International Journal of Agricultural Technology 2019 Vol. 15(5):753-768
Available online http://www.ijat-aatsea.com
ISSN 2630-0192 (Online)

Based zoometric description of adult Phu Quoc Ridgeback dog (*Canis familiaris*)

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Quan, Q. D., Nguyen, T. C., Tran, B. H., Chung, A. D. and Tran, H. D. (2019). Based zoometric description of adult Phu Quoc Ridgeback dog (*Canis familiaris*). International Journal of Agricultural Technology 15(5):753-768.

Abstract Phu Quoc Ridgeback is one of the unique dog breeds in Vietnam. However, Fédération Cynologique Internationale (FCI) has not yet recognized as standard breed due to unspecified morphological and genetic information. Phu Quoc Ridgeback dog is even assumed to be the descendant of Thai Ridgeback dog. There is a certain demand for studies to point out specific morphological and/or genetic traits of this dog breed to use as a foundation for comparison with other breeds. It would serve as a guideline to form particular characteristics that aim toward a standard breed recognition by FCI for this dog. In this study, 175 matured (at least 19 months old) Phu Quoc Ridgeback dogs were sampled at Phu Quoc and Ho Chi Minh City. Difference in morphology was statistically estimated by t-test and linear regression showed that measured size parameters (body height at withers and weight) in sampled and observed population were different from the morphological standard defined by the Vietnam Kennel Association (VKA). Moreover, Phu Quoc Ridgeback dog is entirely different from Thai and African Rhodesian ridgeback ones based on recorded height and weight parameters.

Keywords: body height at withers, body length, regression, t-test

Introduction

Phu Quoc is an island located at southwestern Vietnam and also a district of Kien Giang Province. The Phu Quoc Ridgeback dog is a native animal breed of this island with a distinctive morphological trait of a ridge-like pattern on the coat at the back of the dog. Fernand Doceul, an official in French colonial government in southern Vietnam, was the first person who brought the

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ridgeback breed from Phu Quoc to Paris in 1886. The first hypothesis described on Phu Quoc Ridgeback dog's origin was proposed by Emile Oustalet (Oustalet, 1981), a biologist and the director of the Department of Birds and Mammals at Muséum National d'Histoire Naturelle in 1873 – 1905 (Hellmayr, 1906). Later, Henri de Bylandt described *Phu Quoc Hunting dog (Lévrier Phu Quoc)* in his book *Les Races de Chien* (first published in 1897, reprinted in 1994, described 316 worldwide dog breeds, printed in English, French and German) (Bylandt, 1897). Nodaway, Phu Quoc Ridgeback is one of the three ridgeback breeds in the world; however, the Fédération Cynologique Internationale (FCI) only recognized the two other breeds which are the African Ridgeback (Rhodesian Ridgeback) and the Thai Ridgeback (FCI, 1996 and 2004). Since 2012 studies on genetic and morphological diversity of Phu Quoc Ridgeback in Vietnam have been published, including (Quan *et al*., 2016b), (Thai *et al*., 2016), (Tran *et al*., 2016), (Thai *et al*., 2019) that were studied on mitochondrial genetic diversity of Phu Quoc ridgeback; while (Quan *et al*., 2016a, 2017) studied on Phu Quoc ridgeback's morphology at Phu Quoc Island and the relationship between body size ratio and the occurrence of haplogroup E (one rare haplogroup in dogs) in this breed. However, some individual dogs born in Phu Quoc were sampled in previous studies; the result did not represent sufficient morphological diversity to identify and differentiate the Phu Quoc Ridgeback from the African and Thai ridgeback. The result was also not enough to evaluate the differences in morphology and body size among Phu Quoc Ridgeback population. This study applied several conventional basic methods in morphological identification on Phu Quoc Ridgeback sampled from Phu Quoc Island and Ho Chi Minh City, where Phu Quoc Ridgeback breeding kennels were mostly located in Vietnam.

Materials and Methods

Materials and samples

In this study, 175 Phu Quoc dog individuals with and without the ridge on dorsal (ridgeback) (including 96 males and 79 females) were observed. Samples must be at least 18 months old - the age at which the dogs are sexually matured and body size parameters no longer change (Morey, 1992). Samples were collected at Phu Quoc Island (where is considered the origin of Phu Quoc dog) and at Ho Chi Minh City with adjacent areas (where the Phu Quoc Ridgeback individuals were mostly transferred to and trading for commercial breeding and conservation). Among 175 samples, 31 of them were located at Phu Quoc's breeding kennels, and 144 of them were at natural and semi-natural breeding kennels in Ho Chi Minh City and adjacent areas. All samples had both

paternal and maternal origins from Phu Quoc Island. Thirty samples hadn't ridgeback while 146 ones had.

Body size measurement

This study applied measurement methods used in published researches of Dingo (Crowther *et al*., 2014; Smith *et al*., 2018), New Guinea Signing (Koler-Matznick *et al*., 2003), Italiano Bracco (Cecchi *et al*., 2015), Italian Cane Corso (Marelli *et al*., 2003) (Italy), Nigeria Indigenous (Bukar-Kolo *et al*., 2016) and Spanish Sigh Hound (Gonz âez *et al*., 2014) (Spain).

Body size measurement taken in this study was: body weight (BW) by digital weight-scale, body height at withers (BHW), body length (BL), chest circumference (ChC), waist circumference (WC), muzzle length (ML), ear length (EL) and tail length (TL) (Sutter *et al*., 2008) using straight ruler and measuring tape (German *et al*., 2006).

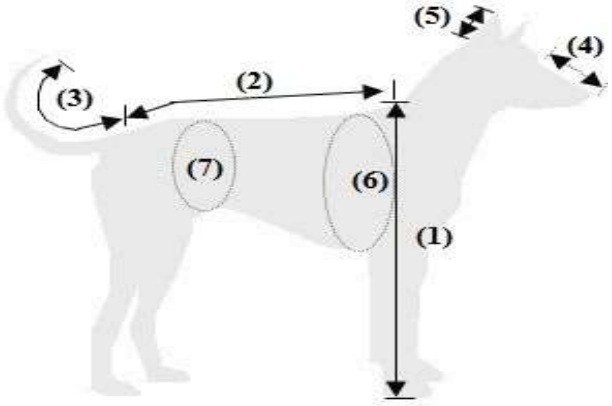

Figure 1. Morphological measurements of Phu Quoc dog. Sampled individuals were kept at stacked stance during measurement. (1) Body height at withers (BHW) is the height of the withers above ground level and was measured by a straight ruler. (2) Body length (BL) is the length of backline from withers to tail base, measured by measuring tape. (3) Tail length (TL) is the length from tail base to the tail end, measured by measuring tape. (4) Muzzle length (ML) is the length from the furthest point of the upper jaw along the nasal bridge to the juncture between nasal bone and cranium, measured by measuring tape. (5) Ear length (EL) is the length from the ear tip to the middle point of the borderline between ear and skull, measured by measuring tape. (6) Chest circumference (ChC) is the largest circumference of the chest, measured by measuring tape. (7) Waist circumference (WC) is the smallest waist circumference at the abdomen right next to the hind legs, measured by measuring tape. (8) Body weight (BW) is the weight at normal condition before a meal

Statistical analysis

Descriptive statistics and body size criteria were presented in average values with corresponding standard errors. ANOVA and t-test analysis was used for the differences in body size between sexes and sampled populations at a confidence interval of 95% (or level of significance of 0.05). The t-test was used to analyze two samples with non-identical variances. Regression analysis was used to evaluate the correlation between size parameters to predict the possibility of changes in body size during natural selection and artificial selection. The study made use of XLSTAT program, developed by Addinsoft for non-annual database market since 1993. Results of descriptive statistics of all Phu Quoc dog individuals were recorded in tables. Body weight was measured in kilogram (kg) and other size parameters were measured in centimeter (cm). The body scores and morphology of Thai Ridgeback dog and Rhodesian ridgeback dog collected and investigated from Fédération Cynologique Internationale (FCI).

Results

Average body size of Phu Quoc Ridgeback dog

The basic body size measurements of sampled Phu Quoc Ridgeback dog was presented in Table 1. In most cases there was no observable difference in body size between sexes. At confidence interval of 95%, average body size parameters were: BW = 19.6 ± 2.3 (kg); BL = 50.6 ± 6.4 (cm); BHW = 45.9 ± 6.3 (cm); ML = 10.3 ± 0.6 (cm); ChC = 55.9 ± 8.0 (cm); WC = 45.6 ± 6.9 (cm); EL = 9.8 ± 0.8 cm; TL = 29.1 ± 3.1 (cm).

Body height at withers (BHW) is one important criterion to define dog breeds according to FCI's regulations, researches on dog phenotype used this criterion to evaluate featured morphological traits, phylogenetic origins (Hubbard, 1948;Olsen, 1974; Sechi *et al*., 2016; Jagatheesan *et al*., 2016) and conservation characteristics via breeding expressed by phenotype (Sutter *et al*., 2008). BHW is also a manifestation of the dog breed's nature, instinct and behaviour during its coexistence and evolution process together with human (Gwatkin, 1934; Benecke, 1987; Morey, 1992; Vilà *et al*., 1997; Brewer *et al*., 2001; Favier *et al*., 2001; Clutton-Brock, 2016). Aside from tail length (28.2 ± 5.3 cm in female and 29.6 ± 11.2 cm in male) (Table 2), there was no difference in observed phenotype between different sexes in Phu Quoc dog.

Table 1. Average values of basic morphological size on ridged and non-ridged Phu Quoc Ridgeback dog sampled at different locations

Ridged Phu Quoc dogs at Phu Quoc Island, Kien Giang				
Sex	**BW (kg)**	**BL (cm)**	**BHW (cm)**	**ML (cm)**
Male	19.7 ±3.4	53.2 ±4.6	48.9 ±5.2	10.4 ±0.7
Female	18.1 ±2.1	50.3 ±2.7	46.4 ±2.0	10.1 ±0.6
	ChC (cm)	**WC (cm)**	**EL (cm)**	**TL (cm)**
Male	57.6 ±5.7	47.1 ±5.2	9.8 ±0.7	29.3 ±3.0
Female	53.5 ±5.6	44.4 ±5.3	9.7 ±0.6	26.8 ±1.7
Ridged Phu Quoc dogs at Ho Chi Minh City and adjacent areas in southern Vietnam (Vung Tau, Binh Duong, Hoc Mon)				
Sex	**BW (kg)**	**BL (cm)**	**BHW (cm)**	**ML (cm)**
Male	20.1 ±2.2	50.0 ±6.2	45.9 ±6.4	10.2 ±0.6
Female	20.1 ±2.0	49.4 ±6.2	44.6 ±6.4	10.3 ±0.5
	ChC (cm)	**WC (cm)**	**EL (cm)**	**TL (cm)**
Male	56.4 ±8.8	45.8 ±7.4	9.9 ±0.8	29.9 ±3.6
Female	54.4 ±8.1	44.2 ±7.3	9.8 ±0.8	28.2 ±2.2
Non-ridged Phu Quoc dogs at Ho Chi Minh City and adjacent areas in southern Vietnam (Vung Tau, Binh Duong, Hoc Mon)				
Sex	**BW (kg)**	**BL (cm)**	**BHW (cm)**	**ML (cm)**
Male	18.6 ±1.7	51.3 ±8.0	45.3 ±6.6	10.5 ±0.5
Female	18.4 ±2.1	53.1 ±9.6	47.2 ±8.2	10.2 ±0.6
	ChC (cm)	**WC (cm)**	**EL (cm)**	**TL (cm)**
Male	54.9 ±8.3	45.6 ±6.9	9.7 ±0.9	29.9 ±2.6
Female	60.6 ±7.5	49.5 ±4.9	9.7 ±0.8	29.9 ±2.4

Table 2. Results of t-test on basic morphological size between sexes in Phu Quoc dog

	BW	**BL**	**BHW**	**ML**	**ChC**	**WC**	**EL**	**TL**
t	-0.743	-0.698	-1.056	-0.360	-0.832	-0.853	-0.385	-3.371
tC	1.974	1.974	1.974	1.974	1.974	1.974	1.974	1.974
p<0.05	0.458	0.486	0.292	0.719	0.395	0.407	0.700	0.000*

*: significantly different at p<0.05

Observed phenotypes of ridged Phu Quoc dogs at Phu Quoc Island and Ho Chi Minh City

The BWH and BL measurements of male ridged individuals in Phu Quoc were 48.9 and 53.2 (cm) respectively. Corresponding values in Ho Chi Minh City were 45.9 and 50.0 (cm) respectively (Table 1). Statistical results showed differences between BHW and BL in these two groups. Ridged individuals in Phu Quoc Island were 3cm higher in BHW than Ho Chi Minh City and 3.2cm longer in BL ($p<0.05$) (Table 3).

Female ridged individuals in two areas were not different in BHW and BL but had differences in body weight and tail length. Individuals in Ho Chi Minh City were 2kg heavier than in Phu Quoc Island (20.1 kg and 18.1 kg respectively; $p<0.05$) and the tail length was 1.2 cm longer (28.0 and 26.8 cm respectively; $p<0.05$) (Table 3).

Table 3. Results of t-test on basic morphological size between Phu Quoc Ridgeback dog in Phu Quoc Island and at Ho Chi Minh City, divided by sex

	BW	**BL**	**BHW**	**ML**	**ChC**	**WC**	**EL**	**TL**
Male								
t	-0.461	2.358	2.038	1.035	0.650	0.814	-0.843	-0.824
tC	2.077	2.024	2.030	2.069	2.015	2.201	2.032	2.030
p<0.05	0.649	0.023*	0.049*	0.311	0.518	0.420	0.405	0.415
Female								
t	-3.158	0.752	1.703	-1.456	-0.514	0.147	-0.835	-2.349
tC	2.085	2.007	1.999	2.093	2.039	2.048	2.048	2.059
p<0.05	0.005*	0.456	0.094	0.162	0.611	0.884	0.410	0.026*

*: significantly different at $p<0.05$

Observed phenotypes of ridged and non-ridged Phu Quoc dogs

Ridged Phu Quoc dogs were 1.4 kg heavier than non-ridged ones (19.9 and 18.5 kg respectively; $p<0.05$). Tail length (TL) of ridged individuals was 1.1cm shorter than non-ridged ones (29.9 and 28.8 cm respectively; $p<0.05$) (Table 4).

Table 4. Results of t-test on basic morphological size between ridged and non-ridged in total Phu Quoc dog

	BW	**BL**	**BHW**	**ML**	**ChC**	**WC**	**EL**	**TL**
t	-3.566	1.101	0.162	1.148	1.092	1.520	-0.965	2.232
tC	2.004	2.024	2.019	2.013	2.014	2.010	2.015	2.004
p<0.05	0.000*	0.277	0.871	0.257	0.280	0.135	0.344	0.029*

*: significantly different at $p<0.05$

Growth correlation between body height and length in ridged Phu Quoc Ridgeback dog at Phu Quoc and Ho Chi Minh City

BHW and BL are common criteria in the identification of dog breeds since they can be easily measured, do not depend on the nutritional condition and is proportional to other size parameters (Frynta *et al*., 2012). Allometry is the ratio between body sizes during animal growth. Statistical results showed differences in size between sexes in Phu Quoc Ridgeback dog population sampled in Phu Quoc; male individuals had greater body length (male: 53.2 cm;

female: 50.3 cm), higher BHW (male: 48.9 cm and female: 46.3 cm). Meanwhile, males and females in Ho Chi Minh City were not significantly different in BL (50.33 and 50.17 cm respectively) and BHW (45.74 and 45.11cm respectively).

Table 5. Average BHW and BL of Phu Quoc dogs in different sampling areas, measured in cm

Sampling area	**Phu Quoc**		**Ho Chi Minh City and adjacent area**	
Sex	**Female**	**Male**	**Female**	**Male**
BL	50.285[a]	53.222[a.c]	50.169	50.333[c]
BWH	46.357[b]	48.888[b.d]	45.107	45.743[d]
The confidence interval of 95%; a, b, c, d: significantly different at $p<0.05$				

In observed male individuals, BL and BHW were different between Phu Quoc and Ho Chi Minh City (Phu Quoc: 53.2 and 48.8 cm respectively, Ho Chi Minh City: 50.3 and 45.7 cm respectively; $p<0.05$ (Table 5).

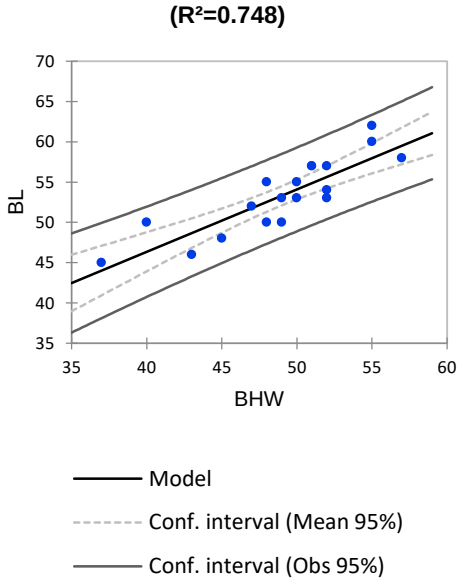

Figure 2. Graph of the regression function on the correlation between BHW and BL of Phu Quoc Ridgeback dog in Phu Quoc Island. The equation estimated is: BL = 15.41+0.77*BHW

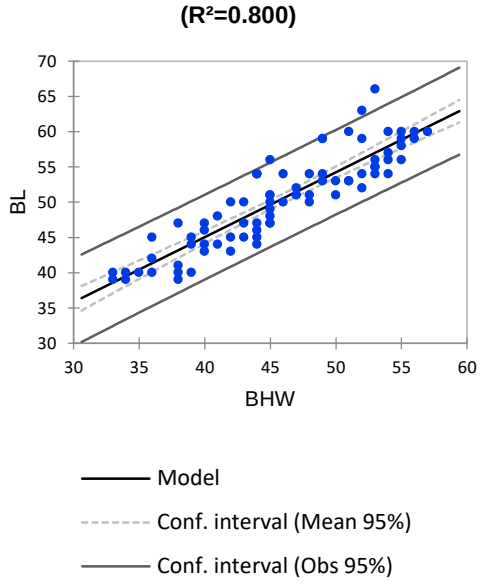

Figure 3. Graph of the regression function on the correlation between BHW and BL of Phu Quoc Ridgeback dog at Ho Chi Minh City and adjacent area. The equation estimated is: BL = 8.20+0.92*BHW

Allometry is the growth coefficient of an animal body

Distinct phenotype resulted in different allometry in Phu Quoc Ridgeback dogs at Phu Quoc Island and Ho Chi Minh City (Figure 2 and Figure 3). The results showed that Phu Quoc Ridgeback dog populations in Phu Quoc and other regions tended to differentiate from each other. The allometric equation was built to predict the evolution of population phenotype over time. There was no observed difference between ridged and non-ridged dogs beside body weight, the elements which can be easily affected by environment, nutritional demands and preferences of breeders and buyers. Tail length also had differences however this trait probably is affected by external environments and requires further observations.

Diagnostic BWH and BW of Phu Quoc Ridgeback dog, Thai Ridgeback dog and Rhodesian ridgeback dog

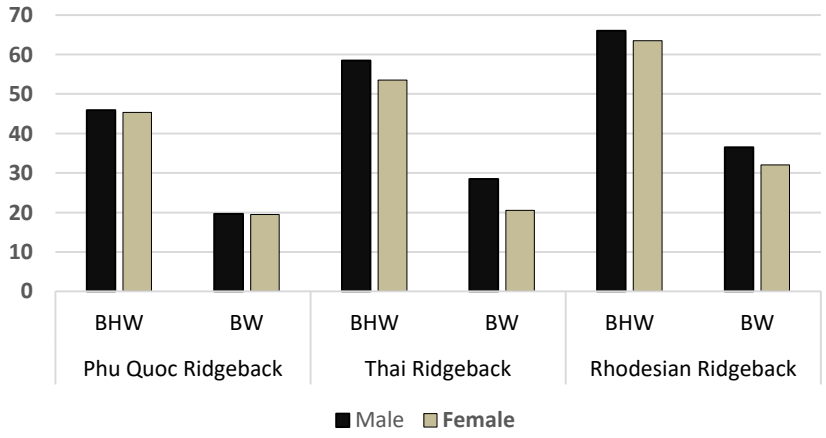

Figure 4. Body height at withers (BHW, cm) and body weight (BW, kg) of Phu Quoc Ridgeback dog in comparison with Thai Ridgeback dog and African Ridgeback dog

When comparing the research data from Phu Quoc Ridgeback dog with database of dog breeds provided by Fédération Cynologique Internationale (FCI) (http://www.fci.be/en/), the body height at withers (BHW) and body weight (BW) measurements of Phu Quoc Ridgeback dog were sharply different from related ridgeback breeds, especially the Thai Ridgeback. Height and weight were not significantly different between sexes in Phu Quoc Ridgeback dog while in Thai Ridgeback the male individuals were clearly heavier and larger than females. Moreover, Phu Quoc dog's average weight was 19.6 (kg)

while in Thai Ridgeback the female weight was 20.4 (kg) and male weight was 28.4 (kg) (https://wagwalking.com/breed/thai-ridgeback); Phu Quoc's average BHW was 45.9 (cm), different from Thai Ridgeback (female: 53.5 cm and male: 58.5 cm) (Berkel, 1998; FCI, 2004) (http://www.fci.be/en/nomenclature/THAI-RIDGEBACK-DOG-338.html). The BW and BHW of Phu Quoc Ridgeback dog were also significantly lower than African Ridgeback (female: 32.0 kg and 63.5 cm; male: 36.5 kg and 66.0 cm) (FCI, 1996).

In addition, when compared with VKA's published criteria on Phu Quoc Ridgeback dog breed in Vietnam, the study results are quite different, for example smaller BHW and heavier BW in both genders than previously published criteria (Figure 4, Table 6).

Table 6. Three ridgeback dog breeds with body scores: body height at withers (BHW) and body weight (BW)

	Rhodesian Ridgeback dog[1]		**Thai Ridgeback dog[1]**		**Phu Quoc Ridgeback dog[2]**		**Phu Quoc Ridgeback dog[3]**	
	BHW (cm)	**BW (kg)**	**BHW (cm)**	**BW (kg)**	**BHW (cm)**	**BW (kg)**	**BHW (cm)**	**BW (kg)**
Male	66.0	36.5	58.5	28.4	50 - 55	15 - 20	45.9	19.6
Female	63.5	32.0	53.5	20.4	48 - 52	12 - 18	45.3	19.5

1: The data collected from FCI morphology description and certification for breed dogs.
2: The data collected from VKA* morphology description for Phu Quoc Ridgeback dog (Vietnamese language)
3: The results collected in this study
*: Vietnam Kennels Acsociation

Discussion

Phu Quoc Ridgeback has a smaller body size and less weight than Thai and African counterparts, such differences are related to behaviour, environment and human domestication process (Vilà *et al*., 1997). Most publications on origin and genetics of ridgeback breeds mainly refer to African and Thai Ridgebacks and consider Phu Quoc Ridgeback as a subset of the Thai breed (Hofmeyer, 1963; Tshamala and Moens, 2000; Hillbertz, 2005; Hillbertz and Andersson, 2006; Hillbertz *et al.*, 2007; Alvarez and Akey, 2012), but they show no evidence in morphology or genetics. Importantly, the recent published researches in Vietnam by Tran Hoang Dung (Tran *et al*., 2016) and Thai Ke Quan (Thai *et al*., 2016; Thai *et al*., 2019), by investigating the mDNA of Phu Quoc Ridgeback dog, show that there have been no genetic relationship between Thai Ridgeback dog and Phu Quoc Ridgeback dog yet. The results of this study further reinforce the genetic differences expressed by some universal

phenotypic indicators that are often quantified as characteristics of dog breeds in the world nowadays: body height at withers (BHW) and body weight (BW).

Both sexes of Phu Quoc Ridgeback dog matured individuals are not different much in the average value of recorded parameters. Generally, Phu Quoc dogs have less body height at withers (BHW) and body weight (BW) than Thai Ridgebacks (Table 6 and Figure 2) although deviations in morphology between sampling locations, sexes and between ridged/non-ridged groups do occur. There is also apparent dissimilarity in general morphology and coat colour between the two breeds (unpublished data).

Locally, there is no difference in common phenotypic traits (body height and length, chest and waist circumference, ear length) between ridged and non-ridged Phu Quoc Ridgeback dog which reinforced the scientific basis for the argument that the back ridge originates from a mutation due to lack of nutrients from food and environment (Hillbertz and Andersson, 2006). There are observed differences between Phu Quoc Ridgeback dog in Phu Quoc Island and in Ho Chi Minh City plus adjacent areas. Body height and length are significantly different between sexes of the Phu Quoc individuals while no significant difference was observed between sexes in Ho Chi Minh City and adjacent areas. Artificial selection based on human preferences probably facilitates the homogenization of phenotypes in different sexes, similar to the changes in morphology and size of several other breeds (Marelli *et al*., 2003; Sutter *et al*., 2008; Shearin and Ostrander, 2010; Bukar-Kolo *et al*., 2016; Sechi *et al*., 2016).

There is a significant difference in body weight between female ridged individuals in Phu Quoc and Ho Chi Minh City with its adjacent areas. (18.1 ± 2.1 kg and 20.1 ± 2.0 kg) (Table 1 - 3). Body weight is a criterion for the diagnosis of excessive or lack of weight in sheltered dog and recently is used as an important reference for studies in dog obesity (Bland *et al*., 2010; Greer *et al*., 2007). The difference in body weight between sampled populations occurs only in ridged females; other size parameters have no difference. This probably due to excessive nutrients supply for reproduction in artificial breeding; additional researches on hormone content are required for a more detailed and accurate evaluation on body weight.

Body weight between ridged and non-ridged dogs (19.9 ± 5.5 kg and 18.5 ± 3.5 kg respectively) is also significantly different why other size parameters are not (Table 1 - 4). The reason probably is higher nutrient supply for ridged individuals which suit human preferences while non-ridged individuals are not regarded as genuine breed and receive less supply. Researches show that ridged trait is dominant in relation to non-ridged trait; therefore phenotype ratio of

these traits is three ridged: one non-ridged according to Mendelian inheritance (Hillbertz and Andersson, 2006).

Tail length is also different between sexes and between sampled locations, probably related to sex roles and authority structure in dog packs. However additional researches are needed as tail length and morphology are also related to mental behaviour (Leaver and Reimchen, 2008).

Phu Quoc Ridgeback dog has not been acknowledged as a separate dog breed yet; one of the main reasons is the lack of published researches on representative genetic traits and phenotypes of its populations in Vietnam. Previous descriptions of the breed are unsuitable as reference for breed criteria since they were only based on a too small number of individuals (Oustalet, 1981; Bylandt, 1897) to represent the whole Phu Quoc Ridgeback population in Vietnam. The Vietnam Kennels Association (VKA), assigned to develop domestic dog breeds in Vietnam by FCI, published a description of the phenotypic criteria of Phu Quoc Ridge dog but it was not quoted from any previous research literature. The sizes range of this breed dog (male: BHW=50-55cm, BW=15-20kg; female: BHW=48-52cm, BW=12-18kg) has unknown confidence intervals which will be difficult to quantify further studies (Neyman, 1937; Morey *et al*., 2016) (Table 6). Furthermore, nowadays, because the geographic distribution of modern domestic dog breeds is highly overlapped, their traits had been evolving; the evolution process has to be evaluated positive and negative impact on dog breeding and the artificial selection based on human habit (Shearin and Ostrander, 2010; Crowther *et al*., 2014; Teng *et al*., 2016;).

Addition, VKA regulated the BHW of this breed dog is 50-55 (cm) in males and 48-52 (cm) in females. However, it is different with results in this study that BHW in males is 39-51 (cm) (confidence interval of 95%). Clearly, there is a significant discrepancy between regulated criteria and realistic observed value. Body weight of Phu Quoc Ridgeback dog according VKA were 15-20 (kg) in males and 13-18 (kg) in females, so large range for define an exacting phenotype value. Meanwhile, our studies recorded BW values of this breed dog were 17.3-21.9 (kg) in male and 17.3-21.7 (kg) in female (Table 7).

Table 7. General observed morphological parameters in Phu Quoc dogs

Parameter	**BW (kg)**	**BL (cm)**	**BHW (cm)**	**ML (cm)**
Male	19.6 ± 2.3	50.6 ± 6.4	45.9 ± 6.3	10.3 ± 0.6
Female	19.5 ± 2.2	50.2 ± 6.5	45.3 ± 6.2	10.2 ± 0.5
Parameter	**ChC (cm)**	**WC (cm)**	**EL (cm)**	**TL (cm)**
Male	55.9 ± 8.0	45.6 ± 6.9	9.8 ± 0.8	28.9 ± 3.0
Female	55.3 ± 7.9	45.1 ± 6.8	9.8 ± 0.8	28.1 ± 2.3

The VKA regulates that the ratio between BHW and body length (BL) should be 1:1; it is complicated to achieve such ratio in Phu Quoc dog (www.vka.vn, in Vietnamese language). In one published study on Phu Quoc Ridgeback dog at semi-natural conservation site at Kien Giang, we emphasized the probable relationship between haplotype E on Phu Quoc Ridgeback dog with BHW:BL ratio, in which the closer to that ratio is, the higher chance of being haplotype E, maximum probability of being haplotype E can reach 47% (Quan *et al*., 2017). However, haplotype E is an ancient genetic line and has very low proportion, according to Thai Ke Quan (2016) it only makes up 15% of the total breed population; such value is already very high considering that haplotype E in some dog breeds only reached 2 – 3% (Thai *et al*., 2016). Therefore, the VKA standarded ratio 1:1 mean all this breed dogs has haplotype E, it is not impossible (my opinon). Furthermore, the 1:1 ratio was determined based on old images of the very first Phu Quoc dogs which sent to France before, it cannot represent the average ratio of Phu Quoc dogs in Vietnam nowadays.

There are differences between observed data (Table 6) and VKA's criteria on Phu Quoc Ridgeback morphology, such differences requires further studies to standardize the essential morphological criteria (body weight, body height), the body size criteria should represent the real value of Phu Quoc Ridgeback in Vietnam rather than only the standard regulations in morphology and size competitions.

Within the sampled population, morphological parameters are generally consistent on sampling locations, sexes and ridged/non-ridged groups. Ridged and non-ridged groups have no difference in body length and BHW, only have a difference in body weight and tail length. Female individuals between two sampling locations are different in body weight, and that result may be related to nutrition requirements in breeding and reproduction: if these processes are in high demand, females can gain more weight to satisfy the requirements for reproduction. Two important body size parameters that are BHW and body length are different between sexes and between sampling locations.

The regression coefficient of the sampled population at Ho Chi Minh City (0.800) is higher than in Phu Quoc (0.748), which means individuals at Ho Chi Minh City have a stronger linear correlation in BHW and body length. In other words, individuals at Ho Chi Minh City are under stronger artificial selection which leads to indifference between sexes in this area. On the contrary, individuals in Phu Quoc are under stronger natural selection leads to differences in these parameters between sexes.

A sound understanding of the taxonomy of threatened taxa is essential for setting conservation priorities and the development of species management

strategies (Mace, 2004). A poor understanding of species taxonomy can hamper biodiversity conservation efforts by preventing the identification of unique evolutionary units, particularly if the species of potential conservation concern possesses morphological traits that are similar to those of closely related species (Daugherty *et al*., 1990). This is particularly true in canids where separate lineages easily hybridize and produce fertile offspring (Roy *et al*., 1994). Without the taxonomic tools to identify unique evolutionary lineages, it may not be possible to make accurate population estimates of species, identify threatened taxa or develop management strategies to enhance the conservation status of threatened taxa (Bacon and Bailey, 2006).

Today, some dog breeds have phenotypic changes with their original ancestors due to human needs and geographical isolation such as case studies on Dingo dogs (Australia) or Fonni dogs (Italy) (Crowther *et al*., 2014; Sechi *et al*., 2016). The phenotypic indicators regularly need to be evaluated and collected to serve as a basis for the implementation of species conservation processes. Dog breeds phenotype change very quickly because of human habit and favourist (Witzenberger and Hochkirc, 2011). Our research will provide additional data for previous genetic and phenotypic studies in Vietnam about Phu Quoc Ridgeback dogs (Quan *et al*., 2016a; Thai *et al*., 2016; Tran *et al*., 2016; Quan *et al*., 2017; Thai *et al*., 2019). In particular, it will provide a database to register the Phu Quoc Ridgeback dog to FCI (until today, VKA has not done it). The next step for the conservation of Phu Quoc Ridgeback dog is defining the traits differentiate them from hybrids, allowing natural selection and recognizing of the natural variation and the effect of environment and human selection on this breed.

Acknowledgement

This research was funded by The Vietnam National Gene Fund for this project (Project no. 01/2015 – HĐ-NVQG).

References

Alvarez, C. E. and Akey, J. M. (2012). Copy number variation in the domestic dog. Mammalian genome, 23:144-163.

Bacon, C. D. and Bailey, C. D. (2006). Taxonomy and conservation: a case study from *Chamaedorea alternans*. Annals of Botany, 98:755-763.

Benecke, N. (1987). Studies on early dog remains from Northern Europe. Journal of Archaeological Science, 14:31-49.

Berkel, M. J. (1998). Judging the Thai Ridgeback. Rare Insight, 1:14.

Bland, I. M., Guthrie-Jones, A., Taylor, R. D. and Hill, J. (2010). Dog obesity: veterinary practices' and owners' opinions on cause and management. Preventive veterinary medicine, 94:310-315.

Brewer, D., Phillips, A. and Clark, T. (2001). Dogs in Antiquity: Anubis to Cerberus: The Origins of the Domestic Dog, Warminster, Aris & Phillips.
Bukar-Kolo, Y. M., Mustapha, M., Zakariah, M., Allo, A. and Adamu, L. (2016). Relationships between zoometric measurements, coat colors and body condition scores of the Nigerian indigenous dogs in Maiduguri, Northeastern Nigeria. Research Journal for Veterinary Practitioners, 4:51-59.
Bylandt, H. D. (1897). Les Races de Chien, Bruxelles, 1897.
Cecchi, F., Paci, G., Spaterna, A. and Ciampolini, R. (2015). Morphological traits and inbreeding depression in Bracco Italiano dog breed. Italian Journal of Animal Science, 14:374-377.
Clutton-Brock, J. (2016). Origins of the dog: the archaeological evidence, In: Serpell J ed. The Domestic Dog: Its Evolution, Behavior and Interactions with People, Cambridge, Cambridge University Press, pp. 7-21.
Crowther, M. S., Fillios, M., Colman, N. and Letnic, M. (2014). An updated description of the Australian dingo (*Canis dingo* Meyer, 1793). Journal of Zoology, 293:192-203.
Daugherty, C. H., Cree, A., Hay, J. M. and Thompson, M. B. (1990). Neglected taxonomy and continuing extinctions of tuatara (Sphenodon). Nature, 347:177-179.
Favier, R. P., Mol, J. A., Kooistra, H. S. and Rijnberk, A. (2001). Large body size in the dog is associated with transient GH excess at a young age. Journal of Endocrinology, 170:479-484.
FCI (1996). F. C. I.: FCI-Standard N°146 Rhodesian Ridgeback Certificattion.
FCI (2004). F. C. I.: FCI-Standard N°338 Thai Ridgeback Dog Certificattion.
Frynta, D., Baudyšová, J., Hradcová, P., Faltusová, K. and Kratochvíl, L. (2012). Allometry of sexual size dimorphism in domestic dog. PLoS One 7.
German, A. J., Holden, S. L., Moxham, G. L., Holmes, K. L., Hackett, R. M. and Rawlings, J. M. (2006). A simple, reliable tool for owners to assess the body condition of their dog or cat. The Journal of nutrition, 136:2031S-2033S.
González, A., Luque, M., Herrera, M., González, C., Angón, E. and Rodero, E. (2014). Usefulness of discriminant analysis in the morphofunctional classification of Spanish dog breeds. Archiv für Tierzucht, 57:1-16.
Greer, K. A., Canterberry, S. C. and Murphy, K. E. (2007). Statistical analysis regarding the effects of height and weight on life span of the domestic dog. Research in veterinary science, 82:208-214.
Gwatkin, R. D. S. (1934). Dogs and Human Migrations (concluded). Journal of the South African Veterinary Association, 5:29-40.
Hellmayr, C. E. (1906). Emile Oustalet [obituary]. Ornithologische Monatsberichte, 14:57-59.
Hillbertz, N. H. C. S (2005). Inheritance of dermoid sinus in the Rhodesian ridgeback. Journal of Small Animal Practice, 46:71-74.
Hillbertz, N. H. C. S. and Andersson, G. (2006). Autosomal dominant mutation causing the dorsal ridge predisposes for dermoid sinus in Rhodesian ridgeback dogs. Journal of Small Animal Practice, 47:184-188.
Hillbertz, N. H. C. S., Isaksson, M., Karlsson, E. K., Hellmen, E., Pielberg, G. R., Savolainen, P., Wade, C. M., Von Euler, H., Gustafson, U., Hedhammar, A., Nilsson, M., Lindblad-Toh, K., Andersson, L. and Andersson, G. (2007). Duplication of FGF3, FGF4, FGF19 and ORAOV1 causes hair ridge and predisposition to dermoid sinus in Ridgeback dogs. Nature Genetics, 39:1318-1320.
Hofmeyer, C. F. B. (1963). Dermoid sinus in the Ridgeback dog. Journal of Small Animal Practice, 4:5-8.

Hubbard, C. L. B (1948). Dogs in Britain A Description of All Native Breeds and Most Foreign Breeds in Britain, Londonm Macmillan and Co. Ltd, pp. 372-376.

Jagatheesan, M., De Silva, D. N. and Ariyarathna, H. M. H. S. (2016). Body condition score in large pure bred dogs: a preliminary study on agreement between owner's perception and scientific evaluation. Sri Lanka Veterinary Journal, 63:17-21.

Koler-Matznick, J., Brisbin, I. L., Feinstein, M. and Bulmer, S. (2003). An updated description of the New Guinea singing dog (Canis hallstromi, Troughton 1957). Journal of Zoology, 261:109-118.

Laflamme, D. P. (2006). Understanding and Managing Obesity in Dogs and Cats. Veterinary Clinics: Small Animal Practice, 36:1283-1295.

Leaver, S. D. A. and Reimchen, T. E. (2008). Behavioural responses of Canis familiaris to different tail lengths of a remotely-controlled life-size dog replica. Behaviour, 145:377-390.

Mace, G. M. (2004). The role of taxonomy in species conservation. Philosophical Transaction of the Royal Society B, 359:711-719.

Marelli, S. P., Monaghé, A., Polli, M. and Guidobono Cavalchini, L. (2003). Body measurements and morphological evaluation of Italian Cane Corso. Italian Journal of Animal Science, 2:88-90.

Morey, D. F. (1992). Size, shape and development in the evolution of the domestic dog. Journal of Archaeological Science, 19:181-204.

Morey, R. D., Hoekstra, R., Rouder, J. N., Lee, M. D. and Wagenmakers, E. J. (2016). The fallacy of placing confidence in confidence intervals. Psychonomic Bulletin & Review, 23:103-123.

Neyman, J. (1937). Outline of a theory of statistical estimation based on the classical theory of probability. Philosophical Transactions of the Royal Society of London. Series A, Mathematical and Physical Sciences, 236:333-380.

Olsen, S. J. (1974). Early domestic dogs in North America and their origins. Journal of Field Archaeology, 1:343-345.

Oustalet, É. (1891). Les chiens de l'île Phu-Quoc au jardin d'acclimatation de Paris. La Nature pp. 964.

Quan, Q. D., Chung, A. D and Tran, H. D. (2016a). Initially observed some important morphological characteristics on Phu Quoc Ridgeback dogs (Canis familiaris) in Vietnam. Internafional Journal of Science and Research, 5:719-725.

Quan, Q. D., Tran, H. D. and Chung, A. D. (2017). The relation of body score (body height/body length) and haplotype E on Phu Quoc Ridgeback dogs (Canis familiaris), Journal of Entomology and Zoology Studies, 5:388-394.

Quan, T. K., Dung, T. H., Dung, C. A., Cong, N. T. and Hieu, T. V. (2016b). Origin of Phu Quoc Ridgeback dog by using mitochondrial D-loop sequences. Journal of Biology, 38:269-278.

Roy, M. S., Geffen, E., Smith, D., Ostrander, E. A. and Wayne, R. K. (1994). Patterns of differentiation and hybridization in North American wolflike canids, revealed by analysis of microsatellite loci. Molecular iology and Evolution, 11:553-570.

Sechi, S., Polli, M., Marelli, S., Talenti, A., Crepaldi, P., Fiore, F., Spissu, N., Dreger, D. L., Zedda, M., Dimauro, C., Ostrander, E. A., Di Cerbo, A. and Cocco, R. (2016). Fonni's dog: morphological and genetic characteristics for a breed standard definition. Italian Journal of Animal Science, 16:22-30.

Shearin, A. L. and Ostrander, E. A. (2010). Canine morphology: hunting for genes and tracking mutations. PLoS biology, 8:e1000310.

Smith, B. P., Lucas, T. A., Norris, R. M. and Henneberg, M. (2018). Brain size/body weight in the dingo (*Canis dingo*): comparisons with domestic and wild canids. Australian Journal of Zoology, 65:292-301.

Sutter, N. B., Mosher, D. S., Gray, M. M. and Ostrander, E. A. (2008). Morphometrics within dog breeds are highly reproducible and dispute Rensch's rule. Mammalian Genome, 19:713-723.

Teng, K. T., McGreevy, P. D., Toribio, J. A. L. and Dhand, N. K. (2016). Trends in popularity of some morphological traits of purebred dogs in Australia. Canine Genetics and Epidemiology, 3:2.

Tshamala, M. and Moens, Y. (2000). True dermoid wst in a Rhodesian ridgeback. Journal of Small Animal Practice, 41:352-353.

Thai, K. Q., Nguyen, V. T., Tran, N. T., Huynh, V. H., Chung, A. D. and Tran, H. D. (2016). Evaluation of genetic diversity of Phu Quoc Ridgeback dogs based on mitochondrial DNA Hypervariable-1 region. Journal of Biotechnology, 14:245-253.

Thai, K. Q., Nguyen, T. C., Pham, C. H., Chung, A. D., P., S., and Tran, H.-D. (2019) Phu Quoc Ridgeback dog mtDNA HV1 analysis: clarifying the relative relationship with Vietnamese village and Thai Ridgeback dogs. Diversity (Underreview).

Tran, H. D., Thai, K. Q., Huynh, V.-H., Nguyen, T. C. and Chung, A. D. (2016). Origin of Phu Quoc Ridgeback dog by using mitochondrial d-loop sequences. Tap Chi Sinh Hoc, 38:269-278.

Vilà, C., Savolainen, P., Maldonado, J. E., Amorim, I. R., Rice, J. E., Honeycutt, R. L., Crandall, K. A., Lundeberg, J. and Wayne, R. K. (1997). Multiple and ancient origins of the domestic dog. Science, 276:1687-1689.

Witzenberger, K. A. and Hochkirch, A. (2011). Ex situ conservation genetics: a review of molecular studies on the genetic consequences of captive breeding programmes for endangered animal species. Biodiversity and Conservation, 20:1843-1861.

(Received: 24 May 2019, accepted: 31 August 2019)