

Determination of vertebral heart scale reference ranges in *Gazelles subgutturosa*

Determinación de los rangos de referencia de la escala vertebral cardíaca en *Gacelas subgutturosa*

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ABSTRACT

Species-specific reference data for radiographic evaluation of cardiac structures in gazelles (*Gazella subgutturosa*) are limited; therefore, this prospective anatomical reference range study aimed to initiate the determination of vertebral heart scale values in clinically healthy young gazelles and evaluate the possible effects of position, sex, and age on these measurements. Twenty healthy gazelles aged between 0 and 6 months (10 females and 10 males) were included in the study. Right lateral and ventrodorsal thoracic radiographs of all individuals were obtained during the full inspiration phase. The long and short axes of the heart were measured digitally, and the sum of these measurements vertebral heart scale was recorded in vertebral units using the fourth thoracic vertebra as the reference point. The mean vertebral heart scale values were determined to be 9.59 ± 0.59 vertebral units in the right lateral position and 9.61 ± 0.58 vertebral units in the ventrodorsal position, with no statistically significant difference between the positions ($P=0.494$). The long-axis measurement was significantly greater in the ventrodorsal position than in the right lateral position ($P=0.001$); however, this difference was not reflected in the total vertebral heart scale value. No significant differences were detected between the sexes in terms of the vertebral heart scale or cardiac axis measurements ($P>0.05$). Measurement repeatability was found to be high, and inter-observer agreement was assessed as excellent (Intraclass Correlation Coefficient = 0.91; 95% CI: 0.85–0.96; $P<0.001$). The mean vertebral heart scale values obtained were like the reference range reported for dogs (9.7 ± 0.5 vertebral units) and did not show a statistically significant difference. In conclusion, this study is the first to define the vertebral heart scale reference range for gazelles and provides an objective criterion for radiographic evaluation of the cardiac silhouette, thereby contributing scientifically to clinical cardiac diagnosis and monitoring in exotic ruminant species.

Key words: Gazella; cardiac size; exotic ruminants; thoracic radiography; vertebral heart scale

RESUMEN

Los datos de referencia por especie, corresponden a la evaluación radiográfica de las estructuras cardíacas en gacelas (*Gazella subgutturosa*) son limitados; por lo tanto, este estudio prospectivo de referencia anatómica, la cual tuvo como objetivo determinar los valores de la escala cardíaca vertebral en gacelas jóvenes clínicamente sanas y evaluar los posibles efectos de la posición del cuello, el sexo y la edad en estas mediciones. Se incluyeron en el estudio veinte gacelas sanas, con edades comprendidas entre 0 y 6 meses (10 hembras y 10 machos). En todos los individuos se obtuvieron radiografías torácicas en proyección lateral derecha y ventrodorsal durante la fase de inspiración completa. Los ejes largo y corto del corazón se midieron de forma digital, y la suma de estas mediciones escala cardíaca vertebral se expresó en unidades vertebrales, utilizando la cuarta vértebra torácica como punto de referencia. Los valores medios de escala cardíaca vertebral fueron de $9,59 \pm 0,59$ unidades vertebrales en la proyección lateral derecha y de $9,61 \pm 0,58$ unidades vertebrales en la proyección ventrodorsal, sin diferencias estadísticamente significativas entre ambas posiciones ($P=0,494$). La medición del eje largo fue significativamente mayor en la proyección ventrodorsal en comparación con la lateral derecha ($P=0,001$); sin embargo, esta diferencia no se reflejó en el valor total de la escala cardíaca vertebral. No se detectaron diferencias significativas entre sexos en cuanto a la escala cardíaca vertebral ni en las mediciones de los ejes cardíacos ($P>0,05$). La repetibilidad de las mediciones fue elevada y la concordancia interobservador se consideró excelente (Coeficiente de Correlación Intraclass = 0,91; IC del 95 %: 0,85–0,96; $P<0,001$). Los valores medios de escala cardíaca vertebral obtenidos fueron similares a los rangos de referencia descritos en perros ($9,7 \pm 0,5$ unidades vertebrales), sin evidenciarse diferencias estadísticamente significativas. En conclusión, este estudio constituye el primer reporte que define los rangos de referencia de la escala vertebral cardíaca en gacelas subgutturosa y proporciona un criterio objetivo para la evaluación radiográfica de la silueta cardíaca, contribuyendo de manera significativa al diagnóstico clínico y al seguimiento cardiológico en especies de rumiantes exóticos.

Palabras clave: Gacelas; escala vertebral cardíaca; radiografía torácica; rumiantes exóticos; tamaño cardíaco

INTRODUCTION

Although echocardiography is an advanced diagnostic modality for the evaluation of cardiac diseases, thoracic radiography is still regarded as a fundamental imaging method for routine and initial assessments of the cardiovascular system [1, 2, 3]. Thoracic radiography allows the evaluation of changes in cardiac size and contour, as well as the assessment of pulmonary vascular structures [2, 3].

However, accurate and reliable interpretation of abnormalities observed in the cardiac silhouette necessitates the comparison of normal cardiac dimensions with species-specific reference values [3].

The Vertebral Heart Scale (VHS) method was defined by Buchanan and Bücheler [1] and enables objective, repeatable, and practical assessment of cardiac size. In this method, the sum of the long (L) and short (S) cardiac axes measured on lateral thoracic radiographs is compared to that of vertebral bodies, starting from the cranial edge of the fourth thoracic vertebra (T4). In healthy dogs, the mean VHS value has been reported as 9.7 ± 0.5 vertebrae, and this value is accepted as the clinical upper limit of normal cardiac size in dogs [1, 3].

Numerous Veterinary studies have demonstrated that the VHS method is applicable to various species, including cats (*Felis catus*) [4, 5], ferrets (*Mustela furo*) [6], goats (*Capra hircus*) [7], rabbits (*Oryctolagus cuniculus*) [8], and alpacas (*Vicugna pacos*) [9]. These studies have established the interspecies validity and measurement reliability of this method. However, pronounced VHS differences reported among different dog breeds clearly indicate that a single reference range is not appropriate for all species or breeds, emphasizing the necessity of determining species – and breed-specific reference values in cardiac assessment [10, 11, 12].

Gazelles (*Gazella subgutturosa*) are protected wild ruminants adapted to high-speed running and endurance with a thoracic conformation that differs from that of many domestic species [13, 14, 15]. However, species-specific reference values for the radiographic assessment of cardiac size in this species have not yet been defined [15, 16]. This lack of reference data leads to subjective interpretations in clinical evaluations and creates uncertainty in the diagnosis of cardiomegaly and other cardiac abnormalities.

This study aimed to determine species-specific vertebral heart scale reference ranges in clinically healthy male and female gazelles by using right lateral (RL) and ventrodorsal (VD) thoracic radiographs. This study represents the first scientific investigation in which cardiac morphology in gazelles is evaluated objectively using radiographic methods and aims to contribute to improved diagnostic accuracy in the fields of veterinary cardiology and wildlife medicine.

MATERIALS AND METHODS

The study protocol was approved by the Local Ethics Committee on Animal Experiments, Harran University (session and permit number: 2025/004/10).

Experimental animals

This study was conducted on 20 healthy gazelles; 10 females and 10 males) aged between 0 and 6 months who were brought to the Harran University Faculty of Veterinary Medicine Animal Hospital for routine clinical examinations. Individuals with no clinical or radiographic evidence of cardiopulmonary disease were included in this study. The study included individuals with normal physical examination findings, no pathological findings related to the cardiac or respiratory systems, and body weight, which was measured using a digital veterinary scale (Demirtaş weighing scale for small livestock, manufactured in Türkiye).

During the clinical evaluation process, multiparameter Veterinary monitor (Mindray® uMEC12VET; Shenzhen Mindray Bio-Medical Electronics Co., China) was used to monitor the heart rate, respiratory rate and oxygen saturation cardiorespiratory parameters. None of the gazelles included in the study had a history of medication use that could affect the cardiovascular system and all individuals were determined to be in good body condition. All procedures were performed while the animals were conscious and did not receive sedative or anesthetic agents.

Radiographic study

Radiographic images were acquired using a Hasvet 838 HF50 Veterinary portable digital radiography (DR) system (70 kV, 50 mA) and digitally evaluated. The measurement methodology was based on the original VHS technique described by Buchanan and Bücheler [1], with reference to previously reported studies in cats [4] and dogs [17].

Right lateral and VD thoracic radiographs of all gazelles were obtained at full inspiration using a 100 cm focal-film distance (FIGS. 1 A and B).

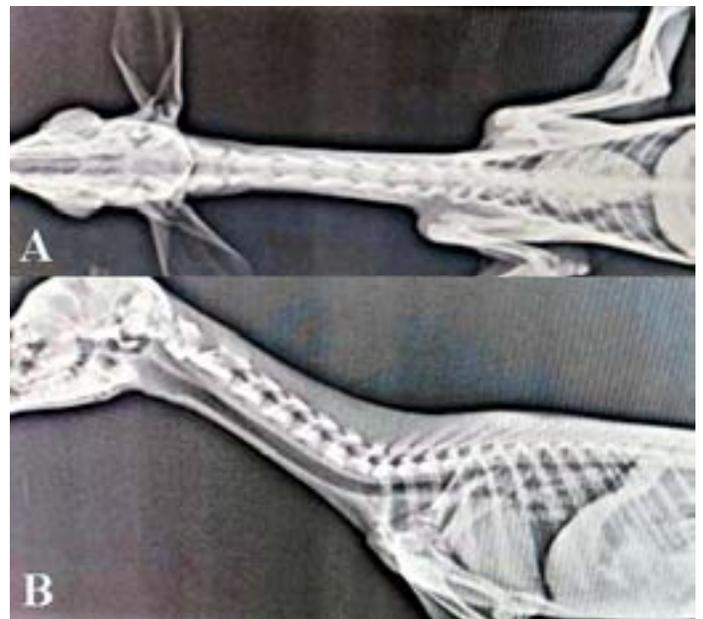


FIGURE 1. Thoracic radiographic images of gazelles presented to the Harran University, Faculty of Veterinary for routine examination. (A) Representative thoracic radiograph obtained in the ventrodorsal (VD) projection. (B) Representative thoracic radiograph obtained in the right lateral (RL) projection

Vertebral heart scale measurement method and evaluation

The long and S cardiac axes were identified on thoracic radiographs in accordance with the method originally described by Buchanan and Bücheler [1]. The long axis was defined as the distance extending from the ventral border of the carina corresponding to the anatomical bifurcation of the trachea into the main bronchi to the most distal ventral point of the cardiac apex. The S axis was defined as the maximum transverse width of the heart, measured perpendicular to the L axis at its widest point.

All measurements were performed directly on digital images using a DR system, allowing precise visualization and measurement of cardiac dimensions. The obtained L and S axis measurements were then transposed onto the thoracic vertebral column, beginning at the cranial edge of the T4, following the standard VHS methodology.

Measurements were recorded with magnification correction and a precision of 0.25 vertebral lengths. The sum of the L and S axes was calculated and recorded as the VHS value. To ensure methodological consistency and minimize inter-observer variability, all radiographic measurements were performed by the same investigator throughout the study.

Statistical analysis

Statistical analyses were conducted using the IBM SPSS Statistics v25.0 software (IBM Corp., Armonk, NY, USA). Normality of data distribution was assessed using the Shapiro-Wilk test. Differences between sexes were evaluated using the independent-samples *t*-test, whereas differences between positions were assessed using the paired-samples *t*-test. One-sample *t*-tests were applied to compare the measured VHS values with the standard vertebral heart size reference value of 9.7 v reported in the literature.

The consistency of the measurements performed by the two observers was evaluated using the Intraclass Correlation Coefficient (ICC) method, and 95% confidence intervals were reported. Statistical significance was set at *P*<0.05. All data are presented as mean ± standard deviation (SD), median, minimum, and maximum values.

RESULTS AND DISCUSSION

The mean body weight of the gazelles included in the study was recorded as 7.2 ± 0.8 kg. In all individuals, VHS and cardiac axis measurements were evaluated in both the RL and VD positions using standard thoracic radiographic techniques (FIG. 2A-B).

All measurement parameters were found to follow a normal distribution (Shapiro-Wilk test, *P*>0.05); therefore, parametric tests were used for statistical comparisons. Descriptive statistical findings for the cardiac axis measurements and VHS values are presented in TABLE I and II, respectively.

Descriptive statistics for the cardiac L and S axis measurements and VHS values are provided in TABLE I. The mean VHS values were determined as 9.59 ± 0.59 v in the RL position and 9.61 ± 0.58 v in the VD position.

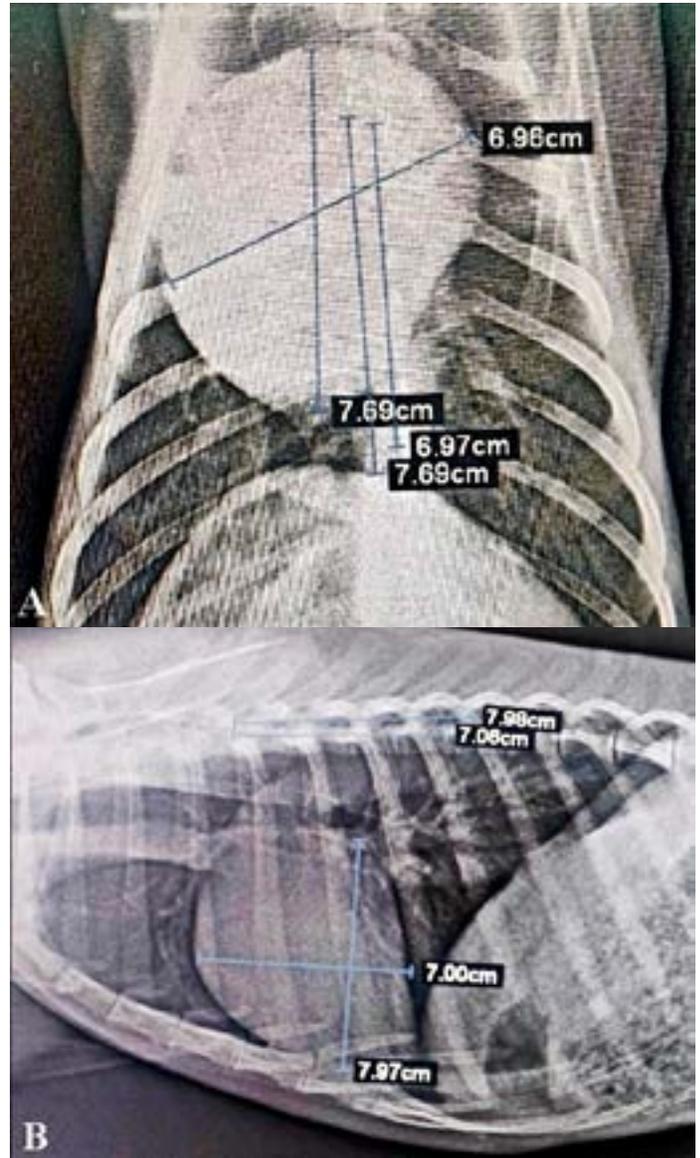


FIGURE 2. Representative thoracic radiographic images obtained in the (A) ventrodorsal (VD) and (B) right lateral (RL) projections. Vertebral heart scale (VHS) measurements were performed in both projections using the Hasvet 838 HF50 portable digital radiography system

TABLE I
Descriptive statistics of cardiac axis measurements and vertebral heart scale values in healthy gazelles aged 0–6 months (n = 20)

Measurement	Mean ± SD (v)	Min-Max (v)	Median (v)
RL-L	6.96 ± 1.02	5.66–9.20	7.00
RL-S	6.37 ± 1.49	4.46–9.02	6.41
VD-L	7.45 ± 1.12	6.60–10.54	7.17
VD-S	6.57 ± 1.19	5.20–8.86	6.21
RL VHS	9.59 ± 0.59	8.75–10.50	9.50
VD VHS	9.61 ± 0.58	9.00–10.50	9.50

RL: Right lateral; VD: Ventrodorsal; Long axis: L; Shorth axis: S; VHS: Vertebral heart scale; SD: Standard deviation. All values are presented as mean ± SD, with median, minimum, and maximum values also provided

TABLE II
Comparison of cardiac long axis, short axis, and vertebral heart scale values measured in the right lateral and ventrodorsal positions

Measurement (v)	RL (Mean ± SD)	VD (Mean ± SD)	Mean difference ± SD	P value
L	6.96 ± 1.02	7.45 ± 1.12	-0.49 ± 0.54	0.001
S	6.37 ± 1.49	6.57 ± 1.19	-0.20 ± 0.77	0.256
VHS	9.59 ± 0.59	9.61 ± 0.58	-0.03 ± 0.16	0.494

RL: Right lateral; VD: Ventrodorsal; Long axis: L; Short axis: S; VHS: Vertebral heart scale; SD: Standard deviation. All values are presented as mean ± SD, with median, minimum, and maximum values also provided. Comparisons were performed using the paired-samples t-test. The VHS was calculated as the sum of the L and S cardiac axes. Values are presented as mean ± SD. L axis measurements differed significantly between positions ($P < 0.05$), whereas no statistically significant differences were detected for S axis or total VHS measurements ($P > 0.05$).

This study is the first to define VHS values in clinically healthy gazelles. In addition, the potential effects of factors such as sex, age, and body position on the cardiac size were evaluated. When compared with the VHS values reported in different animal species, the findings indicate that the cardiac silhouette in gazelles exhibits similar or slightly lower vertebral values, proportionate to their long and narrow thoracic conformation [4, 11, 18].

In comparisons between sexes, VHS values measured in both the RL and VD positions were slightly higher in male gazelles than in females; however, these differences were not statistically significant (RL VHS: $P = 0.783$; VD VHS: $P = 0.926$). Similarly, no statistically significant differences were detected between the sexes with respect to the cardiac L and S axis measurements ($P > 0.05$).

No statistically significant differences in VHS values were detected between sexes. This finding is consistent with those of previous studies conducted on dogs (*Canis lupus domesticus*) [17, 18] and sheep (*Ovis aries*) [19]. However, sex-related differences have been reported in some species. For example, significantly higher VHS values have been documented in male rats than in females [20], which has been attributed to greater thoracic volume and a relatively larger cardiac silhouette in males.

The absence of sex-related differences in gazelles may be associated with similarities in thoracic conformation and body proportions between the sexes. Moreover, the balanced distribution of age and body weight among the individuals may have contributed to the lack of statistically significant sex-related differences.

In the analyses comparing positions, a statistically significant difference was identified only for the long-axis measurements. The L axis values measured in the VD position were significantly higher than those measured in the RL position (mean difference = -0.49 ± 0.54 v; $P = 0.001$). In contrast, no statistically significant differences were observed between the positions for the S axis measurements ($P = 0.256$) or total VHS values ($P = 0.494$).

These findings indicate that position-related differences in cardiac axis measurements did not significantly affect overall VHS measurements (TABLE II).

A comparison of the measured VHS values with the standard reference value of 9.7 v reported in the literature for dogs and

cats revealed that neither the RL VHS ($P = 0.402$) nor the VD VHS ($P = 0.505$) differed significantly from this reference value. On the other hand, all long and short axis measurements (RL long axis, RL short axis, VD long axis, VD short axis) were found to be significantly lower than the 9.7 v reference value ($P < 0.001$).

Excellent agreement was observed between the measurements performed by two independent observers. Intraclass ICC analysis yielded an ICC value of 0.91 for VHS measurements (95% CI: 0.85–0.96; $P < 0.001$), which was interpreted as indicating “excellent” reliability.

The mean VHS values obtained in gazelles were lower than the classical reference values reported for dogs by Buchanan and Bücheler [1] (9.7 ± 0.5 v); however, this difference was not statistically significant. Similarly, the mean VHS values reported in cats [4] and rats (*Rattus norvegicus*) [20] have also been shown to be lower than those in dogs.

These differences may be explained by interspecies variations in thoracic morphology and the spatial orientation of the heart within the thoracic cavity. In gazelles, a long and deep thoracic structure may result in a more vertically oriented heart along the vertebral axis, leading to expression of the long-axis measurement in fewer vertebral units. In contrast, higher VHS values reported in athletic dog breeds, such as Greyhounds [21, 22] and Whippets [10] (10.5 – 11.3 v), are associated with increased cardiac mass and wider thoracic volume, which are considered physiological adaptations. These findings indicate that VHS differences are influenced not only by morphology but also by physiological adaptations.

No statistically significant differences were observed between the VHS values measured in the RL and VD positions. This result is consistent with those of similar studies conducted in ferrets [23, 24], rats [20], cats [25], and dogs [18]. Furthermore, the high interobserver agreement observed in this study (ICC = 0.91) demonstrates that the VHS method has high repeatability, both between positions and between observers. This value is comparable to the high agreement coefficients reported in dogs (ICC ≈ 0.95) [11], and indicates that the method can be reliably applied to gazelles.

As all individuals included in the study were within the juvenile age range of 0–6 months, the effect of age on the VHS was evaluated within a limited interval. The literature indicates that in young animals, the cardiac silhouette grows proportionally with age and that VHS values may show a slight increase until adulthood [19].

Similarly, studies in dog breeds, such as the Norwich Terrier and Beagle, have emphasized that age has a minimal effect on VHS in later life stages and that age-related cardiac remodeling does not result in clinically significant changes [11, 17]. Although the narrow age distribution in the present study limited the analysis of age as an independent variable, the homogeneous results obtained suggest that thoracic proportions in young gazelles stabilize at an early stage of development.

The VHS reference ranges defined in this study provide an important foundation for the radiographic evaluation of cardiomegaly, pericardial effusion, and congenital cardiac defects in the gazelles. Although the modified VHS and cardio-vertebral ratio methods have been reported to improve diagnostic accuracy,

particularly in pathologies [23], the high repeatability observed in the present study suggests that the classical Buchanan method may provide sufficient accuracy and sensitivity for gazelles.

CONCLUSION

This study is the first to define a species-specific vertebral heart scale reference range for *Gazella* and demonstrate that these values can be used in the radiographic diagnosis and monitoring of cardiac pathologies in exotic ruminants. Future studies are recommended to compare VHS measurements with echocardiographic and computed tomography findings, encompassing different age groups and individuals with cardiac pathology.

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Conflict of interest

The authors declare no conflicts of interest related to the design, execution, data collection, analysis, or publication of this study.

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