models for each breed, Lin's Concordance Correlation Coefficient was used, as shown in (Figure 2).

According to the results shown in (Figure 2), the models for Belgian Shepherd Malinois and Siberian Husky exhibit moderate concordance, with Lin's concordance coefficients of 92.90% and 91.10%, respectively. In Algerian Sloughi, the model showed poorer performance, with a Lin's concordance coefficient of 85.70%. Finally, the model for German Shepherd demonstrated substantial concordance, with a coefficient of 98.40%. The evaluation of each

model's quality was guided by the strength-of-agreement criteria proposed by Lin (McBride, 2005).



**Figure 2.** Concordance Correlation Coefficient of Observed vs. Predicted Body Weight in Each Breed.

Separate models were developed for each breed and gender group to estimate weight from body measurements. The coefficients of determination ( $R^2$ ) and Lin's concordance coefficients were analyzed to determine whether they increased or decreased, as shown in (Table 3) and (Figures 3, 4, 5, and 6).

The regression analysis presented in (Table 3) shows that for female Belgian Shepherd Malinois, live weight could be estimated using two independent variables: height at withers and wrist girth. In males, only height at withers was the principal predictive variable. For Siberian Husky, three predictive variables were used to estimate body weight: in females, these were height at withers, chest girth, and abdominal girth; while in males, height at withers, body length, and muzzle length were the principal predictive variables.

In Algerian Sloughi, four independent variables were used to predict body weight in both males and females. For females, the final model included height at withers, height at rump, head length, and head girth. In males, the final model comprised height at withers, height at rump, muzzle length, and chest girth. Finally, for German Shepherd, the females' final model included three independent variables: height at withers, head girth, and ears length. In males, the final model comprised four variables: height at withers, head width, muzzle length, and chest girth. These models explained a total variance of 78.5% and 74.2% in females and males of Belgian Shepherd Malinois, 68.6% and 80.5% in females and males of Siberian Husky, 65.8% and 74.9% in females and males of Algerian Sloughi, and 90.1% and 99.6% in females and males of German Shepherd, respectively. The tolerance statistics, variance inflation factors, and Durbin-Watson statistics for these final models suggest that there was no problem with multicollinearity.

Height at withers can be suggested as a universal predictive variable, as it is present in all separate models. Muzzle length can also be suggested as an indicator of live weight in males of Siberian Husky, Algerian Sloughi, and German Shepherd, as it is one of the main components of the models obtained for males in these breeds.

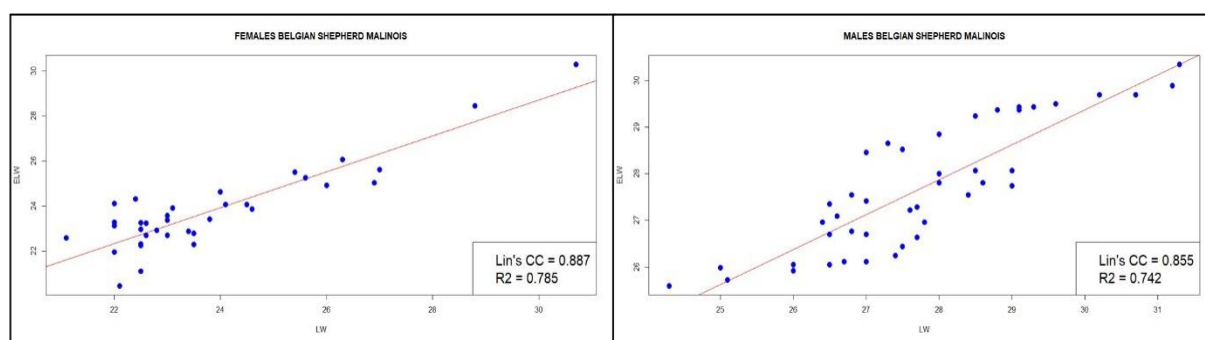
The coefficient of determination ( $R^2$ ) and Lin's concordance coefficient (Lin's CC) were used to quantify the quality of each model according to breed and gender, as shown in (Figures 3, 4, 5, and 6).

**Table 3.** Weight Estimation Models According to Breeds and Gender Using Stepwise Regression Analysis

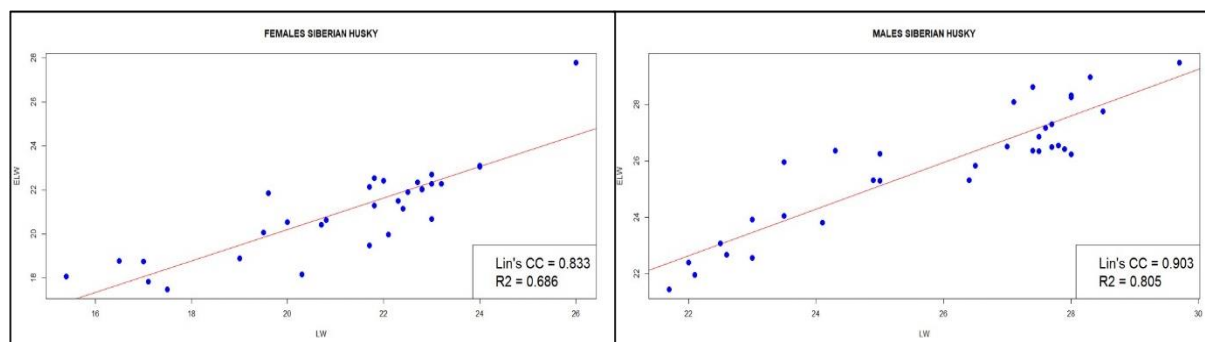
| Breed | Gender | Independent variable | RC±SE           | P-value | Tol   | VIF   | DWS   | P-value | R2    |
|-------|--------|----------------------|-----------------|---------|-------|-------|-------|---------|-------|
| BSM   | F      | Intercept            | -27.201 ± 4.782 | <0.001  | --    | --    |       |         |       |
|       |        | HW                   | 0.818 ± 0.090   | <0.001  | 0.800 | 1.248 | 1.882 | >0.05   | 0.785 |
|       |        | WG                   | 0.299 ± 0.141   | <0.05   | 0.800 | 1.248 |       |         |       |
|       | M      | Intercept            | -12.619 ± 3.606 | <0.01   | --    | --    | 2.135 | >0.05   | 0.742 |
|       |        | HW                   | 0.651 ± 0.058   | <0.001  | --    | --    |       |         |       |
|       |        |                      |                 |         |       |       |       |         |       |
| SH    | F      | Intercept            | -33.460 ± 7.019 | <0.001  | --    | --    |       |         |       |
|       |        | HW                   | 0.361 ± 0.106   | <0.01   | 0.630 | 1.581 | 1.763 | >0.05   | 0.686 |
|       |        | CG                   | 0.333 ± 0.091   | <0.01   | 0.960 | 1.037 |       |         |       |
|       |        | AG                   | 0.293 ± 0.098   | <0.01   | 0.650 | 1.549 |       |         |       |
|       | M      | Intercept            | -22.183 ± 4.338 | <0.001  | --    | --    |       |         |       |
|       |        | HW                   | 0.360 ± 0.152   | <0.05   | 0.160 | 6.152 | 1.781 | >0.05   | 0.805 |
|       |        | BL                   | 0.284 ± 0.144   | >0.05   | 0.170 | 5.733 |       |         |       |
|       |        | ML                   | 0.726 ± 0.297   | <0.05   | 0.820 | 1.219 |       |         |       |
|       |        |                      |                 |         |       |       |       |         |       |
|       |        |                      |                 |         |       |       |       |         |       |
| SLG   | F      | Intercept            | -0.561 ± 0.411  | >0.05   | --    | --    |       |         |       |
|       |        | HW                   | 0.500 ± 0.097   | <0.001  | 0.170 | 6.019 |       |         |       |
|       |        | HR                   | -0.163 ± 0.096  | >0.05   | 0.160 | 6.306 | 1.809 | >0.05   | 0.658 |
|       |        | HL                   | 0.349 ± 0.165   | <0.05   | 0.460 | 2.161 |       |         |       |
|       |        | HG                   | -0.313 ± 0.111  | <0.01   | 0.480 | 2.090 |       |         |       |
|       |        |                      |                 |         |       |       |       |         |       |
|       | M      | Intercept            | -39.446 ± 6.123 | <0.001  | --    | --    |       |         |       |
|       |        | HW                   | 0.591 ± 0.125   | <0.001  | 0.330 | 2.997 |       |         |       |
|       |        | HR                   | 0.211 ± 0.114   | >0.05   | 0.290 | 3.499 | 2.177 | >0.05   | 0.749 |
|       |        | ML                   | -0.362 ± 0.197  | >0.05   | 0.730 | 1.378 |       |         |       |
|       |        | CG                   | 0.106 ± 0.051   | <0.05   | 0.940 | 1.062 |       |         |       |
|       |        |                      |                 |         |       |       |       |         |       |
| GS    | F      | Intercept            | -58.682 ± 9.136 | <0.001  | --    | --    |       |         |       |
|       |        | HW                   | 1.235 ± 0.149   | <0.001  | 0.309 | 3.229 | 1.600 | >0.05   | 0.901 |
|       |        | HG                   | 0.623 ± 0.319   | >0.05   | 0.340 | 2.937 |       |         |       |
|       |        | EL                   | -0.973 ± 0.428  | <0.05   | 0.830 | 1.201 |       |         |       |
|       | M      | Intercept            | -68.118 ± 1.202 | <0.001  | --    | --    |       |         |       |
|       |        | HW                   | 0.990 ± 0.052   | <0.001  | 0.100 | 9.728 |       |         |       |
|       |        | HEW                  | 1.326 ± 0.114   | <0.001  | 0.220 | 4.610 | 1.846 | >0.05   | 0.996 |
|       |        | ML                   | 0.352 ± 0.126   | <0.01   | 0.230 | 4.442 |       |         |       |
|       |        | CG                   | 0.304 ± 0.026   | <0.001  | 0.300 | 3.334 |       |         |       |
|       |        |                      |                 |         |       |       |       |         |       |

*F* : females, *M* : males, *RC* : regression coefficient, *SE* : standard error, *Tol* : tolerance, *VIF* : variance inflation factor, *DWS* : Durbin-Watson statistics, *R2* : coefficient of determination, *BSM*: Belgian Shepherd Malinois, *SH*: Siberian Husky, *SLG*: Algerian Sloughi, *GS*: German Shepherd.

The results presented in (Figure 3) show that in both female and male Belgian Shepherd Malinois, both  $R^2$  and Lin's CC decreased compared to the general model shown in (Figure 2). Specifically,  $R^2$  values were 78.5% for females and 74.2% for males, compared to 86.5% in the general model. Lin's CC in the general model was 92.9%, while it was 88.7% for females and 85.5% for males in the separate models. We can deduce that the separate models according to breed and gender are less effective compared to the general model. Therefore, it is preferable to use the general model for predicting body weight in both female and male Belgian Shepherd Malinois.

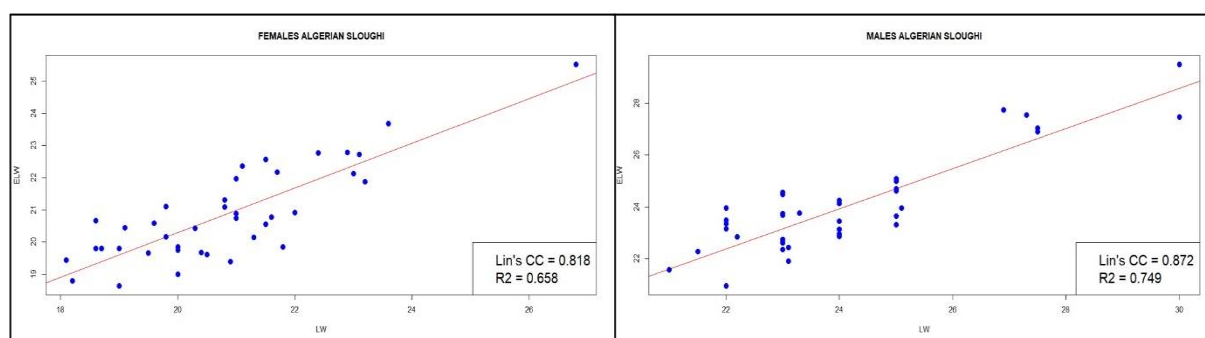


**Figure 3.** Concordance Correlation Coefficient of Observed vs. Predicted Live Weight in Female and Male Belgian Shepherd Malinois



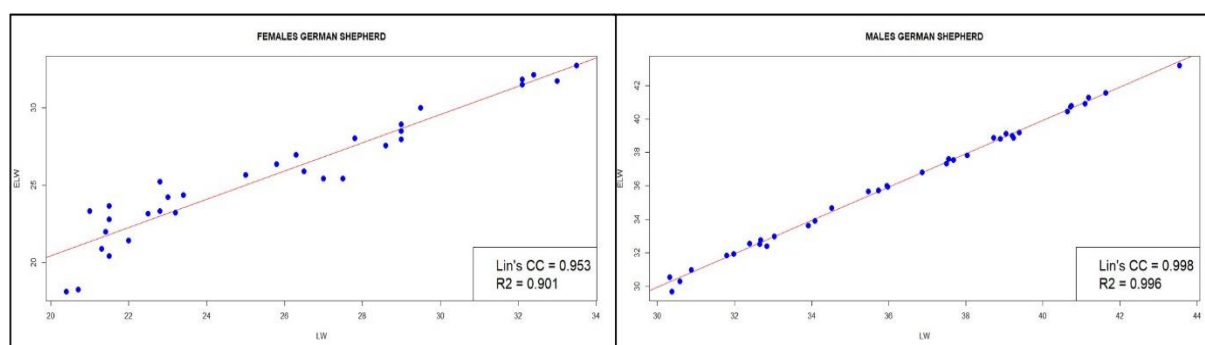
**Figure 4.** Concordance correlation coefficient of observed vs predicted live weight in females and males Siberian Husky

The results of (Figure 4) show that both  $R^2$  and Lin's CC decreased in both female and male Siberian Huskies compared to the general model presented in (Figure 2). In the general model,  $R^2$  and Lin's CC were 82.9% and 91.1%, respectively. In the separate models, females and males Siberian Huskies had  $R^2$  values of 68.6% and 80.5%, respectively, while Lin's CC values were 83.3% and 90.3%, respectively. Therefore, it is better to use the general model rather than the separate models to estimate live weight in Siberian Huskies, as it provides higher values for both  $R^2$  and Lin's CC and a higher degree of accuracy.



**Figure 5.** Concordance correlation coefficient of observed vs predicted live weight in females and males Algerian Sloughi

We can see from the results in (Figure 5) that in female Algerian Sloughi, both  $R^2$  and Lin's CC decreased compared to the general model (Figure 2). The  $R^2$  value was 74.7% in the general model versus 65.8% in the separate model, and Lin's CC was 85.7% in the general model versus 81.8% in the separate model. In males Algerian Sloughi, however, there was a slight increase in both  $R^2$  and Lin's CC. The  $R^2$  value was 74.7% in the general model and increased to 74.9% in the separate model, while Lin's CC improved from 85.7% to 87.2%. Thus, it is suggested to use the general model for estimating body weight in female Algerian Sloughi and the separate model for males Algerian Sloughi.



**Figure 6.** Concordance correlation coefficient of observed vs predicted live weight in females and males German Shepherd

(Figure 6) shows that in female German Shepherds, both  $R^2$  and Lin's CC values decreased compared to the general model presented in (Figure 2), with  $R^2$  being 90.1% and Lin's CC being 95.3% versus 96.7% and 98.4%, respectively. Conversely, in males, both  $R^2$  and Lin's CC values increased compared to the general model, with  $R^2$  being 99.6% and Lin's CC being 99.8% versus 96.7% and 98.4%, respectively. Similar to the Algerian Sloughi case, it is recommended to use the general model for estimating body weight in female German Shepherds and the separate model for males.

In this study, prediction equations were developed specifically for Belgian Shepherd Malinois, Siberian Husky, Algerian Sloughi, and German Shepherd breeds. Similar findings were observed in Nigerian native dogs (Emehelu et al., 2012), where the strongest correlation was found between live weight and chest circumference. For Zerdava dogs, weight predictions relied on wither height, chest width, chest circumference, and head length, while Zağar dogs used body length, chest width, chest circumference, rear cannon bone circumference, and ear spacing as predictors. In Çatalburun dogs, live weight could be predicted from withers height, body length, and chest circumference (Özkul et al., 2021).

On the other hand, Valdez and Valencia (2004) found in Philippine native dogs that all body measurements were positively correlated with body weight, with chest circumference being the strongest predictor across both sexes ( $R^2 = 0.468$ ). In contrast, Elmaz et al. (2006) identified ear length as the most significant predictor of live weight in German Shepherds at the Gemlik Military Veterinary School. Additionally, Çelik and Yilmaz (2018) demonstrated that 68% and 91% of the variation in live weight and morphometric measurements in Turkish Tazi dogs could be explained using classification and regression tree (CART) and multivariate adaptive regression splines (MARS) methods.

## Conclusion

In this study conducted in Algeria, the models developed to predict the live weight of Belgian Shepherd Malinois, Siberian Husky, Algerian Sloughi, and German Shepherd dogs using specific body measurements proved to be quite effective. Height at withers consistently emerged as a key predictor across all breeds and genders, indicating its strong relevance in estimating live weight. For example, the general models, which included height at withers along with other important measurements, demonstrated higher accuracy compared to breed-specific models. This trend was evident as the general model outperformed the separate models in predicting live weight for Belgian Shepherd Malinois and Siberian Husky, with the general model being more reliable than the breed-specific ones.

The accuracy of the models varied among breeds and genders. For Algerian Sloughi, the general model provided better overall predictions compared to separate models for females and males. In contrast, the German Shepherd models showed that while the general model was highly accurate, separate models for males provided even better predictions than the general model. This indicates that while general models offer broad applicability, specific models tailored to individual breeds and genders can enhance prediction accuracy.

Overall, the study highlights the importance of specific body measurements, especially height at withers, in predicting live weight and guiding breeding practices. These findings can be used to refine selection criteria and improve breeding strategies by focusing on the most indicative morphological traits. Future research could build on these results to further enhance prediction models and tailor them to the needs of specific breeds and gender groups.

## References

- AKC breeds nomenclature 2022.** American Kennel Club website. Available at: <https://images.akc.org/pdf/breeds/standards/Sloughi.pdf>.
- Cecchi F. Paci G. Spaterna A. Ciampolini R 2015.** Genetic variability in Bracco Italiano dog breed assessed by pedigree data. *Ital J Anim Sci*, 12:348–352.
- Çelik S. Yilmaz O 2018.** Prediction of body weight of Turkish Tazi dogs using data mining techniques: classification and regression tree (CART) and multivariate adaptive regression splines (MARS),” *Journal of Zoology*, vol. 50, no. 2, pp. 575–583.
- Deabold K. Harriz J. Madeiros B. Davies W. Shmalberg J. Miscioscia E 2023.** Inter- and intra-observer reliability of thoracic limb circumference measurement methods in sound dogs. *Front. Vet. Sci.* 10:1172033. 01-07.
- Djaout A. Belharfi FZ. Kourichi A. Larabi N. Benidir M. Gaouar SBS 2022.** Morphometric assessment and physico-chemical description of the milk of Arbia goat breed in province of Tlemcen. *Genetics & Biodiversity Journal*, 6(2), 143–158.
- Elmaz O. Aksoy OA. Dikmen S. Zonturlu A 2006.** Growth performance, survival ratio and body measurements until weaning age of German Shepherd dog. *World Small Animal Veterinary Association, Proc. 31st World Congress, Prague, Czech Republic*.
- Emehelu CO. Eze JI. Akune A. Chah KF 2012.** Estimation of Live Body Weight From Body Measurements in Nigerian Local Dogs. *African Journals Online* 30(2): 65-73.
- González A. Luque M. Rodero E. González C. Aguilera R. Jiménez J. Sepúlveda N. Bravo S. Herrera M 2011.** Use of morphometric variables for differentiating Spanish hound breeds, *International Journal of Morphology*, 29, 1248–1255.
- Haddam HY. Mennani A. Hamel W. Benhamadi MEA. Gaouar SBS 2021.** Morphological characterization of an Algerian Sighthound known as The Sloughi raised in the Wilaya of Tlemcen, Northwest of Algeria. *Gen. Biodiv. J*:5 (1): 74-86.
- Haddam HY. Mennani A. Yilmaz O. Abdelbari H. Mkedder I. Benhamadi MEA. Hamel W. Gaouar SBS 2024b.** The first morphological study of the Sloughi dog breed in Algeria. *South African Journal of Animal Science.*, 54(2): 135-46. (DOI: 10.4314/sajas.v54i1.15).
- Haddam HY. Zenagui M. Hasnaoui I. Mkedder I. Gaouar SBS 2024a.** Morphometric comparative study between Algerian Sloughi and Galgo cross Sloughi dogs raised in north west of Algeria and body weight estimation using morphometric traits. *Genet. Biodiv. J*, 2024; 8 (1): 31-41.
- McBride, G. B. 2005.** A proposal for strength-of-agreement criteria for Lin’s concordance correlation.
- McCarthy DA. Millis DL. Levine D. Weigel JP 2018.** Variables Affecting Thigh Girth Measurement and Observer Reliability in Dogs. *Front. Vet. Sci.* 5:203. 01-08.
- Meghelli I. Kaouadji Z. Yilmaz O. Cemal I. Karaca O. Gaouar SBS 2020.** Morphometric characterization and estimating body weight of two Algerian camel breeds using morphometric measurements, *Tropical Animal Health and Production*, 52, 2505–2512.
- Official website of the International Cynological Federation** (<https://www.fci.be/fr/Nomenclature/Default.aspx>).
- Oğrak YZ. Yoldaş A. Urosevic M. Drobnjak D 2014.** Some morphological traits of Tarsus Çatalburun breed of Turkish hunting dog. *Eurasian Journal of Veterinary Sciences*, 1, 25-29.

- Özkul BY, Doka PCK, Özen D, Özbaşer FT, Özarslan B, Atasoy F 2021.** Correlation between live weight and body measurements in certain dog breeds. South African Journal of Animal Science 2021, 51 (No. 2): 151-159.
- R Core Team 2023.** R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria. <<https://www.R-project.org/>>.
- Thuller M, Jangarelli M, Couto D, Araújo A 2015.** Sexual dimorphism of Labrador retriever dogs by morphometry. Bioscience Journal 31, 1475–87.
- Traoré A, Tamboura H, Kaboré A, Royo L, Fernández I, Álvarez I, Sangaré M, Bouchel D, Poivey J, Francois D, Toguyeni A, Sawadogo L, Goyache F 2008.** Multivariate analyses on morphological traits of goat in Burkina Faso. Archiv. Tierzucht, 6 :588-600.
- Urosevic M, Drobnjak D, Stojic P, Oğrak YZ 2020b.** Morphometric Characterization of the Akbaş (Akbash) Turkish Shepherd Dog. Turkish Journal of Agriculture - Food Science and Technology, 8(7): 1571-1576.
- Urosevic M, Drobnjak D, Vlaeva R, Stanišić G, Mandić R, Grittner N, Dameski P 2022.** Correlation of morphological parameters of donkey from Austria. VETERINARSKA STANICA 53 (2), 185-199.
- Urosevic M, Matejevic M, Drobnjak D, Ozkanal U 2020a.** Use of Morphometric Variables for Differentiating Breed Variations in Turkish Tazi (Sighthound) Population. Pakistan J. Zool., 52:1765-1770.
- Valdez CA, Valencia JPL 2004.** Weight prediction in medium to large sized adult Philippine native dogs using external body measurements. Philippine J. Vet. Anim. Sci. 30(1): 161-169.
- Yilmaz O, Cemal I, Karaca O 2013.** Estimation of mature live weight using some body measurements in Karya sheep. Trop. Anim. Heath Prod. 45: 397–403.
- Yilmaz O, Ertuğrul M 2011.** Some morphological characteristics of Turkish Tazi (Sight Tazi). J. Anim. Pl. Sci., 21: 794-799.