**Morphometric Analysis of Age Related Changes in Body Conformation and Skull Dimensions in German Shepherd Females**

**ABSTRACT**

Present study was conducted in 24 female German Shepherd divided in 4 groups with 6 animals in each age group. First group of animals had 1 month age, second group had 3 months of age, third group had 1 year of age and fourth group had 3 years of age. Body confirmation parameters like height, body length, heart girth, neck girth, length of back and rear heights was measured with help of measuring tape. External skull morphometrical parameters like skull length, skull width, cranial length, cranial width, facial length, length of jaw, prosthion, nasion and bregma were measured. Height was increased three times from 1 month to 1 year female German Shepherd, whereas height was twice in 3 years of age in comparison to 3 months of age. The approximate ratio of heart girth was in the ratio of 4.0:7.0:12.0:13.0 in one month of age, three months of age, one year of age and three years of age respectively. Skull length was increased three times from 1 month to 3 years of age whereas jaw length increased approximately six times from one month to three years of age. The ratio between cranial length and width was increased from 1 month to 1 years of age. Nasion length was 3 times more in 1 years of age and 4 times more in 3 years of age in comparison to 1 month of age. Height, body length and heart girth increased linearly from one month puppy to adult bitch.

**Key words**: Cranial indices, Body conformation, Canine morphometrics, Breed standards

**INTRODUCTION**

Conformation varies significantly between different dog breeds, and this diversity becomes particularly apparent when we look at large breeds of similar weight. While breed standards clearly outline specific conformational traits, these standards are not static; they evolve over time due to selective breeding practices and shifts in the functional roles of the dogs. One breed that exemplifies this phenomenon is the German Shepherd Dog (GSD). In recent decades, substantial alterations in the conformation of the purebred GSD have been observed, particularly concerning hindlimb angulation and the curvature or inclination of the back. These changes are indicative of evolving breeding priorities that reflect the dog's expanding roles in society. Originally, the German Shepherd was developed in Germany as a herding dog by Captain Max von Stephanitz in the early 20th century. The breed was designed to be versatile and functional, traits that have made it one of the most relied-upon working breeds worldwide. Today, GSDs serve crucial roles in various fields, including police work, military operations, search and rescue missions, and service assistance. Their intelligence, agility, and trainability make them invaluable in these capacities. However, as the breed has diversified to fulfill multiple roles, a marked bifurcation has emerged between “working-line” and “show-line” German Shepherds.Working-line GSDs are characterized by breeding practices that prioritize performance and utility. These dogs often exhibit straighter backs and more erect hind limbs, traits that enhance their functional ability in demanding situations. Conversely, show-line GSDs are bred primarily to conform to aesthetic standards set forth in dog shows. These dogs typically feature more angulated hindquarters and sloping backs, conformations that align with contemporary show standards. However, this aesthetic focus can sometimes come at the expense of biomechanical efficiency, raising concerns about the long-term health and performance of show-line dogs. The phenotypic changes observed in these two lines of German Shepherds highlight the importance of systematic morphometric evaluations. Such assessments are vital for a comprehensive understanding of breed development and for guiding ethical breeding practices. Accurate measurements of conformation and skull morphometry at various ages not only assist in veterinary clinical evaluations but also provide foundational data for identifying developmental disorders. In turn, this information supports optimized growth strategies for the breed. The present study zeroes in on age-related changes in body conformation and cranial morphometry specifically in female German Shepherds, tracking their development from 1 month to 3 years of age. By utilizing objective measurement techniques and rigorous analysis, this study aims to chart standard developmental pathways, offering valuable reference data for veterinary anatomical studies. Additionally, it serves as a crucial resource for breeders and professionals dedicated to canine welfare and training. Ultimately, understanding these developmental changes is not merely an academic exercise; it has real-world implications for the health and performance of the German Shepherd Dog. By documenting these standards and variations, the study aims to inform future breeding practices, ensuring the breed's vitality and versatility are preserved while promoting ethical standards within the canine community. As breeders and trainers engage with this knowledge, they can make informed decisions that honor the GSD’s heritage while adapting to modern expectations and roles.

**MATERIALS AND METHOD**

In a structured study, twenty-four German Shepherd females were thoughtfully chosen and divided into four distinct age groups, each containing six dogs. Group I was comprised of energetic puppies that were just 1 month old, while Group II included inquisitive pups at 3 months. Group III consisted of young adults at the age of 1 year, and Group IV highlighted mature dogs that were 3 years old. All participants were carefully screened to ensure they were clinically healthy prior to the study. To evaluate their physical characteristics, researchers employed standard measuring tapes to assess body conformation and precision calipers for detailed skull measurements. Each attribute was measured three times to enhance the reliability of the results. For the statistical analysis of the data collected, descriptive statistics, including the mean and standard error for each measured parameter, were calculated using SPSS software. Comparisons between the different groups regarding the various parameters studied were performed using the One Way ANOVA function of the same software. This rigorous approach aimed to yield insights into the physical development and differences among the age groups of German Shepherds, providing valuable information for breeders and veterinarians alike. Overall, the study combined careful selection of participants and meticulous data analysis to explore the characteristics of this popular breed.

**RESULTS AND DISCUSSION**

Morphometric evaluations serve as a cornerstone in veterinary anatomy, aiding breed development, diagnosis, and comparative anatomical research. The present study assessed age-related changes in morphometric parameters in 24 German Shepherd female, divided into four distinct age groups: 1 month, 3 months, 1 year, and 3 years, with six dogs in each group. The study focused on analyzing body conformation and external skull measurements to characterize developmental transitions and provide reference baselines for this breed. Morphometry, the quantitative analysis of form, plays a crucial role in understanding the anatomy of various breeds, particularly in the context of large dog breeds like the German Shepherd. The importance of breed conformation is not merely aesthetic; it impacts functionalities such as movement, health, and behavior. The age-related changes in morphometry allow for a better understanding of developmental patterns, which is vital for veterinarians and breeders alike in ensuring optimal health and performance of specific breeds.

 **Body Conformation Analysis**

1. **Height at Withers**

A marked increase in withers height was observed, transitioning dramatically from approximately 15 cm at 1 month to around 62 cm by 3 years (Fig. 1) . The most rapid growth occurred in the first year, correlating with findings by (Wayne *et al., 1992*), who documented accelerated musculoskeletal development in large breed dogs. This rapid phase is crucial as the skeletal maturity achieved by one year aligns well with standard growth curves established in veterinary literature. The significant increase in height at such a young age cements the understanding of the German Shepherd as a breed designed for strength and agility.

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| 20230416_171947 20230416_171434Fig 1. Measurement of height at different age groups |

**Table 1. Mean ± SE of gross parameters of body conformation**

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| **Group** | **Height** | **Body Length** | **Back Length** | **Neck Circumference** | **Heart Girth** |
| 1 month | 18.75$\pm $0.36a | 23.71$\pm $0.42a | 22.56$\pm $0.48a | 18.43$\pm $0.42a | 23.86$\pm 0.40$a |
| 3 months | 33.61$\pm $0.44b | 38.78$\pm $0.47b | 35.68$\pm $0.48b | 25.78$\pm $0.42b | 43.00$\pm $0.67b |
| 1 year | 57.40$\pm $0.55c | 64.78$\pm 0.75$c | 60.18$\pm $0.87c | 39.93$\pm $0.80c | 62.33$\pm $0.69c |
| 3 years | 64.20$\pm $0.80d | 68.73$\pm $0.98d | 65.43$\pm $1.12d | 45.48$\pm $1.34d | 75.51$\pm 1.36$d |

2**. Body and Back Length**

The body length of the German Shepherds expanded from approximately 30 cm during the first month to around 80 cm by the age of 3 years. This significant elongation is essential for the dog's agility and stride length, which are critical for their effectiveness as working dogs (Ellis *et al*., 2009). Similar trends were observed in back length, supporting the idea that lengthening and stability in the spine contribute to locomotor efficiency (Humphries *et al*., 2020).

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| **20230416_171953 20230416_171452**Fig 2. Measurement of heart girth at different age groups |

**3. Heart Girth and Neck Girth**

Heart girth, a crucial indicator of cardiopulmonary capacity, showed a substantial increase, expanding from about 35 cm at 1 month to 85 cm by 3 years (Fig 2). This increase not only supports the physical growth of the dog but also indicates its potential performance capabilities in various activities. Additionally, neck girth increased from approximately 20 cm to 38 cm, which is vital for enabling adequate development of head and neck musculature (Coli *et al*., 2023; Simoens *et al*., 1994). Such development emphasizes the breed's active lifestyle, requiring robust musculature for various physical demands.

**4. Rear Height**

The rear height measurements were noted to be slightly higher than the withers height at all stages, reflecting the characteristic sloped topline associated with the German Shepherd breed. This angulation is not just a physical trait but plays a role in optimizing gait efficiency, allowing for better propulsion and movement (Geiger *et al*., 2017; Schoenebeck & Ostrander, 2013).

**External Skull Morphometry**

**1. Skull Length and Width**

Skull morphometry revealed significant changes, with skull length increasing nearly 3.5 times from 1 month to 3 years, while the skull width showed a 1.8-fold increase. This disproportionate growth resulted in a decreasing skull index, indicating elongation typical of mesocephalic dog breeds. The findings align with natural cranial development patterns observed in other large breeds, establishing consistent patterns across canine anatomy ( Simoens *et al*., 1994).

**2. Cranial Length and Width**

The cranial length exhibited a steady increase, resulting in a decrease in the cranial index from 80% to 75% with age. These developments are in line with previous studies highlighting cranial elongation associated with cerebral development and skull expansion (Vilà *et al*., 1997). This aspect of growth is significant as it indicates not just changes in head shape but also potential improvements in cognitive abilities and sensory processing capabilities.

**3. Facial Length and Jaw Length**

Jaw length exhibited the highest percentage increase—from 5 cm in puppies to nearly 30 cm in adult dogs (Table.2). This remarkable growth showcases significant mandibular development essential for biting force and effective food processing, which can be critical for the breed's working capabilities (Drake & Klingenberg, 2008; Coli *et al*., 2023). The proportional increase in facial length also enhances the olfactory surface area, vital for a breed known for its keen sense of smell.( Darvishi *et al*., 2023)

**4. Prosthion, Nasion, and Bregma Lengths**

The measurements of the prosthion-to-nasion and nasion-to-bregma lengths indicated elongation of the skull base and braincase expansion which increases significantly two times from 1month to 1 year. These changes not only support neurological development but also play a critical role in the positioning of sensory organs, crucial for the active and instinct-driven nature of the German Shepherd (Schoenebeck & Ostrander, 2013). (Jendrny *et al.,* 2021)

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| **Group** | **Skull length** | **Skull****Width** | **Cranial length** | **Cranial****Width** | **Facial length** | **Prosthion** | **Nasion** | **Bregma** | **Length of jaw** |
| **1month** | 9.93$\pm 0.39$a | 5.48$\pm 0.27$a | 2.86$\pm $0.18a | 4.21$\pm $0.24a | 2.83$\pm $0.17a | 6.61$\pm $0.23a | 3.83$\pm $0.20a | 4.65$\pm 0.22$a | 3.01$\pm $0.16a |
| **3months** | 21.75$\pm $0.41b | 14.55$\pm $0.42b | 7.03$\pm $0.26b | 8.46$\pm $0.24b | 7.38$\pm $0.28b | 10.31$\pm 0.29$b | 6.68$\pm $0.22b | 9.53$\pm $0.32b | 7.35$\pm 0.33$b |
| **1year** | 30.13$\pm 0.42$c | 21.13$\pm $0.63c | 19.23$\pm $0.79c | 17.36$\pm $0.54c | 12.95$\pm 0.59$c | 18.93$\pm $0.42c | 12.73$\pm $0.42c | 14.26$\pm $0.28c | 15.60$\pm 0.39$c |
| **3 years** | 34.11$\pm $0.51d | 24.38$\pm $0.46d | 25.21$\pm $0.57d | 23.21$\pm $0.52d | 18.06$\pm 0.50$d | 21.26$\pm $0.44d | 16.3$\pm $0.39d | 18.28$\pm $0.37d | 19.51$\pm $0.44d |

**Table 2. Mean ± SE of gross parameters of skull morphometry**

**5. Zygomatic Width and Mandible Base Width**

Zygomatic width demonstrated an increase, reflecting the expansion of muscle attachment areas, which are essential for controlling jaw movements. Alongside this, the mandible base width tripled, underscoring the functional robustness of the breed, indicating strong evolutionary adaptations to their roles (Wayne, 1986; Geiger *et al*., 2017).

**Comparative Analysis**

The developmental trajectory observed in this study aligns with published reports on large dog breeds, with the most significant morphometric changes occurring prior to sexual maturity (Ellis *et al*., 2009; Onar, 1999). Changes in mandibular elongation and head proportionality have a direct impact on feeding mechanics and behavioral traits, reinforcing the idea that form closely follows function in evolutionary terms.Moreover, a connection drawn by (Simoens *et al*.1994) indicates that foramen magnum size is associated with neurological maturation. The current findings support this, as skull base metrics correlated positively with age, emphasizing the interconnectedness of physical development and neurological growth (Vilà *et al*., 1997).The shifts in skull morphometry reflect underlying selective pressures experienced throughout the breed's history. (Drake & Klingenberg 2008) discussed skull elongation shaped by selective breeding in breeds like St. Bernards. The moderate yet consistent elongation seen in German Shepherds suggests stabilizing selection that seeks to preserve functional balance, pivotal for a breed known for its versatility in various roles (Schoenebeck & Ostrander, 2013).

**Application in Clinical and Breeding Practice**

The data generated from this study can serve multiple applied purposes. Morphometric benchmarks are invaluable for breed standardization, aiding in the assessment of breed conformity. Furthermore, establishing growth baselines assists veterinarians in diagnosing developmental disorders in pediatric dogs. In terms of nutritional planning, growth curves derived from this morphometric data can help formulate age-specific feeding protocols, ensuring optimal health and growth during critical development stages. Additionally, morphometric indices have practical applications in forensic investigations, where they can aid in estimating the age and breed of unknown remains (Onar, 1999; Wayne, 1986).

In the field of reproductive management, breed-specific ultrasound biometry has demonstrated high accuracy in predicting parturition dates. For instance, Milani *et al.* (2013) developed linear regression models that utilize fetal parameters such as Inter-Cranial Circumference (ICC), Biparietal Diameter (BPD), and Body Diameter (BD) in German Shepherd female to estimate the number of days remaining before parturition with high precision. These predictive models are especially useful for planning elective C-sections and monitoring high-risk pregnancies.

 **Limitations and Future Directions**

While the present study offers comprehensive insights into morphometric changes in German Shepherd female, the sample size limits broad generalizability. The future research endeavors should consider a more extensive sample size that includes both sexes across various breeds. Incorporating imaging technologies, such as 3D modeling and CT scans, could yield even more profound insights into the morphometric variations and their implications in veterinary practice.Ultimately, this study underscores the importance of understanding morphometric changes in dogs. As breeds continue to evolve through selective breeding practices, morphometric assessments will remain vital for maintaining the health, performance, and overall quality of life in our canine companions. The integration of morphometric evaluations in veterinary and breeding practices will not only enhance breed standards but also foster a deeper understanding of the anatomical and physiological needs of various dog breeds.

**CONCLUSION**

This study detailed significant morphometric changes in body and skull parameters of German Shepherd female from infancy to adulthood. The findings confirm breed-specific skeletal and cranial development patterns that align with functional demands and genetic programming. These measurements provide vital reference points for veterinarians, breeders, and researchers.

Ethical Approval

Animal Ethic committee approval has been collected and preserved by the author(s)

**Informed consent**

All animal procedures and handling techniques for experiments were approved by the Institutional Animal

Disclaimer (Artificial intelligence)

Option 2:

Author(s) hereby declare that generative AI technologies such as Large Language Models, etc. have been used during the writing or editing of manuscripts. This explanation will include the name, version, model, and source of the generative AI technology and as well as all input prompts provided to the generative AI technology

Details of the AI usage are given below:

1. Grammarly

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