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Research Article

Sex Ratios of Byzantine Street Dogs in Constantinople: A Zooarchaeological Assessment

Şamil SEFERGİL [1], William PEREZ [2], Seyyid Said SABANCI [1], Mehmet KARTAL [3], Haluk ÖMER [4], Vedat ONAR [1 (*)]

[1] Muğla Sıtkı Koçman University, Milas Faculty of Veterinary Medicine, Department of Anatomy, TR-48000 Muğla - TÜRKİYE
[2] Universidad de la República, Faculty of Veterinary Medicine, Department of Anatomy, 12300 Montevideo, URUGUAY
[3] İstanbul Topkapı University, Faculty of Health Science, TR-34310 İstanbul - TÜRKİYE
[4] Ambarlı Neighbourhood, Cumhuriyet Street. 46/A, TR-34310 İstanbul - TÜRKİYE

(*) **Corresponding author:**
Vedat Onar
Phone: +90 252 211 11 65
Cellular phone: +90 532 714 15 04
E-mail: vedatonar@mu.edu.tr

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Abstract

Geometric morphometric and fluctuating asymmetry investigations provide robust methodologies for elucidating the living conditions, environmental stressors, and ecological contexts of ancient species using archaeological animal remains. Prior research on Byzantine-era canine skulls discovered at the Theodosius Harbor excavations in Yenikapı, Istanbul, has indicated significant asymmetry in these specimens. This indicates that these dogs were not domesticated companions but rather feral canines (pariahs) contending with severe environmental challenges. This study aims to clarify the demographic composition, namely the sex distribution and sexual dominance, of a largely 'mesocephalic' dog community residing in the urban setting of Byzantine Constantinople. A total of 378 canine skulls from the excavation site were analysed. Sex determination was based on 'basioccipital index' values derived from the length and width measurements of the basioccipital area. The acquired data were subjected to statistical analysis utilizing ANOVA and Kruskal-Wallis tests. Analysis demonstrated statistically significant differences between sexes in the examined population. Among those with determinable sex, the proportion of females (55.6%) surpassed that of males, signifying female predominance. This discovery verifies that dogs in the Byzantine capital encompassed not only working canines under human supervision but also a free-roaming, interbreeding stray population possessing its own social dynamics. The numerical predominance of females indicates their pivotal role in reproductive strategies, facilitating lineage continuity and population sustainability within the demanding urban ecology.

Keywords: Zooarchaeology, Dog, Morphometry, Sex determination, Basioccipital index

Introduction

Geometric morphometrics, a fundamental technique for assessing morphological variations, facilitates shape analysis in biological contexts [1,2]. This approach not only indicates the extent of asymmetry but also elucidates the variation patterns of the analysed structures [1].

In morphometric investigations, fluctuating asymmetry a distinct form of asymmetry has been linked to detrimental situations such as stress and hybridization [1] and is recognized as a marker of physiological stress [3]. Fluctuating asymmetry serves as an indicator of environmental stress [4], and its extent generally escalates with heightened environmental stress [5-7]. This method has enabled the assessment of cranial asymmetry and its orientation in dogs [8] Research on Byzantine dogs, in contrast to contemporary domestic breeds, has provided insights about their living standards and conditions [9]. The elevated levels of fluctuating asymmetry identified in these investigations were construed as evidence that canines in Constantinople did not inhabit household settings but were, rather, street dogs.

Understanding the status of Byzantine canines is best achieved through the assessment of both literary sources and zooarchaeological evidence. Byzantine sources indicate that dogs were mostly utilized for hunting, herding, and guarding, but there were also guide dogs for the visually impaired and little 'lap dogs' [10]. Despite being historically appreciated for their loyalty and proximity to people, religious scriptures and dream interpretations frequently portray them unfavourably as emblems of malevolence, humiliation, and animosity [11]. During

crises, this escalated to persecution [10]. Reports indicate that Constantinople accommodated both domesticated dogs and wild animals in its urban environment [10]. Although these animals encountered sporadic persecution in the streets or residences of Constantinople [10], it is well-documented that they were not utilized as a source of meat [10,12]. While dog bones yield significant insights for zooarchaeologists, prudence is necessary when juxtaposing them with contemporary breeds [13]. Regardless of breed comparisons, specific discoveries in archaeological canine remains (e.g., fracture treatments) indicate human influence. These animals, believed to have roamed freely on the streets of Constantinople, occasionally endured hardships during the city's conquests [10]. Substantial evidence for street dogs is derived from a trash site discovered during the Via Carminiello ai Mannesi excavations in Naples, which yielded numerous canine skeletons. It has been proposed that these were probably feral canines pursuing food remnants and rodents [12]. Likewise, canine remains from the Theodosius Harbor region in Constantinople indicate that these were feral animals rather than domesticated pets [9].

This study aims to ascertain the sex distribution and function of these animals, identified as the street dogs of Constantinople [9], inside urban environments. We sought to determine whether male or female dominance was predominant in supporting these generations acclimated to street life. The 'basioccipital index' values [14,15] were utilized for sex determination, with the objective of assessing which sex was more prevalent in interactions with humans.

Material and Methods

Ethics Statement

The materials and methods used in this study were approved by the Muğla Sıtkı Koçman University Local Ethics Committee as not requiring ethical committee approval (E-40051172-050.04-1109624).

The Site and The Background of The Assemblage

This research analysed 378 canine skulls discovered during excavations (2004-2013) at the Yenikapı station, the primary transfer hub for the Metro and Marmaray tunnel on the European side. Excavations verified that this region, referred to as 'Langa Bostanları' during the Ottoman era, was the historical Theodosius Harbor [16], presumably founded by Emperor Theodosius I (AD 379-395) in a cove that extended markedly inland [17]. Excavations in this harbor region uncovered multiple ancient shipwrecks, archaeological artifacts, and animal skeletal remains. The typological classification of the zooarchaeological material revealed that 97% of the dogs were mesocephalic [18]. In addition to this morphometric study, geometric morphometric analysis of fluctuating asymmetry in the same skulls indicated that these animals were probably street dogs suffering from inadequate dietary conditions [9]. This study was designed to investigate the sexual distribution of street canines and identify the dominant sex in urban environments.

Morphometry of The Skulls

A total of 378 skulls from the Byzantine era were analysed [19]. Sex estimation was conducted utilizing morphological [20] and basioccipital morphometric data [14,15], with the results subjected to statistical analysis. Basioccipital measurements were obtained from each skull to compute the index. A digital caliper with a precision of 1 mm was employed for all measurements. Measurements of the Basioccipital [14,15] *(Fig. 1)*.

Length: A line drawn between the most medial points of the jugular foramina and the Basion (in the median line).

Breadth: Distance between the most medial points of the left and right jugular foramina.

Calculated index [14,15];

Basioccipital index = breadth * 100/length

Investigation of other markings (morphological examination): The condition of the sagittal crest, occipital crest, and basioccipital surface.

Sex Assessment

Basioccipital index values below 123 were categorized as male, whereas those over 136 were categorized as female [15] *(Fig. 2, Fig. 3)*. Values that lie between these two thresholds were categorized as morphologically ambiguous or indeterminate [20].

Statistical Analyses

Statistical analyses of the measurements and derived indices were performed using SPSS 21.0 (Version 21.0,

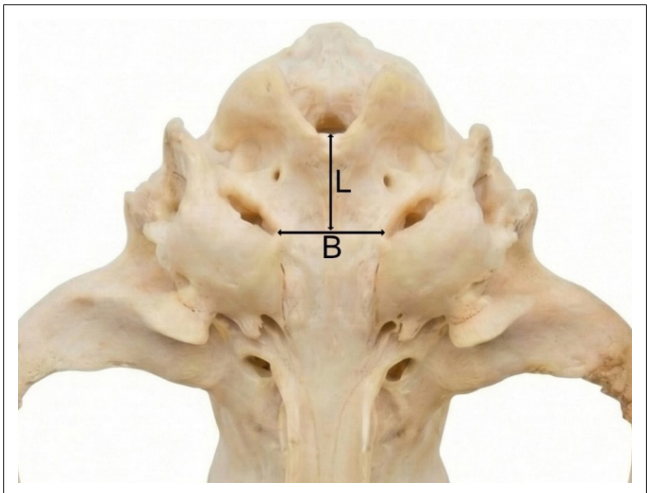

Fig 1. The measurements of the basioccipital region. B. Breadth, L. Length

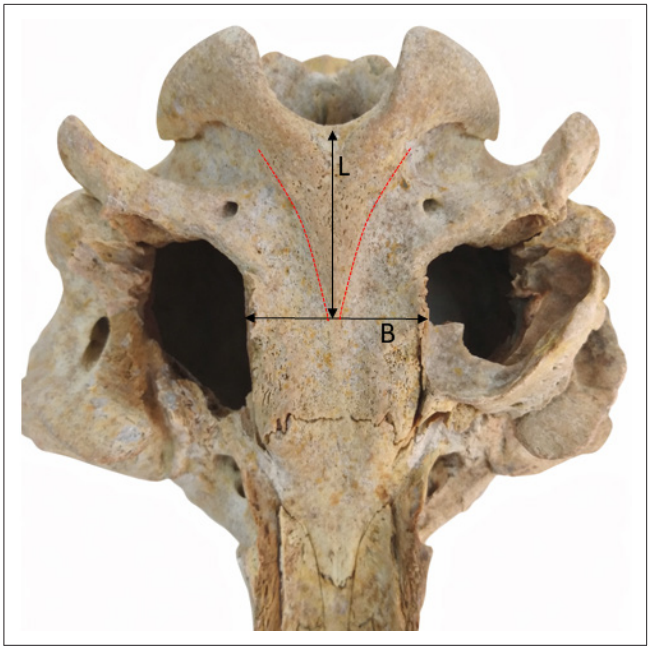

Fig 2. View of the basioccipital bone in male dogs (triangular shape with a pointed apex). B. Breadth, L. Length

Fig 3. View of the basioccipital bone in female dogs (open-ended triangle). B. Breadth, L. Length

SPSS Inc., Chicago, IL, USA). In the analysis of the three groups -those of undetermined sex, females and males- the Kruskal-Wallis test, a non-parametric test, was preferred as the data did not follow a normal distribution. However, in the analysis of the female and male groups, ANOVA was preferred due to the normal distribution of the variances.

Results

Dog skulls were analysed morphologically, although morphometric data constituted the principal foundation for sex classification. Normality assessments for each group demonstrated that the variables followed a normal distribution. Subsequent to this evaluation, statistical analysis commenced. *Table 1* presents the mean values and standard deviations of morphometric measurements categorized by sex.

The One-Way ANOVA test revealed statistically significant differences between the male and female groups (P<0.01). Post-hoc analyses (Tukey HSD) validated substantial differences among all pairs. Consequently, owing to the presence of non-homogeneous variances, the Kruskal-Wallis test, a non-parametric option, was performed.

The Kruskal-Wallis test indicated significant differences among the three groups concerning the 'Index' variable. This outcome aligns with the preliminary One-Way ANOVA results. The elevated H-statistic (303.800) in the Kruskal-Wallis test signifies a significant disparity across the groups.

Table 2 indicates that 24.6% of the dogs could not be categorized into any sex classification based on morphometric measures. Nevertheless, 75.4% of the skulls conformed to the sex classification ranges delineated in the sex scale [14,15].

Skulls that were not classified by sex, although being morphologically categorized with a predominance of females, were omitted from the morphometric sex determination. Morphological characteristics beyond the index, including the position of the sagittal crest, occipital crest, and basioccipital surface, were assessed.

Table 1. *Length and breadth measurements of the basioccipital in dogs*

Sex	Statistical	Length	Breadth
Male	Mean	13.1[a]	15.3[a]
	N	75	75
	SD	1.4	1.7
Female	Mean	11.6[b]	17.2[b]
	N	210	210
	SD	1.2	1.7
Unidentified	Mean	12.4[c]	16.2[c]
	N	93	93
	SD	1.4	1.8

[a,b,c] *Values within a row with different superscripts differ significantly at P<0.01*

Table 2. *Basioccipital indices in the dogs*

Sex	N	Mean	SD
Male	75	117.1[a]	6.0
Female	210	149.2[b]	10.8
Unidentified	93	130.5[c]	3.2

[a,b,c] *Values within a row with different superscripts differ significantly at P<0.01*

Discussion

Geometric morphometrics, increasingly employed in recent years to assess morphological form variations, facilitates the examination of anatomical structures within biological diversity [1,21-23]. A significant application of this technology is fluctuating asymmetry. Fluctuating asymmetry, a type of asymmetry that includes directional and antisymmetric, is regarded as a crucial indicator of living conditions, standards, and environmental impacts on biological structures [1,5,4]. Living environment and related nutrition exert stress on fluctuating asymmetry, leading to heightened asymmetry [4,9]. Geometric morphometric investigations on dogs have unequivocally illustrated this [23,24]. Marked disparities in fluctuating asymmetry have been noted between canines residing on the streets and those under human supervision and care. High levels of fluctuating asymmetry in the Byzantine dog skulls examined in this study indicated that these individuals were more susceptible to environmental influences in urban settings [9]. Byzantine records indicate that, in addition to domesticated dogs, wild or free-roaming animals coexisted inside urban environments [10]. Typologically, 97% of these Byzantine dogs, as indicated by fluctuating asymmetry investigations [9], were classified as mesocephalic [18]. While prior research emphasized the environmental stressors faced by dogs in Constantinople [9,4], the current study sought to investigate which sex predominantly suited to urban life. The port region in Constantinople, which commenced accumulating alluvium from the Lykos stream in the 7th century [16,25], was a disposal location for deceased animals until around the 13th century [26]. The site, recognized as Theodosius Harbor [16], produced no evidence indicating the eating of urban dogs for meat [26]. This is corroborated by analogous, though infrequent, Byzantine research [12,10]. Statistical examinations of the morphometric and index values of these Yenikapı Byzantine dogs reveal considerable differences between male and female individuals. The elevated H-index (303.800) from the Kruskal-Wallis test signified differences. Although each group exhibited a homogeneous distribution internally, considerable differences between groups were evident. The 87.5% accuracy rate of sex determination in basioccipital index computations [14] is notably high. Based on this data, index calculations indicated a greater distribution for females. 55.6% of the skulls were attributed to female individuals. Females outnumbered males in the urban dog population. This indicates a slight female predominance within the social hierarchies of these dogs, which were not categorized as human-fed hunting, herding, or guard dogs [10]. The morphological analysis of the 24.6% unclassified canines, which predominantly exhibited female characteristics, was excluded from the statistical assessment.

In summary, the sex ratio of street dogs in Byzantine Constantinople was predominantly female. Given that dog remains from the Yenikapı excavations represent around 4% of the total findings [26], it is clear that canines were integral to social life and that a predominantly female population was present in the city. The predominance of Mesocephalic individuals [18] indicates that hybrids were prevalent in urban environments rather than canines subjected to human oversight and management. We propose that females had a pivotal role in the reproductive success of these dog lineages.

Declarations

Availability of Data and Materials: Data and Materials are available from the corresponding author (V.O.).

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Author Contributions: Conceptualization/Resources/Supervision/Project administration VO; Formal analysis, SSS; Investigation, MK, HÖ, VO, WP, SSS, ŞS; Methodology, VO and ŞS; Writing - original draft, VO and ŞS; Writing - review & editing, WP, HÖ, SSS and WP.

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