Short Communication

A pilot study of sexual dimorphism in the head morphology of domestic dogs

Johanna J. Carrasco [a], Dana Georgevsky [a], Michael Valenzuela [b], Paul D. McGreevy [a],*

[a] Faculty of Veterinary Science, University of Sydney, New South Wales, Australia
[b] Brain and Mind Research Institute, Faculty of Medicine, University of Sydney, New South Wales, Australia

ABSTRACT

The dog (Canis lupus familiaris) displays more morphological diversity than any other species. It is a direct descendant of the gray wolf (Canis lupus), but shows remarkable behavioral and morphological differences. It has been suggested that differences in skull shape that relate to brain shape and retinal ganglion cell distribution may predict behavioral differences. The aim of this pilot study was to assess head morphology in common breeds for evidence of sexual dimorphism in head length, head width, and the ratio of the 2: cephalic index (CI). When males of 80 breeds studied were compared with females, sexual dimorphism (differences in a t-test at the level of $P < 0.01$) emerged for head length in 5 breeds, for head width in 10 breeds and in CI for 2 breeds. The 2 breeds that showed sexual dimorphism in CI showed no difference (at the level of $P < 0.01$) in either length or width. These results suggest that all 3 types of dimorphism in head morphometrics must be considered separately. Although the longer and wider heads in males may be predicted because, within a breed, they are expected to be generally bigger animals, the sexual dimorphism in CI is of interest. It may belie differences in brain shape and even predict differences in health, welfare, and behavior.

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Introduction

Sexual dimorphism is defined as any morphological difference between male and female of the same species. Dimorphism is not a single feature—it is not expressed uniformly across species and is not due to a single cause (Plavcan, 2012). It results from a polygenetic interaction with additional nongenetic influences. Better characterizing sexual dimorphism has a number of advantages, including helping to explain morphological variations within biological populations and potential sex-linked health problems (Frayer and Wolpoff, 1985).

The dog (Canis lupus familiaris) is a direct descendant of the gray wolf (Canis lupus), but shows a number of behavioral and morphological differences, including body size, shorter muzzle, and smaller dentition (Serpell, 1995). In fact, modern dogs now show more morphological diversity than any other species, primarily as the result of non-natural selection pressure inherent in breeding practices. Size variation has been associated with 2 quantitative trait loci, situated on the X chromosome and autosome 15 (Lark et al., 2006). The autosomal marker is linked to insulin-like growth factor that regulates postnatal skeletal growth. More generally, the "large" trait is dominant in male dogs, whereas the "small" trait is dominant in females. Females fail to grow as large as males through inhibition of major gene networks linked to growth (Lark et al., 2006). Sexual dimorphism in dogs therefore has a fundamental genetic basis and recapitulates trends seen in several mammals, including the ancestral wolf (Hillis and Mallory, 1996). Canine sexual dimorphism is further emphasized by written breed standards for purebred dogs that commonly stipulate that height in males be larger than females.

Circulating testosterone concentrations are associated with bone growth, specifically cranial width growth in several mammals (Stirrat and Perrett, 2010). The canine skull also exhibits more morphological variation than any other species (Roberts et al., 2010) and is of particular interest because of potential correlates with brain development and behavior. Skull morphology can be parsimoniously characterized by the ratio of head width divided by length, known as cephalic index (CI). Roberts et al. (2010) examined the gross morphology of the brain and olfactory lobes in dogs at the extreme ends of CI. High CI (characteristic of brachycephalics) was

Table 1
The means of head length, head width, and cephalic index for male (n = 6) and female (n = 6) representatives of 80 breeds of dog

Breed	Length, mean (±SD)		Width, mean (±S.D)		Cephalic index, mean (±SD)	
	Female	Male	Female	Male	Female	Male
Afghan hound	20.4 (±1.6)	19.8 (±1.4)	9.5 (±1.1)	10.3 (±0.6)	**46.8 (±3.9)**	**52.1 (±2.3)**
Akita	22.2 (±1.9)	22.2 (±2.7)	12.5 (±0.6)	12.9 (±0.6)	56.2 (±3.3)	58.5 (±8.4)
Alaskan malamute	21.9 (±1.7)	22.0 (±2.0)	12.7 (±1.5)	12.8 (±1.4)	58.0 (±6.6)	58.2 (±6.9)
American Staffordshire terrier	18.2 (±1.5)	18.4 (±0.8)	11.7 (±0.4)	12.8 (±0.8)	64.8 (±1.7)	70.0 (±4.4)
Australian cattle dog	17.5 (±1.2)	18.6 (±1.3)	**10.6 (±0.7)**	**11.7 (±0.6)**	60.3 (±10.0)	62.9 (±7.3)
Australian kelpie	17.2 (±0.7)	17.6 (±1.7)	9.7 (±1.4)	10.0 (±0.5)	56.2 (±6.3)	57.3 (±5.7)
Australian shepherd	**16.8 (±2.3)**	**20.3 (±1.3)**	**9.1 (±0.3)**	**10.5 (±0.2)**	54.9 (±6.9)	51.9 (±6.1)
Australian terrier	14.2 (±1.6)	14.7 (±1.0)	8.1 (±0.2)	8.6 (±0.6)	57.5 (±3.1)	58.2 (±3.6)
Basenji	14.6 (±1.4)	15.6 (±0.9)	8.2 (±0.5)	8.6 (±0.4)	56.5 (±8.2)	55.1 (±4.6)
Basset hound	19.7 (±1.3)	20.1 (±0.8)	9.5 (±0.8)	10.4 (±1.2)	48.2 (±6.7)	51.9 (±6.1)
Beagle	15.6 (±0.4)	15.9 (±1.1)	9.0 (±0.5)	9.8 (±0.5)	57.7 (±2.2)	61.8 (±2.3)
Bearded collie	19.2 (±1.2)	20.2 (±0.7)	9.8 (±1.4)	10.1 (±2.0)	51.0 (±7.1)	50.1 (±9.8)
Bernese mountain dog	20.9 (±1.6)	20.5 (±1.9)	12.8 (±0.2)	12.3 (±0.3)	61.2 (±3.6)	60.7 (±6.3)
Bichon frise	11.0 (±1.0)	11.7 (±1.3)	7.2 (±0.5)	7.1 (±0.6)	65.6 (±8.8)	61.5 (±7.7)
Border collie	16.8 (±1.1)	18.6 (±1.0)	9.9 (±0.4)	10.1 (±0.7)	59.0 (±3.5)	54.4 (±5.0)
Borzoi	23.5 (±2.0)	23.2 (±1.8)	8.7 (±0.5)	9.3 (±0.4)	37.1 (±9.7)	40.2 (±6.5)
Boston terrier	10.7 (±0.9)	9.9 (±0.5)	9.1 (±0.6)	9.2 (±0.6)	85.6 (±6.4)	92.6 (±1.8)
Boxer	16.0 (±1.8)	16.8 (±0.7)	10.6 (±1.2)	11.3 (±0.6)	66.3 (±6.4)	67.2 (±5.6)
British bulldog	14.5 (±1.1)	14.8 (±1.3)	12.0 (±0.7)	13.3 (±0.5)	83.0 (±5.3)	90.2 (±3.1)
Bull terrier	21.8 (±2.2)	20.7 (±1.0)	11.6 (±2.0)	11.9 (±1.5)	53.4 (±11.2)	57.8 (±10.6)
Bullmastiff	17.9 (±1.9)	19.1 (±1.8)	13.9 (±0.3)	15.3 (±0.3)	77.9 (±2.8)	80.3 (±3.6)
Cairn terrier	13.9 (±1.2)	14.4 (±1.5)	8.7 (±0.9)	9.1 (±1.0)	62.8 (±3.3)	64.0 (±8.1)
Cavalier King Charles spaniel	10.0 (±1.1)	11.0 (±0.8)	7.6 (±0.6)	8.3 (±0.9)	76.8 (±2.7)	75.7 (±6.2)
Chihuahua	8.7 (±1.0)	8.9 (±0.6)	6.3 (±0.7)	6.3 (±1.1)	72.9 (±4.6)	70.8 (±3.2)
Chinese crested dog	12.3 (±0.6)	12.6 (±0.9)	7.4 (±0.5)	7.5 (±0.4)	60.1 (±3.4)	59.7 (±6.7)
Cocker spaniel	17.0 (±1.4)	17.7 (±1.5)	8.6 (±0.6)	8.3 (±0.9)	50.7 (±4.5)	47.0 (±3.7)
Cocker spaniel (American)	11.7 (±1.0)	13.7 (±1.3)	**7.1 (±1.0)**	**7.9 (±1.8)**	61.0 (±6.5)	57.8 (±6.3)
Collie (rough)	19.1 (±2.6)	20.1 (±1.7)	**8.7 (±1.5)**	**9.4 (±0.5)**	46.2 (±11.9)	47.1 (±6.4)
Dachshund (miniature)	13.5 (±1.7)	14.5 (±1.4)	8.7 (±0.6)	9.4 (±0.3)	46.2 (±6.9)	47.1 (±3.5)
Dalmatian	18.6 (±1.0)	20.0 (±1.3)	**9.5 (±0.7)**	**10.3 (±1.0)**	51.2 (±4.7)	51.9 (±4.6)
Doberman	21.3 (±2.3)	22.9 (±2.2)	9.9 (±0.4)	10.4 (±0.7)	47.0 (±10.2)	45.6 (±10.8)
English setter	20.5 (±2.3)	21.4 (±1.7)	9.3 (±0.4)	9.0 (±0.7)	45.3 (±5.5)	41.8 (±1.9)
English springer spaniel	18.0 (±1.4)	18.2 (±0.8)	8.9 (±0.3)	9.4 (±0.6)	49.3 (±2.1)	52.0 (±3.3)
Finnish Lapphund	18.2 (±1.1)	17.2 (±2.3)	9.5 (±1.4)	10.6 (±0.2)	52.4 (±8.9)	62.3 (±7.7)
Fox terrier (smooth)	17.6 (±1.0)	17.6 (±1.3)	7.7 (±0.7)	8.0 (±0.7)	44.1 (±5.3)	45.9 (±6.0)
French bulldog	10.5 (±1.7)	10.6 (±0.7)	10.6 (±1.0)	10.7 (±0.7)	101.8 (±2.1)	101.3 (±2.7)
German pinscher	17.9 (±1.1)	18.6 (±2.8)	9.0 (±0.4)	9.2 (±0.3)	50.7 (±5.5)	50.6 (±8.4)
German shepherd dog	21.6 (±1.7)	21.8 (±2.6)	10.4 (±1.0)	11.3 (±0.7)	48.4 (±8.0)	52.4 (±9.2)
German shorthaired pointer	21.1 (±1.5)	20.7 (±2.3)	10.1 (±0.8)	10.4 (±0.6)	48.3 (±4.0)	50.7 (±3.2)
Golden retriever	19.6 (±2.2)	20.6 (±1.2)	10.8 (±0.5)	11.6 (±0.4)	55.6 (±3.0)	56.5 (±4.0)
Gordon setter	20.0 (±1.4)	20.5 (±1.8)	9.7 (±0.6)	10.4 (±0.9)	48.6 (±7.1)	50.6 (±8.5)
Great Dane	22.9 (±1.8)	23.8 (±2.9)	12.8 (±0.4)	13.3 (±0.5)	56.5 (±5.6)	56.7 (±3.7)
Greyhound	**19.7 (±1.2)**	**21.9 (±0.7)**	**9.0 (±0.6)**	**10.3 (±0.6)**	45.8 (±5.8)	46.8 (±5.7)
Griffon Bruxellois	7.6 (±0.2)	7.3 (±0.6)	7.5 (±0.6)	6.9 (±1.0)	98.3 (±1.5)	94.7 (±2.9)
Havanese	10.9 (±2.1)	12.3 (±1.3)	7.7 (±0.8)	8.0 (±0.9)	72.2 (±6.1)	65.9 (±5.5)
Hungarian vizsla	20.8 (±1.5)	21.2 (±2.7)	10.0 (±0.8)	10.8 (±0.7)	48.3 (±9.1)	51.3 (±3.0)
Irish setter	22.5 (±2.3)	21.4 (±1.2)	9.7 (±0.6)	9.4 (±0.5)	43.4 (±3.2)	43.8 (±3.7)
Italian greyhound	12.0 (±0.8)	12.5 (±0.9)	6.5 (±0.8)	6.8 (±0.3)	54.2 (±3.4)	54.5 (±2.3)
Jack Russell terrier	12.4 (±1.5)	13.7 (±2.4)	7.8 (±0.9)	8.0 (±0.3)	63.6 (±2.9)	59.3 (±2.6)
Japanese spitz	12.2 (±1.4)	11.1 (±1.3)	7.9 (±0.6)	8.4 (±0.4)	65.7 (±3.3)	76.2 (±3.9)
Keeshond	14.1 (±2.0)	15.4 (±1.3)	8.0 (±0.4)	9.3 (±0.4)	56.5 (±7.3)	60.2 (±3.2)
Labrador retriever	20.6 (±1.1)	21.2 (±1.2)	11.5 (±0.8)	11.8 (±0.8)	56.1 (±4.8)	55.8 (±4.8)
Lagotto Romagnolo	16.8 (±1.7)	15.8 (±1.2)	9.7 (±0.4)	9.4 (±0.5)	57.7 (±1.2)	59.4 (±2.2)
Leonberger	22.2 (±1.3)	22.2 (±0.8)	12.1 (±0.6)	11.8 (±0.5)	54.5 (±2.8)	53.1 (±4.4)
Maltese	**8.5 (±0.5)**	**10.1 (±0.9)**	5.9 (±0.3)	6.6 (±0.5)	68.8 (±6.8)	65.3 (±2.6)
Mastiff	19.6 (±1.4)	22.4 (±2.2)	14.1 (±0.6)	15.3 (±1.0)	72.6 (±4.4)	68.9 (±5.8)
Neapolitan mastiff	19.1 (±1.7)	20.2 (±1.8)	13.9 (±0.6)	14.5 (±0.8)	73.2 (±2.8)	72.0 (±5.2)
Norwegian elkhound	18.7 (±0.6)	19.0 (±1.7)	9.8 (±1.0)	11.0 (±0.4)	52.3 (±3.5)	58.0 (±1.9)
Old English sheepdog	18.1 (±1.2)	19.4 (±1.0)	11.2 (±1.6)	10.6 (±1.6)	62.2 (±6.7)	54.4 (±8.4)
Papillon	9.1 (±0.8)	9.5 (±0.8)	6.5 (±0.4)	6.6 (±0.6)	71.2 (±2.5)	70.1 (±3.9)
Pomeranian	8.1 (±0.5)	8.5 (±0.4)	**6.0 (±1.0)**	**6.6 (±1.3)**	73.9 (±4.2)	77.9 (±2.7)
Pug	9.1 (±0.5)	9.0 (±0.8)	8.9 (±0.9)	8.9 (±0.2)	98.0 (±8.7)	99.1 (±3.9)
Rhodesian ridgeback	21.1 (±1.0)	22.2 (±1.6)	**10.5 (±0.6)**	**11.3 (±0.4)**	49.7 (±2.0)	51.2 (±3.9)
Rottweiler	19.7 (±1.0)	19.6 (±1.3)	12.5 (±0.4)	12.3 (±0.4)	64.0 (±2.0)	63.1 (±2.9)
Saluki	19.3 (±1.7)	19.1 (±0.7)	8.6 (±0.3)	9.0 (±0.4)	44.8 (±8.1)	46.9 (±9.4)
Samoyed	16.6 (±2.0)	18.4 (±2.2)	10.2 (±1.0)	10.6 (±1.1)	62.2 (±5.9)	58.6 (±10.1)
Schnauzer	17.5 (±2.6)	16.8 (±2.3)	9.1 (±0.3)	9.1 (±0.2)	52.7 (±1.5)	54.6 (±3.4)
Schnauzer (miniature)	12.5 (±1.2)	14.4 (±0.8)	6.8 (±0.7)	7.5 (±0.4)	55.0 (±1.7)	51.8 (±3.0)
Scottish terrier	**16.9 (±0.4)**	**19.3 (±1.7)**	**7.7 (±0.5)**	**8.8 (±0.6)**	45.5 (±9.9)	46.2 (±8.3)
Shetland sheepdog	13.7 (±1.8)	15.9 (±1.6)	7.6 (±0.6)	7.2 (±1.2)	**55.7 (±2.4)**	**45.2 (±5.4)**
Shih tzu	9.9 (±1.4)	9.5 (±1.7)	7.3 (±0.9)	7.9 (±0.8)	74.1 (±4.9)	84.8 (±8.6)
Siberian husky	18.1 (±1.6)	20.0 (±1.5)	9.9 (±0.5)	10.9 (±0.7)	55.2 (±3.5)	54.6 (±3.9)