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Original Research Paper

Morphometric comparative study between Algerian Sloughi and Galgo cross Sloughi dogs raised in north west of Algeria and body weight estimation using morphometric traits

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Abstract

The aim of this study is to compare between the Algerian Sloughi dog breed and the Spanish Galgo cross Sloughi raised in the northwest of Algeria and establish mathematical formulas that will allow us to estimate the live weight of dogs based on body measurements in both breeds. Sixteen body measurements, live weight and ten body indexes (cephalic, format, bone, massiveness, head/neck, head/muzzle, tail/body, profile, head length/ears and head width/ears) were used to compare between the studied dogs. 58 Sloughi (34 males and 24 females) and 51 Galgo cross Sloughi (40 males and 11 females) were studied, dogs were adults and unrelated. The effect of breed on body measurements, weight and body indexes was assessed using t-test, the effect of sex on body measurements, weight and body indexes was assessed using the t-test too. Pearson's correlation was used to identify linear relationship among the different body measurement and body weight, Among the obtained multiple regression models, the highest coefficients of determination (R^2) were obtained from the models formed of height at withers, tail length, neck length and head girth in all dogs (R^2 =0.640), the model formed of height at withers and ears length in Sloughi dog (R^2= 0.730) and the model formed of head girth, chest girth and abdominal girth in Galgo cross Sloughi dogs (R^2= 0.712). This study concluded that live weight of Algerian Sloughi and Galgo cross Sloughi dogs could be estimated with a high accuracy using some body measurements and statistical methods.

Keywords: Algeria, breed, comparison, estimation, Galgo, morphometric, live weight, Sloughi.

ملخص:

الهدف من هذه الدراسة هو المقارنة بين سلالة كلاب السلوقي الجزائرية وكلاب القالقو الاسبانية كروس سلوقي التي تربى في شمال غرب الجزائر ووضع صيغ رياضية تسمح لنا بتقدير الوزن الحي للكلاب بناء على قياسات الجسم في كلا السلالتين. تم استخدام ستة عشر قياسًا للجسم والوزن الحي وعشرة مؤشرات للجسم (الرأسي، الشكل، العظام، الضخامة، الرأس/العنق، الرأس/الكمامة، الذيل/الجسم، المظهر الجانبي، طول الرأس/الأذنين وعرض الرأس/الأذنين) للمقارنة بين المدروسين. كلاب. تمت دراسة 58 كلب سلوقي (34 ذكرًا و24 أنثى) و51 كلبًا القالقو كروس سلوقي (40 ذكرًا و11 أنثى)، وكانت الكلاب بالغة وغير مرتبطة. تم تقييم تأثير السلالة على قياسات الجسم والوزن ومؤشرات الجسم باستخدام اختبار t، كما تم تقييم تأثير الجنس على قياسات الجسم والوزن ومؤشرات الجسم باستخدام اختبار t أيضًا. تم استخدام ارتباط بيرسون لتحديد العلاقة الخطية بين قياسات الجسم المختلفة ووزن الجسم، ومن بين نماذج الانحدار المتعددة التي تم الحصول عليها تم الحصول على أعلى معاملات التحديد (R^2) من النماذج المتكونة من الارتفاع عند الذراعين وطول الذيل وطول الرقبة ومحيط الرأس عند جميع الكلاب ($R^2 = 0.640$)، النموذج المتكون من الارتفاع عند الذراعين وطول الأذنين في كلب السلوقي ($R^2 = 0.730$) والنموذج المتكون من محيط الرأس ومقاس الصدر ومقاس البطن في كلاب القالقو كروس سلوقي ($R^2 = 0.712$). خلصت هذه الدراسة إلى أنه يمكن تقدير الوزن الحي لكلاب السلوقي الجزائرية والقالقو كروس سلوقي بدقة عالية باستخدام بعض قياسات الجسم والأساليب الإحصائية.

الكلمات المفتاحية: الجزائر، سلالة، مقارنة، تقدير، القالقو، مورفومترية، الوزن الحي، السلوقي.

Introduction

Among the many species of animals that have been domesticated, the dog is probably the first (Clutton-Brock, 1995). The principal dog's ancestor is certainly the grey wolf according to the important percentage of 98% of mitochondrial DNA shared between them (Vila *et al.*, 1997).

Nowadays, we know more than 400 dog breeds recognized by the different dog societies as the AKC (American Kennel [1]),the FCI (Fédération Cynologique Internationale[2]) and the SCC (Société Centrale Canine [3]). Some breeds are very ancient like the saluki that appears in the Fertile Crescent area of Mesopotamia from the Sumerian period around 7000–6000 years BP. Many breeds were famous in Ancient Egypt (3,000 years BP) where they were used for hunting, as police guards or watch dogs and in military actions (Galibert*et al.,* 2011). Crossbreeding in dogs which means create individuals breeding two purebred dogs of different breeds is the key of the apparition of many breeds in the last centuries, like the Dobermann, these dogs, partly the ancestors of today's Rottweiler, were crossed with a kind of shepherd dog with a black and tan coat which existed in Thuringia. It was through such crosses that Dobermann bred dogs in the 70s of the 19th century (Standard FCI N° 143), or the Dogo Argentino who came from crosses between Mastiffs, Bulldogs and Bull Terriers (Standard-FCI N° 292).

In Algeria, crossbreeding is very practiced among hunting dogs' breeders, they use Sloughis, Spanish Galgo, English greyhound, Podenco and other dog breeds for hunting hares, wild boar, jackals and gazelle, and big antelope species. However, they considered dogs issued from crossing Spanish Galgo and Sloughi more suitable for hunting big game because these individuals would have very developed hunting abilities, in other words, these dogs may have the advantage of heterosis, or crossbreed vigor, unfortunately, the purebred dogs tend to gradually disappear and especially the Sloughi which is the first victim of these anarchic and uncontrolled crossings.

Thus, carrying out work on the morphometry of dog populations in Algeria would be very beneficial for establishing a morphological profile and studying the different variations at the phenotypic level. The aim of this study was a morphological comparison between Sloughi and Galgo cross Sloughi in order to identify the principal differences between them and also identify body measurements which could have an impact on the dog's weight, which will allow us to establish mathematical formulas depending on the dog breed.

Materials and methods

Study area

The study was done in three bordered stats of northwest of Algeria (Ain Temouchent, Tlemcen, and Sidi Belabbes), these stats are very known for their high concentration of breeders of hunting dogs and especially Sloughis and sighthounds such as the Spanish Galgo, the English greyhound and the Podenco. The studied areas are represented by three different colours as shown in figure 1, the geographic map was created using the *mapchart* online application [4].

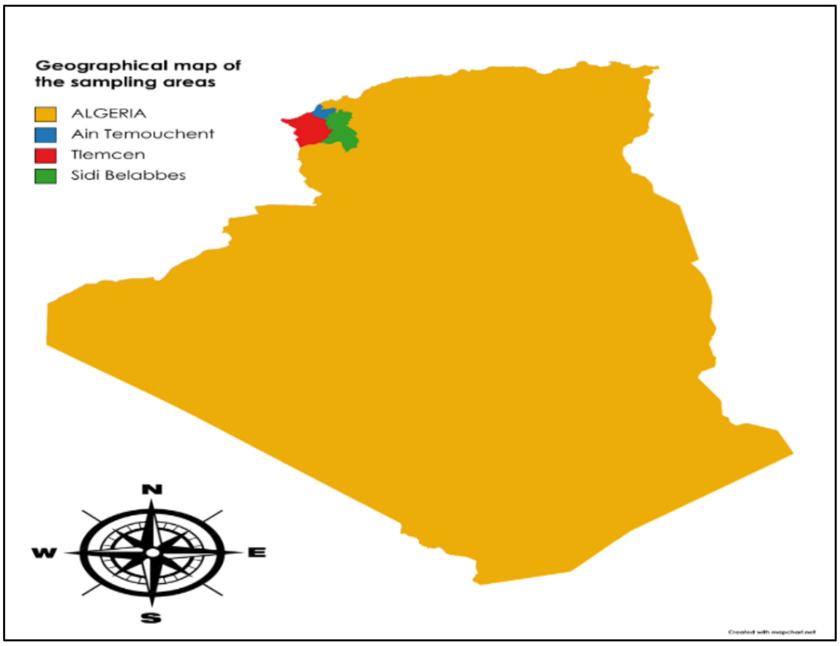

Figure 1. Geographical map of Algeria and the sampling areas

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Animal sampled

109 healthy dogs were used in the present study, a total of 58 Sloughi (34 males and 24 females) and 51 Galgo cross Sloughi (40 males and 11 females). The Galgo cross Sloughi individuals are considered as breed in this study just for comparison between two groups (SLG and CGS) and are always dogs resulting from a cross between a male Galgo and a female Sloughi and not between a male Sloughi and a female Galgo. All the dogs used in the present study were adults (between 24 and 36 months), unrelated and healthy. This work was carried out from January 2021 until March 2023. Studied dogs are grouped according to breed, geographical area and sex as mentioned in table 1.

Table 1. The distribution of the studied samples

Geographical Area (State)	Breed and Sex			
	SLG N= 58		GCS N= 51	
	M	F	M	F
Ain Temouchent	5	6	19	5
Tlemcen	17	9	6	2
Sidi Belabbes	12	9	15	4

SLG: Sloughi; GCS: Galgo cross Sloughi; N: number of samples; M: Males; F: Females

Figure 2. Example of Galgo cross Sloughi (Left) and Pure Algerian Sloughis (Right) (Original photos)

Morphometric variables

As shown in figure 3 below, we used sixteen body measurements which are height at withers (HW), height at rump (HR), body length (BL), tail length (TL), neck length (NL), head length (HL), head width (HeW), ears length (EL), muzzle length (ML), muzzle girth (MG), head girth (HG), chest girth (CG), forearm girth (FG), wrist girth (WG), abdominal girth (AG), thigh girth (TG), and live weight (LW). A measuring rod was used to measure HW and RH, a calliper to measure HL and HeW and finally a tape measure for all remaining measurements. The dogs were weighed using an electronic scale with 100g precision.

Body indices were calculated using the following formula:

- Cephalic Index (CI) = $\frac{HeW}{HL} * 100$
- Head-Muzzle Index (HMI) = $\frac{ML}{HL} * 100$
- Format Index (FI) = $\frac{BL}{HW} * 100$
- Tail-Body Index (TBI) = $\frac{TL}{BL} * 100$

- Bone Index (BI) = $\frac{WG}{HW} * 100$
- Profile Index (PI) = $\frac{HW}{HR} * 100$
- Massiveness Index (MI) = $\frac{CG}{HW} * 100$
- Ear-Head Length Index (EHLI) = $\frac{EL}{HL} * 100$
- Head-Neck Index (HNI) = $\frac{HL}{NL} * 100$
- Ear-Head Width Index (EHWI) = $\frac{EL}{HeW} * 100$

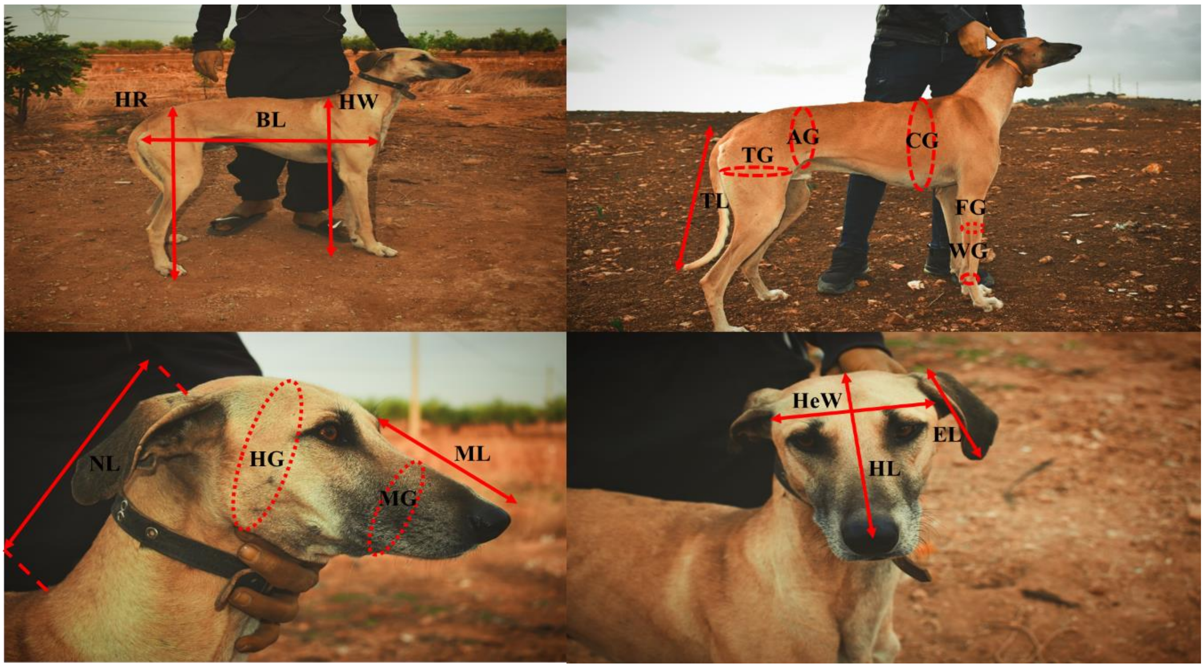

Figure 3. Body measurements used in this study

The calculation of these body indices was inspired by other works on dogs' morphology (Drobnjak *et al.,* 2010, Oğrak *et al.,* 2014) and official standards established by word canine organizations (FCI & AKC) especially for CI, FI, BI, MI, HNI, HMI, TBI and PI.

For EHLI and EHWI, we used breeders' statements as reference, during purebred Sloughi selection some of them use the proportion value between head length and ears length that should equal approximatively 0.5 and the proportion value between head width and ears length that should be close to 1.

Statistical analysis

All the statistical analysis of the present study were made using R-software 4.3.1 for Windows. Descriptive statistics were made using *psych* package. Before applying the parametric tests, the distribution of the data was verified using Kolmogorov-Smirnov test, the variables were normally distributed. The impact of breed on body measurements, live weight and body indices was determined using a t-test for independent samples, another t-test for independent samples was used to check the effect of sex on body measurements, live weight and body indices. The phenotypic correlations between variables were calculated using Pearson's correlation test in order to determine the strength and direction of the relationship between variables, this test was presented by a heatmap for all the studied dogs and for each breed separately using *metan* package. Backward stepwise multiple linear regression using several packages in R (*tidyverse*, *caret*, *leaps* and *MASS*) was used to estimate the live weights of the dogs using some body measurements. Finally, the estimation's equations for live weights were obtained with multiple linear regression analysis using some body measurements according to breed groups (separated models) and stepwise multiple regression. Tolerance and the variance inflation factor were used using *car* and *olsrr* packages to assess collinearity among the predictor variables. Durbin-Watson statistics were used to check the presence of autocorrelation.

Results and discussion

In table 2, means, standard error, standard deviation, minimum, maximum and the coefficient of variation of body measurements, live weight and body indices are presented according to breed. The effect of breed on body measurements, live weight and body indices is also presented by probability value.

Table 2. Descriptive analysis of the two studied breeds and the effect of breed on body measurements and zoometric indices

Breed	SLG N=58					GCS N=51					
Variables	M ± SE	SD	Min	Max	CV	M ± ES	SD	Min	Max	CV	p-value
HW	71.40±0.57	4.33	61.10	79.30	6.06	65.79±0.66	4.70	56.6	77.20	7.14	***
HR	70.34±0.58	4.41	60.40	78.20	6.27	64.50±0.65	4.65	54.4	77.40	7.21	***
BL	68.20±0.60	4.57	57.60	75.30	6.70	67.53±0.77	5.52	51.00	80.40	8.17	ns
TL	42.15±0.52	3.94	34.30	51.70	9.35	46.79±0.74	5.31	30.60	57.10	11.35	***
NL	20.74±0.25	1.87	16.30	24.30	9.02	25.23±0.37	2.63	18.50	34.00	10.42	***
HL	24.69±0.23	1.78	20.40	28.80	7.21	22.09±0.37	2.64	17.00	27.10	11.95	***
HeW	12.75±0.11	0.82	10.80	14.50	6.43	13.87±0.29	2.04	10.00	18.20	14.71	***
EL	12.70±0.17	1.27	9.80	15.40	10.00	10.87±0.18	1.25	7.30	13.00	11.50	***
ML	10.90±0.16	1.19	8.10	14.20	10.92	11.48±0.12	0.89	9.60	13.30	7.75	**
MG	21.43±0.23	1.74	17.20	25.70	8.12	18.48±0.23	1.65	15.20	23.00	8.93	***
HG	32.70±0.34	2.59	26.10	38.70	7.92	35.23±0.38	2.69	30.40	43.00	7.64	***
CG	71.25±0.68	5.21	55.10	80.50	7.31	69.65±0.67	4.78	58.50	80.50	6.86	ns
FG	14.58±0.16	1.22	11.80	17.60	8.37	13.12±0.29	2.08	8.50	16.00	15.85	***
WG	10.83±0.15	1.12	8.40	13.40	10.34	10.29±0.18	1.28	8.00	13.50	12.44	*
AG	45.77±0.73	5.57	35.30	59.10	12.17	46.95±0.62	4.43	38.40	60.20	9.44	ns
TG	34.38±0.39	2.99	27.70	41.10	8.70	36.16±0.45	3.19	26.40	42.20	8.82	**
LW	22.19±0.32	2.44	18.00	28.00	11.00	25.80±0.56	4.02	18.00	35.00	15.58	***
CI	51.72±0.29	2.22	47.86	57.39	4.29	63.50±1.52	10.89	40.74	88.59	17.15	***
FI	95.58±0.57	4.35	86.25	103.89	4.55	102.89±1.17	8.35	78.46	119.46	8.12	***
BI	15.17±0.17	1.30	12.43	17.99	8.57	15.66±0.24	1.72	13.10	19.84	10.98	ns
MI	99.87±0.76	5.75	84.20	113.32	5.76	106.05±0.86	6.17	96.28	124.14	5.82	***
HNI	84.17±0.88	6.74	65.52	100.00	8.01	115.67±2.41	17.24	83.00	158.82	14.90	***
HMI	44.19±0.54	4.12	35.06	57.49	9.32	52.52±0.87	6.19	42.32	65.79	11.79	***
TBI	61.85±0.59	4.51	49.09	70.93	7.29	69.57±1.19	8.48	51.60	90.20	12.19	***
PI	98.53±0.27	2.03	93.69	106.02	2.06	98.05±0.33	2.37	91.43	102.74	2.42	ns
EHLI	51.49±0.58	4.39	39.56	61.69	8.53	49.66±0.91	6.53	30.42	66.67	13.15	ns
EHWI	99.75±1.27	9.66	74.24	122.40	9.68	80.05±2.12	15.11	46.79	118.18	18.88	***

*SLG: Sloughi; GCS: Galgo Cross Sloughi; N: number of samples; M: mean; SE: standard error; SD: standard deviation; Min: minimum; Max: maximum; CV: coefficient of variation; p: probability, *: significant ($p<0.05$); **: highly significant ($p<0.01$); ***: very highly significant ($p<0.001$); ns: not significant ($p>0.05$).*

According to the results reported in Table 1, in Sloughi dog breed the highest coefficient of variation was that of abdominal girth (12.17%) and the lowest was that of profile index (2.06%). In Galgo cross Sloughi the highest coefficient of variation was that of ears-head width index (18.88%) and the lowest was that of profile index (2.42%). We can probably deduce an important variability of the body measurements and body indices with the highest coefficient of variation and a less variability for body measurements and body indices with lower coefficients of variation in both breeds.

The difference between Sloughi and GCS was very highly significant for HW, HR, HL, EL, MG and EHWI with more developed traits in Sloughi, the difference was also significant and in favour of the Sloughi for the WG trait. These differences could be explained by the dominance of the alleles of the male parent (Spanish Galgo) which dominate the alleles of the female parents (Sloughi) in GCS.

For all TL, NL, HeW, HG, CI, FI, HNI, HMI, and TBI the difference was very highly significant, and for ML and TG the difference was highly significant, the GCS's traits were more developed than SLG's traits. GCS's live weight was higher than that of SLG with a very highly significant difference.

There was no significant difference between Sloughi and GCS for BL, CG, AG, BI, MI, PI and EHLI, we can probably deduce that these traits have been preserved in the GCS and therefore we cannot rely too much on them to evaluate the purity of Sloughi such as for example the EHLI, which is widely used as an archaic method in the selection of Sloughi.

These significant differences in favour of GCS can probably be explained by the heterosis or crossbreed vigor effect. So, these differences can be at the origin of the improvement in hunting quality in crossbred dogs.

Crossbreeding in dogs has its advantages and disadvantages, it can give birth to rustic individuals, physically stronger, and more suited to hunting a certain category of game, such as jackals and African golden wolves for example, especially among greyhounds. One of the disadvantages of crossbreeding is the loss of genetic diversity in a breed's gene pool over time, which increases the risk of health problems (Melis *et al*, 2022).The geneticists always claim that the solution for this is crossbreeding that will introduce new diversity into the breed. However, conservative and protective breeders of the Sloughi fear that crossbreeding may improve genetic diversity, but will destroy the breed type.

The results of the effect of sex on body measurements, live weight and body indexes in both breeds are presented in table 3.

Table 3. The effect of sex on body measurements, live weight and body indices in the two studied breeds.

Variables	SLG			GCS		
	M	F	p-value	M	F	p-value
	N=34	N=24		N=40	N=11	
HW	73.97±0.40	67.75±0.79	***	67.02±4,36	61.35±0.87	***
HR	72.81±0.49	66.85±0.79	***	65.54±4.57	60.70±0.78	***
BL	70.26±0.54	65.28±0.97	***	68.26±5.26	64.88±1.77	ns
TL	43.75±0.64	39.89±0.63	***	47.65±4.61	43.68±2.01	ns
NL	21.52±0.26	19.64±0.36	***	25.47±2.80	24.33±0.53	ns
HL	25.52±0.24	23.51±0.32	***	22.53±2.73	20.49±0.45	**
HeW	13.16±0.11	12.18±0.15	***	14.05±2.10	13.23±0.52	ns
EL	13.08±0.23	12.15±0.20	**	11.07±1.23	10.15±0.34	*
ML	11.32±0.18	10.30±0.24	**	11.52±0.89	11.33±0.28	ns
MG	22.27±0.22	20.23±0.33	***	18.89±1.57	17.00±0.29	***
HG	33.87±0.34	31.04±0.50	***	36.03±2.43	32.30±0.31	***
CG	73.47±0.72	68.11±1.02	***	71.13±3.98	64.25±1.02	***
FG	15.15±0.17	13.78±0.22	***	13.51±1.97	11.73±0.57	*
WG	11.19±0.18	10.31±0.21	**	10.57±1.26	9.27±0.22	***
AG	47.61±0.94	43.16±0.95	**	47.67±4.19	44.35±1.35	*
TG	35.57±0.43	32.70±0.59	***	37.21±2.50	32.36±0.74	***
LW	23.53±0.34	20.29±0.34	***	26.85±3.78	22.00±0.66	***
CI	51.64±0.40	51.85±0.43	ns	62.12±11.31	64.88±2.87	ns
FI	95.04±0.75	96.35±0.87	ns	102.09±8.21	105.80±2.59	ns
BI	15.13±0.23	15.22±0.27	ns	15.80±1.81	15.14±0.39	ns
MI	99.35±0.92	100.61±1.29	ns	106.40±6.67	104.76±1.15	ns
HNI	84.47±1.04	83.74±1.58	ns	114.66±18.29	119.35±3.84	ns
HMI	44.43±0.68	43.84±0.90	ns	51.69±6.03	55.56±1.82	ns
TBI	62.27±0.81	61.24±0.86	ns	70.12±7.83	67.58±3.23	ns
PI	98.42±0.35	98.68±0.42	ns	97.80±2.45	98.98±0.56	ns
EHLI	51.27±0.79	51.81±0.85	ns	49.67±6.87	49.64±1.64	ns
EHWI	99.49±1.70	100.11±1.94	ns	80.68±15.89	77.76±3.68	ns

*SLG: Sloughi; GCS: Galgo Cross Sloughi; M: male; F; female; N: number of samples; p: probability; *: significant (p<0.05); **: highly significant (p<0.01); ***: very highly significant (p<0.001); ns: not significant (p>0.05).*

The results reported in table 3 showed that in SLG, there was a difference between males and females for all body measurements and live weight but no difference for body indexes. The difference was very highly significant for all HW, HR, BL, TL, NL, HL, HeW, MG, HG, CG, FG, TG, males were more developed than females. The difference was also very highly significant for LW where males were

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heavier than females too. For EL, ML, WG and AG the difference was highly significant in favour of males.

In GCS, there was no significant difference between sexes for all body indexes, BL, TL, NL, HeW and ML. Otherwise, males GCS were more developed than females where the difference was very highly significant for HW, HR, MG, HG, CG, WG and TG. Males were also heavier than females with p<0.001. Males GCS had a longer head comparing to females where the difference was highly significant. Always the difference was significant in favour of males GCS for EL, FG and AG.

We can deduce that sexual dimorphism is evident in both SLG and GCS for some body measurements and live weight. Referring to many official standards of the FCI (Fédération Cynologique Internationale) and the AKC (American Kennel Club) and also to the numerous studies carried out on different breeds of dogs, we can deduce that this phenomenon is common within the different breeds of dogs. Another study on body measurements in Turkish Tazi revealed that males had more developed measures than females for HW, HR, CG, and BL. The males in this latest study were also heavier than females (Yilmaz & Ertuğrul, 2011). In Tarsus Çatalburun breed of Turkish hunting dogs, males were more developed than females for HW, HR, BL, CG and HL (Oğrak*et al.*, 2014).In the Labrador, a study of sexual dimorphism of Labrador retriever dogs showed that the differences between genders were for HW and BL (Thuller*et al.*, 2015). In the Italian pointing dog (Bracco Iatliano), males had more developed measures than females for all HW, CG, BL, HR and HL (Cecchi *et al.*, 2013). In Turkish Tazi sighthound, males were more developed than females for HW, HR, CG, HL, HEW and BL (Urosevic*et al.*, 2020a). Finally, in the Akbash Turkish Shepherd dogs, the difference between the genders was for HW, HL and the back height, where males had more developed body measurements than females (Urosevic*et al.*, 2020b).

The phenotypic correlation coefficients between weight and body measurements among all studied dogs, SLG and GCS separately are represented by figure 4, figure 5 and figure 6 respectively.

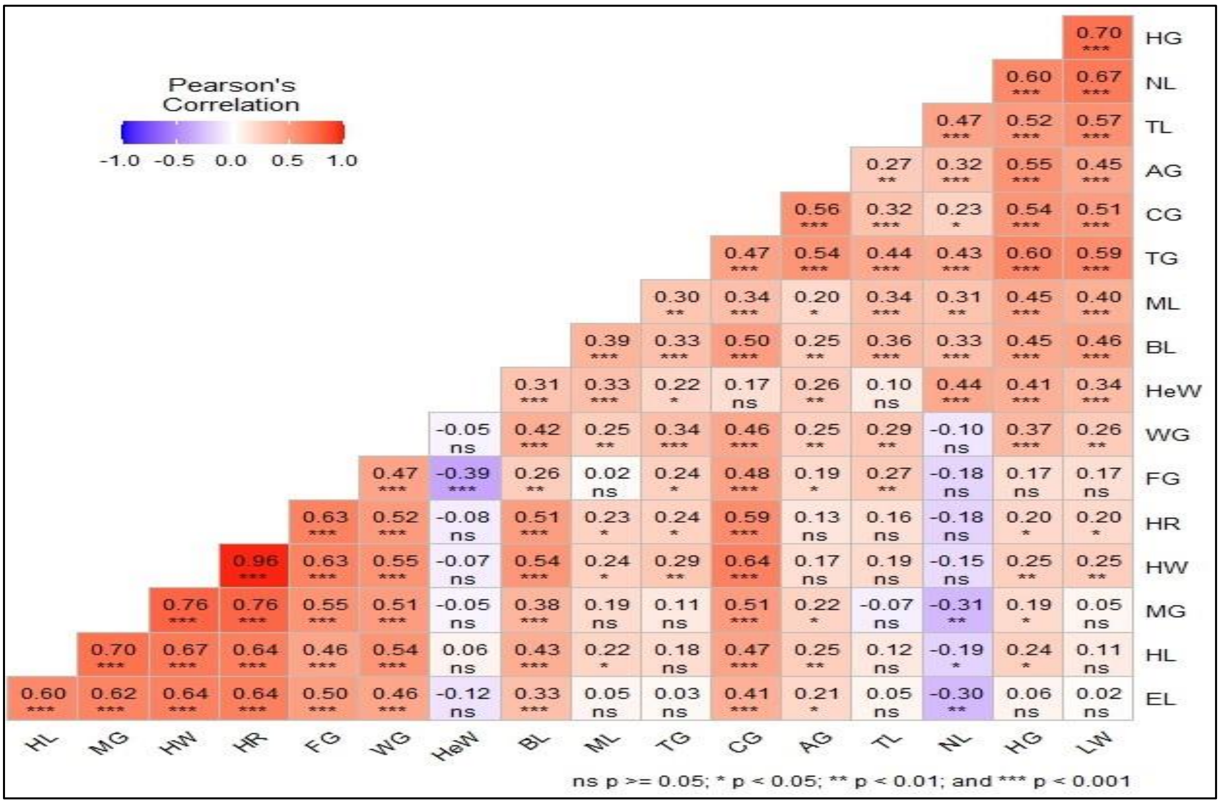

Figure 4. Heat map of Pearson's correlations between body measurements in all the studied dogs

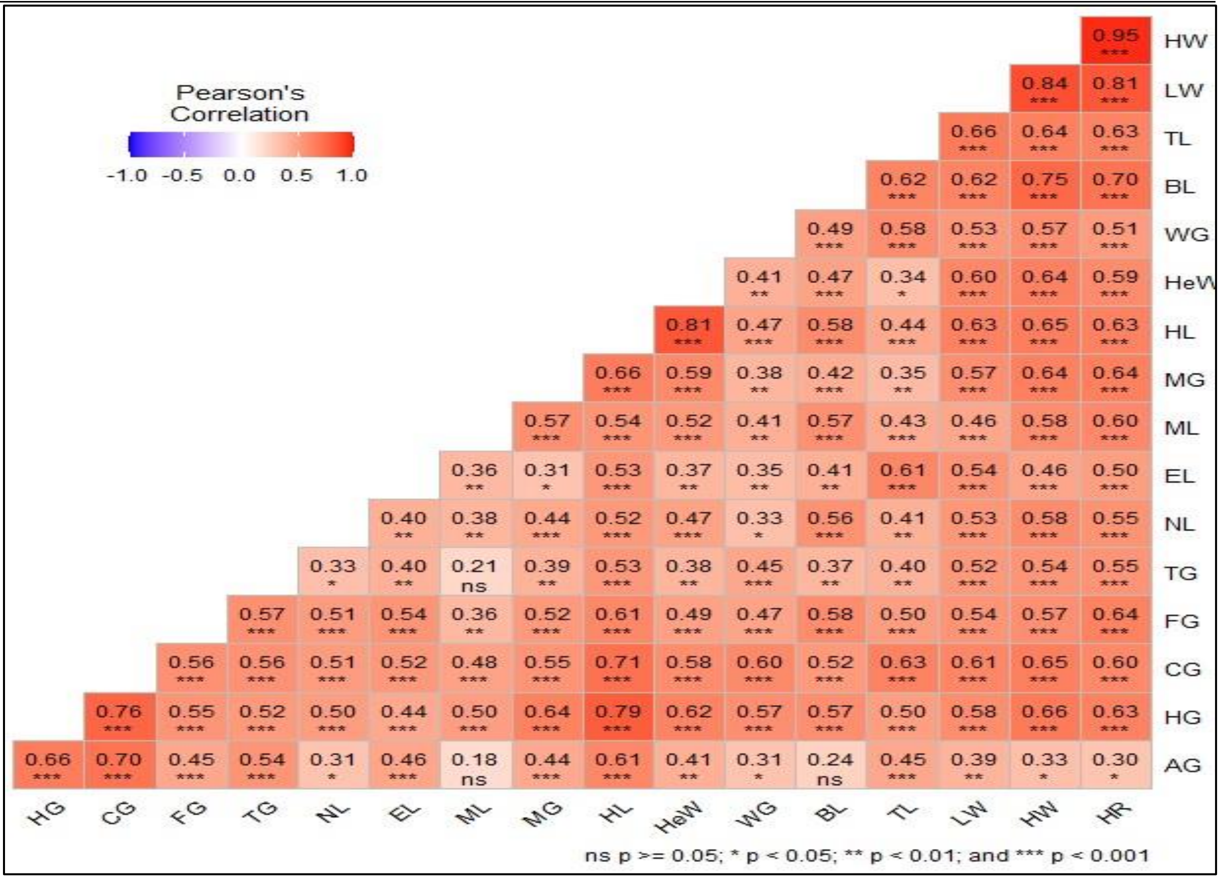

Figure 5. Heat map of Pearson's correlations between body measurements and live weight in SLG

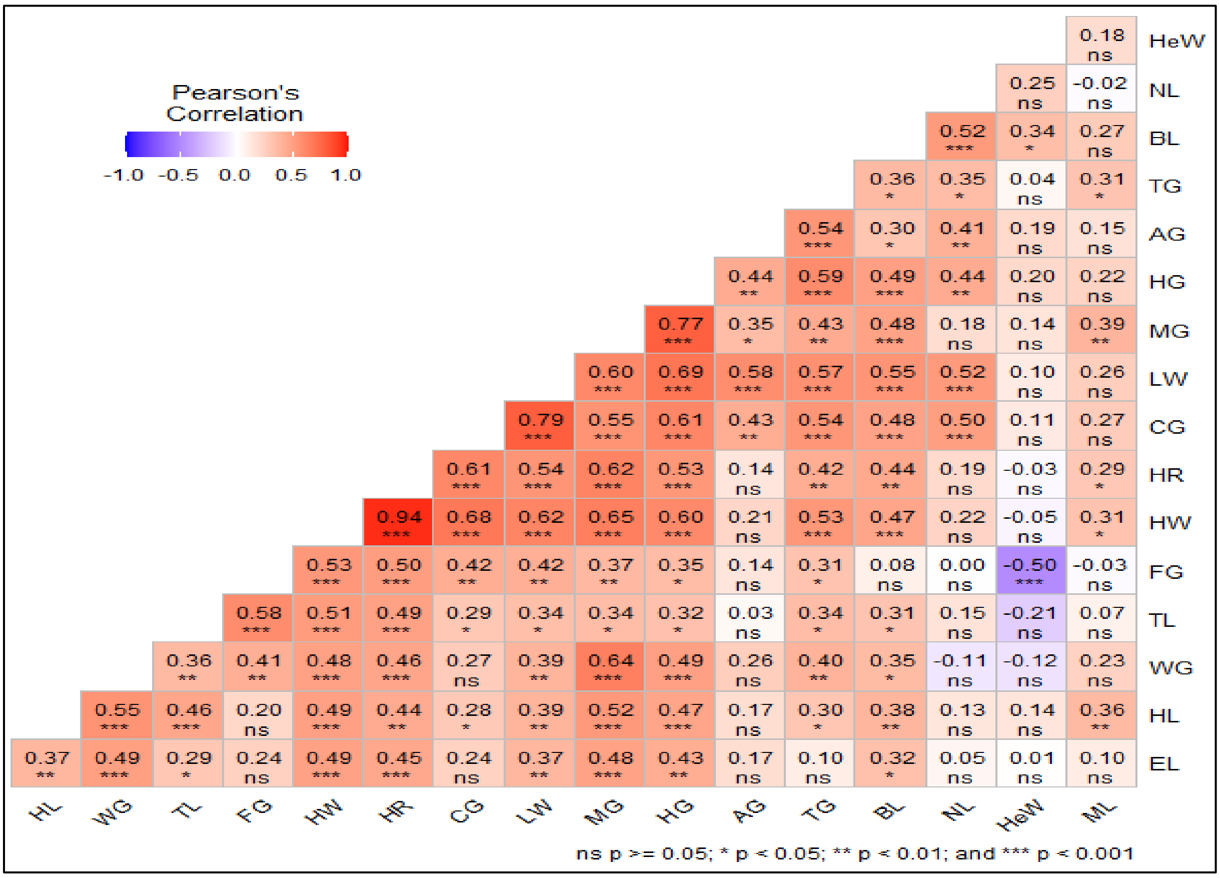

Figure 6. Heat map of Pearson's correlations between body measurements and live weight in GCS

A general evaluation shows that there were positive phenotypic correlations between weight and some body measurements in the studied dogs, for HG, NL, TL, AG, CG, TG, ML, BL and HeW the

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correlation with LW was very highly significant ($p<0.001$), for WG and HW the correlation with LW was highly significant ($p<0.01$), while the correlation between LW and HR was significant ($p<0.05$),finally, there was no negative phenotypic correlations between LW and body measurements (figure 4).

In SLG (figure 5), all body measurements were positively correlated with LW with a very high significance ($p<0.001$) except for AG where the correlation was highly significant ($p<0.01$).

In GCS, LW was positively correlated with all body measurement except with HeW and ML where the correlation was not significant (figure 6).

These body measurements could be used for body weight estimation in all the studied dogs using a general model and according to breed using separate models in order to get the most appropriate model with the highest coefficient of determination.

General models and separate models were developed for all dogs and for each breed group respectively for the estimation of body weight using body measurements and coefficients of determination (R^2) are presented in Table 4.

Table 4. Live weight estimation models in all dogs and according to breed

Breed	N	Models	β_i						
			β_0	β_1	β_2	β_3	β_4	R^2	P
SLG and GCS	109	$\hat{y}_1 = \hat{\beta}_0 + \hat{\beta}_1 x_{11}$	-6.668	0.902				0.491	***
		$\hat{y}_2 = \hat{\beta}_0 + \hat{\beta}_1 x_5 + \hat{\beta}_2 x_{11}$	-6.951	0.449	0.608			0.581	***
		$\hat{y}_3 = \hat{\beta}_0 + \hat{\beta}_1 x_1 + \hat{\beta}_2 x_5 + \hat{\beta}_3 x_{11}$	-16.185	0.171	0.583	0.442		0.626	***
		$\hat{y}_4 = \hat{\beta}_0 + \hat{\beta}_1 x_1 + \hat{\beta}_2 x_4 + \hat{\beta}_3 x_5 + \hat{\beta}_4 x_{11}$	-16.665	0.152	0.116	0.520	0.386	0.640	***
SLG	58	$\hat{y}_1 = \hat{\beta}_0 + \hat{\beta}_1 x_1$	-11.747	0.475				0.706	***
		$\hat{y}_2 = \hat{\beta}_0 + \hat{\beta}_1 x_1 + \hat{\beta}_2 x_8$	-12.842	0.425	0.368			0.730	***
GCS	51	$\hat{y}_1 = \hat{\beta}_0 + \hat{\beta}_1 x_{12}$	-20.177	0.660				0.609	***
		$\hat{y}_2 = \hat{\beta}_0 + \hat{\beta}_1 x_{12} + \hat{\beta}_2 x_{15}$	-25.407	0.554	0.270			0.676	***
		$\hat{y}_3 = \hat{\beta}_0 + \hat{\beta}_1 x_{11} + \hat{\beta}_2 x_{12} + \hat{\beta}_3 x_{15}$	-28.810	0.391	0.439	0.219		0.712	***

x_1= HW; x_4=TL; x_5= NL; x_8= EL; x_{11}= HG; x_{12}=CG; x_{15}=AG; SLG: Sloughi; GCS: Galgo cross Sloughi; N: Number of samples;β_0=Constant;β_i=Regression coefficient; R^2=Adjusted estimation power; P=p-value.

According to Table 4, the results of multiple linear regression show that in all dogs (SLG and GCS) we have had four different models for body weight estimation, in SLG, two models and in GCS, three models with different level of R^2. The most appropriate model for both SLG and GCS was model number 4 ($\hat{y}_4$)usingfour predictive variables HW, TL, NL and HG with a coefficient of determination R^2=0.640.
In SLG, the highest coefficient of determination was 0.730 in the second model using two predictive variables, HW and EL. Finally, in GCS, the most suitable model was ($\hat{y}_3$) using HG, CG and AG as predictive variables and 0.712 as the highest value of R^2.

The tolerance statistics and variance inflation factors of each appropriate model in all dogs and according to breed are presented in table 5.

The tolerance statistics and variance inflation factors for the final models suggested there was not a problem with multi-collinearity or autocorrelation ($p>0.05$) and all value of VIF were less than 5. (Allison, 1999)

Table 5. Final regression models retained to predict live weight after checking autocorrelation and collinearity

Breed	Model	Independent variable	RC±SE	P-value	Tol	VIF	DWS	P-value
SLG and GCS	$\hat{\gamma}_4$	Intercept	-16.664 ± 3.523	***	--	--	2.017	ns
		HW	0.152 ± 0.046	**	0.769	1.299		
		TL	0.116 ± 0.050	*	0.669	1.493		
		NL	0.520 ± 0.096	***	0.497	2.011		
		HG	0.386 ± 0.105	***	0.492	2.031		
SLG	$\hat{\gamma}_2$	Intercept	-12.842 ± 2.806	***	--	--	2.407	ns
		HW	0.425 ± 0.043	***	0.784	1.274		
		EL	0.368 ± 0.148	*	0.784	1.274		
GCS	$\hat{\gamma}_3$	Intercept	-28.809 ± 4.871	***	--	--	2.327	ns
		HG	0.391 ± 0.148	*	0.586	1.705		
		CG	0.438 ± 0.082	***	0.592	1.687		
		AG	0.218 ± 0.078	**	0.768	1.300		

RC: regression coefficient; SE: standard error; P: probability; Tol: tolerance; VIF: variance inflation factor; DWS: Durbin-Watson statistics.

We can conclude that in the present study on SLG and GCS according to separate models, there is no universal predictive variable between the two breeds.

In the present study, the prediction equations were specific to the studied breeds together and separately. The correlation and regression analyses in Philippine native dogs showed that all body measurements were positively linearly related to body weight, regardless of sex, whereas only the best body weight determinant of both sexes factor was chest circumference, with a coefficient of determination of $R^2 = 0.468$ (Valdez & Valencia, 2004). However, in contrast to our current study, in the Gemlik Military Veterinary School study, ear length was the most important and significant predictor of live weight in German Shepherds dogs (Elmaz *et al.*, 2006). The results obtained were similar in terms of the significant correlations between weight and body measurements (Dirlik. 2008). The obtained results were also similar in Nigerian native dogs (Emehelu *et al.*, 2012). In this latest study, it has been shown that the highest correlation was between live weight and chest circumference. In Zerdava dogs, the weight can be predicted based on wither height, chest width, chest circumference, and head length. In the study of Çelik and Yilmaz, it has been shown that 68% and 91% of live weight variation and morphometric measurements in Turkish Taj dogs could be explained by using the classification and regression tree method (CART) and multivariate adaptive regression splines (MARS) (Çelik & Yilmaz 2018). Concerning Zağar dogs, live weight can be reasonably predicted from body length, chest width, chest circumference, rear cannon bone circumference, and ear spacing. Finally, in Çatalburun dogs, we were able to predict live weight from withers height, body length, and chest circumference (Özkul *et al.*, 2021).

Conclusion

The results of our study showed that there was a significant difference between Sloughi and Galgo cross Sloughi in thirteen body measurements, live weight and seven body indices. In both breeds, sex had an impact on body measurements and live weight but not on body indices. It is true that crossbreeding is sometimes beneficial and meets the needs of breeders, but these crossbreeds must be controlled in order to avoid degradation and genetic pollution of pure breeds. The best way to take advantage of the vigor of crossbreeding is above all to breed purebred dogs, because this vigor is generally only observed in first generation crossbreeding of two purebred subjects but of distinct breeds, also taking advantage of genetic diversity.

In this study, the measured live weight of the studied breeds and the prediction of their live weight using some body measurements indicate that the weight can be predicted with a reasonable degree of accuracy using the models constructed with the regression analysis. These models allowed us to use the most important body measurements that are likely to change between breeds, in other words, the body measurements of these studied dog breeds could be indicative of their usefulness in selection and direct each breed towards the most appropriate activity like racing or hunting dogs.

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