



RADIOLOGIC EVALUATION OF THORACIC SIZE IN THE NIGERIAN INDIGENOUS DOG BY VERTEBRAL, HALLER AND FRONTOSAGITTAL INDICES

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SUMMARY

Reproducible and easily applied measurements for radiologic evaluation are needed in the day-to-day clinical practice for diagnosis and treatment or management of thoracic disorders in the Nigerian Indigenous Dog. The objective of this prospective cross-sectional study was to document measurement indices used for the evaluation of canine thoracic silhouette. Thirty healthy Nigerian Indigenous Dogs, 10 puppies and 20 adults of average body weight 8.19 ± 2.45 kg and comprising equal number of both sexes. Ninety survey dorsoventral, right lateral and left lateral thoracic radiographs of the animals were obtained. The shape of the thoracic silhouette in each radiograph was objectively evaluated and adequately described. In the right and left lateral views, sternovertebral distance and sagittal vertebral diameter of the tenth vertebra were measured and recorded; while the dimension measured in the dorsoventral view was costocostal distance. In the lateral radiographs, mean values of vertebral indices (VI) for right/left lateral radiographs were $0.10 \pm 0.00 / 0.10 \pm 0.00$, respectively. Results of normal thoracic silhouette determined in dorsoventral versus right lateral orthogonal radiographs were: frontosagittal index (FSI) 1.06 ± 0.05 and Haller index (HI) 0.95 ± 0.04 . The clinical relevance of this investigation is that it provides measurement indices for the morphological evaluation of the thoracic silhouette in the Nigerian Indigenous Dog. These indices are reproducible, objective and easy to apply in small animal clinical practice.

Key words: Radiology, measurement, thorax, indices, dog

INTRODUCTION

There are numerous thoracic cage deformities that variably affect the contour and volume of the thorax. Congenital deformities of the sternum, ribs, and thoracic spine are frequently encountered clinically, radiographically, and incidentally (Bauer, 1989). However, some of the patients, including humans and animals, hardly experience respiratory disorders unless the condition is accompanied by primary cardiac or pulmonary defects (Bauer, 1989; Gurkok *et al.*, 2003). Majority of these malformations involve the following skeletal elements in order of decreasing frequency: sternum, spine, and ribs (Farrow, 1996). Pectus deformities are the most common types of congenital thoracic wall developmental malformations and usually cause a marked cosmetic defect associated with a psychological trauma in human patients (Golladay and Golladay, 1997; Donnelly and Frush, 1999; Einsiedel and Clausner, 1999; Suita *et al.*, 2001). Pectus deformities may be quantified using the vertebral, frontosagittal, and other cardiothoracic indices necessary for accurate preoperative and postoperative assessments of patients with the pectus disorders (Gurkok *et al.*, 2003; Kilda *et al.*, 2007; Rahal *et al.*, 2008). Lateral radiographic measurements are more valuable than dorsoventral views in patient assessment because the main effect of pectus repair operation on the anatomy of the thoracic cavity is a dorsoventral effect rather than a transverse effect (Kaguraoka *et al.*, 1992; Haller *et al.*, 1996; Pretorius *et al.*, 1998; Hebra *et al.*, 2000).

Pectus excavatum (funnel chest) or dorsal displacement of the sternum is a sternal deformity that typically involves the caudal sternbrae and costal cartilages (congenital chondrosternal depression). Funnel chest has been attributed to

excess traction of the diaphragm during the early stages of late intrauterine or early neonatal development (Smallwood and Beaver, 1977; Shires *et al.*, 1988). This deformity is associated with varying degrees of local and regional concavity. The inward displacement of some of the sternbrae secondarily alters the shape of the caudoventral aspect of the thoracic cavity. Occasionally, pectus excavatum may result in clinical signs referable to the displacement and or compression of the heart or lung (*i.e.*, cardiorespiratory anomalies *e.g.* heart palpitations, tachycardia, disturbed comprehensive inspiration) and these problems lead to impaired development and physical exercise intolerance (Haller *et al.*, 1989; Donnelly and Frush, 1999; Saxena *et al.*, 1999). However, only severe chest wall deformations can cause malfunctioning of thoracic organs (Kaguraoka *et al.*, 1992; Ohno *et al.*, 2001) and surgical correction of funnel chest is predicted on the severity of clinical signs (Saperstein *et al.*, 1976; McAnulty and Harvey; 1989). In humans, pectus excavatum may be acquired or congenital, but all documented cases in animal species are congenital malformations (Fossum *et al.*, 1989). The cause of pectus excavatum is unknown but heredity has been incriminated (Ellison and Halling, 2004). In man, cosmetic and psychological indications for surgical treatment gained more importance after the introduction of minimally invasive Nuss operation for pectus excavatum (Miller *et al.*, 2001; Croitoru *et al.*, 2002; Hoise *et al.*, 2002). Radiologic evaluation using thoracic radiographs and CT is very important for the assessment of indications for surgically corrective treatment even in cases of moderate thoracic wall deformity with no clinical signs

of thoracic organ compression and or displacement (Nakahara *et al.*, 1987; Ohno *et al.*, 2003). Radiographic indicators of pectus excavatum are a marked dorsal deviation of the caudal aspect of the sternum, resulting in abnormally reduced sternospinal distance (dorsal to ventral narrowing of thorax) at the affected part, acute angulation of the associated costal cartilages, and dorsal displacement of the heart in lateral views. Lateral heart displacement is often pronounced in VD views (Owens, 1982; Kealy, 1989). In severe cases, the sternum is superimposed on the heart in lateral projection (Suter, 1984). Cardiothoracic measurements, made from preoperative and postoperative thoracic projections, have been employed to quantitatively assess the degree of surgical correction (Fossum *et al.*, 1989; Gurkok *et al.*, 2003; Rahal *et al.*, 2008). Congenital syndromes associated with pectus excavatum in both man and animals include osteogenesis imperfecta, osteodysplasty, and human foetal alcohol syndrome (Taybi and Lachman, 1990; Reeder and Bradley, 1993). Pectus carinatum (pigeon chest), the opposite of pectus excavatum, is a congenital anomaly that results in a laterally compressed thorax secondary to ventral (outward) displacement of the caudal aspect of the sternum (Suter, 1984). When viewed laterally, the vertical diameter of the thorax is increased in the affected animal. In the cat, only mild pectus carinatum has been observed, typically represented radiographically by a caudoventral deflection of the xiphoid process and one or two adjacent sternbrae (Farrow, 1996). The ventral aspect of the diaphragm is straighter than normal, and the diaphragm, on the whole, is more vertically oriented (Farrow, 1996). Congenital syndromes associated with pectus carinatum include osteogenesis imperfecta, mucopolysaccharidosis

(especially in cats), spondyloepiphyseal dysplasia congenital, foetal alcohol syndrome and homocystinuria (Taybi and Lachman, 1990; Reeder and Bradley, 1993; Farrow, 1996).

Various parameters to measure the severity of pectus defects have been proposed for human cases using plain radiography, computed tomography, pulmonary function tests, and cardiac investigations (Kaguraoka *et al.*, 1992; Shields, 1994; Donnelly *et al.*, 2000; Fonkalsrud *et al.*, 2000; Hebra *et al.*, 2000). Different thoracic cage indices have been reported in some exotic companion animals and a few wild lives (Fossum *et al.*, 1989; Linklater and Smith, 1997; Gulamber *et al.*, 2005; Gardner *et al.*, 2007). Unfortunately, there is a dearth of published documents on the methods used for thoracic cage appraisal in the Nigerian Indigenous Dog (NID). The aim of the present study was to determine measurement indices for the evaluation of thoracic size in the NID.

MATERIALS AND METHODS

Procurement of Nigerian Indigenous Dogs and Acclimatization

The study adopted prospective cross-sectional radiologic design using thirty Nigerian Indigenous Dogs of equal sexes, procured from breeders in the neighbourhood by non-probability convenience sampling method. The dogs consisted of adult dogs (≥ 12 months old) and puppies (< 12 months old) (Blood & Studdert, 2005). The animals were kept in separate kennels and acclimatized for a month. The dogs were generally examined and screened for diseases. Results of vital parameters (heart rate, rectal temperature,

respiratory rate, and pulse rate), serum biochemistry, and haematological analyses of the dogs were within the normal values reported for the NID (Atata *et al.*, 2018). None of the dogs manifested any clinical sign of cardiovascular or pulmonary disease. Therefore, the animals were adjudged healthy and appropriate for the present research (Ukaha *et al.*, 2022). The dogs were identified with neck tags numbered 1-30.

Ethical Approval

The housing, feeding and management procedures adopted while acclimatizing the dogs used in the present work were in tandem with the ethical standards of Research Ethical Committee (Approval No: MOUAU/CVM/REC/202124) of the College of Veterinary Medicine, Michael Okpara University of Agriculture, Umudike, Nigeria; the management procedures were also based on the Helsinki Declaration of 1975 revised in 2000.

Animal Restraint and Radiographic Procedures

The study NIDs were restrained for radiography with xylazine hydrochloride (XYL-M2[®], VMD, Belgium) at 2.0mg/kg i.m and ketamine hydrochloride (Ketanir[®], Aculife Healthcare, India) injected i.m. at 10mg/kg. The x-ray machine used to obtain all the radiographs was mobile Dynamax 40 (GEC Medical Equipment Group Ltd, England), with the focus-film-distance set at 90 cm and the object-film-distance at 0 cm for all the exposures. Other exposure factors used (namely, kilovoltage and milliamperage-second) were different depending on the thoracic thicknesses of individual dogs. A viewing box, x-ray films (Begood[®], China), cassettes and screens (NACAL Medical, England), processing chemicals (developer and fixer powders) (Begood[®], China), standard metre rule, a pair of

calipers and a weighing scale were also used. Ninety radiographs consisting of dorsoventral (DV), right lateral (RtL) and left lateral (LeL) views of the thirty dogs were obtained at peak of inspiration. The entire thorax (from a few centimetres cranial to the first rib to a point just caudal to the first lumbar vertebra) was exposed in each projection with the photon being centred at the most prominent parts of the scapulae for DV views and at the midpoint of the 4th intercostal space for the lateral radiographs (Douglas *et al.*, 1987; Ukaha *et al.*, 2018). Exposed films were processed manually and stored in labelled envelopes. With the use of a viewing box, the study radiographs were examined. The relevant parameters were measured with a meter rule in centimetres and recorded.

Data Collection and Determination of Indices

In the RtL and LeL views, measurements recorded were sternovertebral distance (SV), taken between the ventral border of T10 and the dorsal border of the xyphoid cartilage (XC) (Kilda *et al.*, 2007; Rebeis *et al.*, 2007); and vertebral sagittal diameter of T10 measured along SV (VD) (Plate 1 a). In each DV view (Plate 1 c), the parameter recorded was the costo-costal (latero-lateral) distance (CC), measured between the inner surfaces of the costal cage through the midpoint of the tenth thoracic vertebra (T10). The recorded parameters were used to determine radiologic indices for the NID as follows:

- a) The vertebral index (VI) was calculated with the formula $VI = VD \div (SV+VD)$, or the ratio of tenth vertebral diameter (VD) to sum of the sternovertebral distance (SV) and the VD measured in line with SV.
- b) The frontosagittal index (FSI) was

determined using, FSI = CC/SV (i.e. costocostal distance-to-sternovertebral distance ratio), and c) The Haller index (HI) obtained using the relationship, HI = SV/CC (i.e. sternovertebral distance-to-costocostal distance ratio) (Haller *et al.*, 1987; Kilda *et al.*, 2007; Khanna, 2010; Poston, 2015)

Data Analyses

Obtained data, expressed in descriptive statistics, were presented in plates and tables. Results in the tables are presented as Means ± standard errors of means (SEM). Mean value differences (TABLES II a - V) obtained in the dorsoventral DV versus right lateral projections, and right lateral RtL versus left lateral LeL views of the sexes and ages were subjected to student’s t-test using SPSS version 22 for windows. The mean, range, standard error of mean, and variance, were calculated for each sex, age bracket separately, and for all the dogs pooled. A probability value less than, or equal to, five percent (P ≤0.05) was

considered statistically significant.

RESULTS

Demography of the NID

Thirty dogs of the Nigerian indigenous breed (comprising fifteen males and fifteen females) were made up of 20 adult dogs (66.7%) and 10 puppies (33.3%). Body weights of the research dogs ranged from 4.0 to 15.6 kg (mean: 8.19±2.45). Adult dogs had an average weight of 9.65±1.93 (range: 8.3 – 15.6 kg), while puppies weighed 5.76±0.93 on the average (range: 4.0 – 7.2 kg). As shown in Table 1, out of the 20 adult dogs evaluated, 11 (55%) were males while 9 (45%) were females. On the other hand, 4 (40%) of the puppies were males and 6 (60%) females.

TABLE I: Sex and age distributions of the dogs used for the study on Radiologic Evaluation of Thoracic Size in the Nigerian Indigenous Dog by Vertebral, Haller and Frontosagittal Indices.

Age	Sex		Total
	Male	Female	
Adult (≥ 12 months)	11	9	20
Puppy (< 12 months)	4	6	10
Total	15	15	30

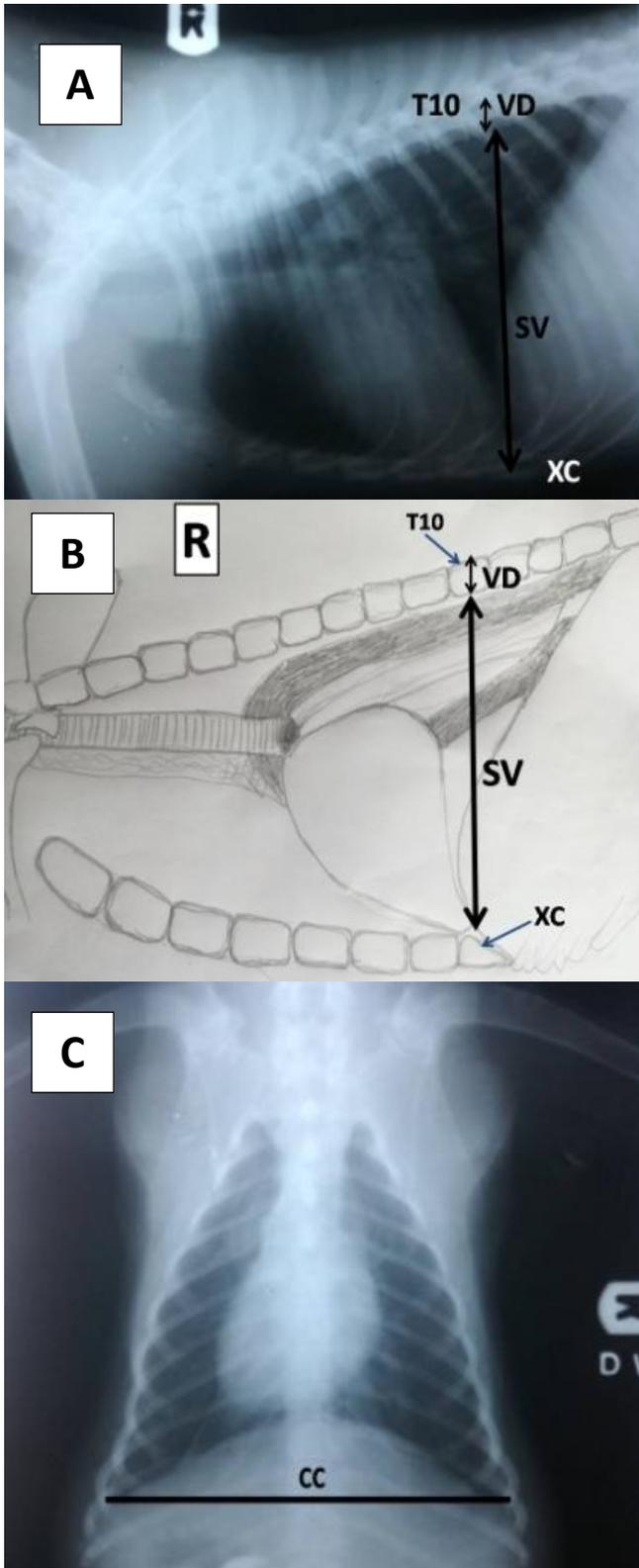


PLATE 1: Thoracic radiographs of healthy Nigerian Indigenous Dog showing measurements taken for thoracic evaluation: (a) Right lateral thoracic radiograph, (b) Annotated diagram of the right lateral thoracic radiograph, and (c) Dorsoventral thoracic projection.

Legends: VD, sagittal vertebral diameter = measured from the dorsal to ventral borders of the vertebra. T10 = tenth thoracic vertebra. XC = xiphoid cartilage. SV, sternovertebral distance = measured distance in line with VD from the ventral border of the tenth thoracic vertebra to the dorsal surface of the xiphoid cartilage. CC = costocostal distance, measured at the midpoint of the tenth thoracic vertebra (T10).

Vertebral indices (VI) in right lateral (RtL) and left lateral (LeL) thoracic radiographs.

In TABLE II (a), the right lateral (RtL) mean vertebral diameter VD (1.06 ± 0.02) and mean sternovertebral distance SV (9.93 ± 0.23) are both varied with their respective mean values (1.05 ± 0.02 and 9.96 ± 0.24) in the left lateral (LeL) projections. However, there is no significant difference between the RtL and LeL mean vertebral indices ($P \geq 0.05$). There are also dimensional mean differences in the measured VD and SV parameters between RtL and LeL views of the male and female dogs, as seen in TABLE II (b); but there is no statistical difference between any two of the sex VI indices (0.10 ± 0.01 and 0.09 ± 0.00 ; 0.10 ± 0.00 and 0.10 ± 0.00) obtained ($P \geq 0.05$). In TABLE II (c), the mean differences between RtL and LeL VI values of adult dogs and puppies (0.09 ± 0.01 and 0.09 ± 0.00 ; 0.10 ± 0.01 and

0.10±0.01) are not significant ($P \geq 0.05$).

TABLE II (a): Vertebral indices (VI) in right lateral (RtL) and left lateral (LeL) thoracic radiographs of the Nigerian Indigenous Dog; measurements in cm. $VI = VD/(SV+VD)$.

Vertebral indices	Right lateral views	Left lateral views
VD	1.06±0.02	1.05±0.02
SV	9.93±0.23	9.96±0.24
VI	0.10±0.00	0.10±0.00

Index means are not significantly different from each other ($P \geq 0.05$).

TABLE II (b): Sex differences in vertebral indices in right lateral and left lateral thoracic radiographs of Nigerian Indigenous Dogs; measurements in cm. $VI = VD/(SV+VD)$.

VI	RtL (Females)	LeL (Females)	RtL views (Males)	LeL (Males)
VD	1.07±0.03	1.05±0.03	1.05±0.04	1.04±0.03
SV	10.03±0.26	10.10±0.32	9.84±0.37	9.81±0.37
VI	0.10±0.01	0.09±0.00	0.10±0.00	0.10±0.00

Index means are not significantly different from each other ($P \geq 0.05$).

TABLE II (c): Age differences in vertebral indices in right lateral and left lateral thoracic radiographs of the Nigerian Indigenous Dog; measurements in cm. $VI = VD/(SV+VD)$.

VI	RtL (Adult dogs)	LeL (Adult dogs)	RtL (Puppies)	LeL (Puppies)
VD	1.09±0.02	1.09±0.02	0.99±0.12	0.96±0.11
SV	10.50±0.16	10.51±0.20	8.80±1.03	8.85±1.04
VI	0.09±0.01	0.09±0.00	0.10±0.01	0.10±0.01

Index means are not significantly different from each other ($P \geq 0.05$).

Haller index (HI) in dorsoventral (DV) versus right lateral (RtL) thoracic radiographs In TABLE III (a), the mean costo-costal distance (CC) in dorsoventral (DV) views is greater than the mean sterno-vertebral distance (SV) in right lateral thoracic (RtL) views. The Haller index (HI) obtained is 0.95 ± 0.01 .

In TABLE III (b), the HI mean obtained in female radiographs is less than the mean value calculated for the males, but the mean indices (0.93 ± 0.01 and 0.96 ± 0.01) are not significantly different from each other ($P\geq 0.05$).

As shown in TABLE III (c), we also see mean HI values (0.95 ± 0.01 and 0.94 ± 0.01) not significantly different between adult dogs and puppies.

TABLE III (a): Haller index obtained in dorsoventral versus right lateral thoracic radiographs of Nigerian Indigenous Dogs; measurements in cm. $HI=SV/CC$.

	SV in RtL view	CC in DV view	HI
Haller index	12.53 ± 0.26	13.22 ± 0.28	0.95 ± 0.01

TABLE III (b): Haller indices in dorsoventral versus right lateral thoracic radiographs of male and female Nigerian Indigenous Dogs; measurements in cm. $HI=SV/CC$.

Haller index	HI in Females	HI in Males
SV (RtL)	12.62 ± 0.36	12.43 ± 0.38
CC (DV)	13.51 ± 0.42	12.93 ± 0.37
HI	0.93 ± 0.01	0.96 ± 0.01

Index means are not significantly different from each other ($P\geq 0.05$).

TABLE III (c): Age differences in Haller index in dorsoventral versus right lateral thoracic radiographs of Nigerian Indigenous Dogs; measurements in cm. $HI=SV/CC$.

Haller index	HI in Adult dogs	HI in Puppies
SV in RtL	13.14 ± 0.26	11.31 ± 0.31
CC in DV	13.80 ± 0.32	12.06 ± 0.32
HI	0.95 ± 0.01	0.94 ± 0.01

Index means are not significantly different from each other ($P\geq 0.05$).

Frontosagittal indices (FSI) in dorsoventral (DV) versus right lateral (RtL) thoracic radiographs. The mean fronto-sagittal index FSI (1.05 ± 0.01) of the Nigerian Indigenous Dog is shown in TABLE IV (a), with the mean costo-costal distance CC (13.22 ± 0.28) in dorsoventral (DV) views slightly greater than the mean sterno-vertebral distance SV (12.53 ± 0.26) in right lateral thoracic (RtL) views.

Female mean FSI (1.06 ± 0.01) is greater than male FSI mean value (1.04 ± 0.01) (TABLE IV b), but the sex mean indices are not significantly different from each other ($P \geq 0.05$).

Puppy FSI mean value (1.06 ± 0.01), as shown in TABLE IV (c), is greater than the mean value determined for adult dogs (1.05 ± 0.01). However, the mean indices are not significantly different from each other ($P \geq 0.05$).

TABLE IV (a): Frontosagittal indices in dorsoventral versus right lateral thoracic radiographs of Nigerian Indigenous Dogs; measurements in cm. FSI= CC/SV.

Frontosagittal Index	CC in DV views	SV in RtL views	FSI
Parameters	13.22 ± 0.28	12.53 ± 0.26	1.05 ± 0.01

Index means are not significantly different from each other ($P \geq 0.05$).

TABLE IV (b): Frontosagittal indices in dorsoventral versus right lateral thoracic radiographs of male and female Nigerian Indigenous Dogs; FSI = CC/SV.

FSI Indices	Females	Males
CC in DV views	13.51 ± 0.42	12.93 ± 0.37
SV in RtL views	12.62 ± 0.36	12.43 ± 0.38
FSI	1.06 ± 0.01	1.04 ± 0.01

Index means are not significantly different from each other ($P \geq 0.05$).

TABLE IV (c): Age differences in frontosagittal indices in dorsoventral versus right lateral thoracic radiographs of Nigerian Indigenous Dogs; measurements in cm. FSI = CC/SV.

FSI Indices	Age difference in FSI (Adult dogs)	Age difference in FSI (Puppies)
CC (DV)	13.80 ± 0.32	12.06 ± 0.32
SV (RtL)	13.14 ± 0.26	11.31 ± 0.21
FSI	1.05 ± 0.01	1.06 ± 0.02

Index means are not significantly different from each other ($P \geq 0.05$).

TABLE V: Summary of index results obtained for the Nigerian Indigenous Dog

TABLE V shows the pooled index means, ranges, sex and age mean differences of the vertebral index (VI), Haller index (HI) and fronto-sagittal index (FSI). n = number of radiographs studied; Var = variance

	VI (RtL/LeL) (Range)	HI (DV versus RtL) (range)	FSI (DV versus RtL) (range)
Male (n = 15)	0.10±0.01/0.09±0.00 (0.08-0.12/0.08-0.10)	0.96±0.02 (0.92 – 0.99)	1.04±0.03 (1.01 – 1.09)
Female (n = 15)	0.10±0.00/0.10±0.01 (0.09-0.11/0.09-0.10)	0.93±0.04 (0.84 – 0.98)	1.06±0.05 (1.02 – 1.19)
Adult (n = 20)	0.09±0.01/0.09±0.00 (0.08-0.10/0.08-0.10)	0.95±0.03 (0.88 – 0.99)	1.05±0.04 (1.01 – 1.13)
Puppy (n = 10)	0.10±0.01/0.10±0.01 (0.09-0.12/0.09-0.10)	0.94±0.04 (0.84 – 0.98)	1.06±0.05 (1.02 – 1.19)
Pooled (n = 30)	0.10±0.00/0.10±0.00 (0.08-0.12/0.08-0.10)	0.95±0.04 (0.84 – 0.99)	1.05±0.04 (1.01 – 1.19)
Pooled Var	0.000007/0.000004	0.001439	0.001793

The mean VI, FSI, and HI values were not significantly different between sexes and ages ($p \geq 0.05$).

DISCUSSION

The thirty Nigerian Indigenous Dogs used for the radiologic research were made up of fifteen male and fifteen female dogs distributed into two age brackets: (a) adult dogs, numbering twenty and (b) puppies, consisting of ten animals (TABLE I). Mean vertebral indices (VI) obtained in both the RtL and LeL thoracic radiographs of the NID ranged from 0.08 to 0.12 and 0.08 to 0.10 with 0.10±0.00 and 0.10±0.00 being their respective means (TABLE II a). These indices did compare very well with 0.10±0.01, the result established for the rabbit (*Oryctolagus cuniculus*) in a previous investigation by Ukaha *et al.* (2018). However, the pooled samples VI means (and adult and puppy mean values) determined in this work diverged widely from earlier findings of

7.32±0.15 in puppies by Nnaji *et al.* (2010). In the West African Dwarf Goat, Nnaji *et al.* (2014) also reported unlike mean VI results of 13.11±0.34 and 13.00±0.79 for female and male goats, respectively. These variations were probably due to methodological or procedural differences. In the present investigation, we adopted the approach, VD/(SV+VD), developed by the pioneer workers (Donnelly *et al.*, 2000). However, the present VI means did not line up very well with the results, 0.26 and 0.25, published by Donnelly *et al.* (2000) and Croitoru *et al.* (2002), which have successfully been utilized in the pre- and post-surgical evaluation of children and other patients with thoracic wall malformation. Neither the Croitoru nor Donnelly collaborators recorded any sex difference in their reports just like our

own findings. *Pectus carinatum* (a congenital deformity in which the sternum bulges caudoventrally and protrudes) and lordosis (downward curvature of lumbar spine) are the causes of less than normal VI values while *pectus excavatum* (a congenital deformity in which the sternum and caudal ribs are concave and depressed towards the spine reducing thoracic cavity space) and kyphosis (abnormally increased convexity in thoracic spine curvature as seen in lateral views) will result in VI values greater than normal (Farrow, 1996; Linklater and Smith, 1996; Blood *et al.*, 2008). Ankylosing spondylosis (spondylosis deformans) is another condition in which VI appraisal may be indicated. The exostosis that develop on the ventral and lateral aspects of the vertebral bodies, mostly reported on the caudal end of thoracic vertebrae and the cranial end of lumbar vertebrae (especially in middle-aged male dogs) usually result in abnormal increase in vertebral diameter (Walker, 1986; Wright, 1982). Haller index (HI) is a ratio measured from an axial computed tomographic (CT) scan and used to describe the internal dimensions of the thoracic cage. It was established in human chest sections first by Haller *et al.* (1987) and later applied by Daunt *et al.* (2004) and Archer *et al.* (2016) as a mathematical relationship between the transverse thoracic diameter of the inner ribcage surfaces and the anteroposterior (sternovertebral) distance of the chest. However, recent studies have shown that thoracic radiographs are equally as effective as CT scans in the determination of the Haller index thereby recommending replacing CT scans with radiography to eliminate radiation exposure issues (associated CT scanning) except in complex cases of ribcage deformities (Khanna, 2010; Poston, 2015). In a retrospective study of 154 human patients who underwent a surgery for pectus excavatum deformity, the mean preoperative.

Haller indices obtained in thoracic radiographs and CT scans were 3.82 ± 1.17 (range, 2.0-10.2) and 4.61 ± 1.58 (range, 2.6-11.9), respectively, and the correlation coefficient between the two parameters was 0.757 (Wu *et al.*, 2013). However, the normal Haller index in man in the original paper was 2.56. In this present research, the mean HI was 0.95 ± 0.04 (TABLES 3 a - c). This result is not comparable with the finding in man due to the flatness of the human chest compared with the barrel shape of the canine thoracic cage. Literature is devoid of any report on HI in animals, and the present inquiry may be the first time the index was established in a non-human species. Thoracic wall anatomic anomalies such as pectus deformities can cause the sternum to invert (excavatum) or evert (carinatum), thus increasing or decreasing the index to abnormal values. HI is a descriptive and decision making tool for the management of pectus deformation. Frontosagittal index (FSI) is the ratio of the thoracic width at the 10th thoracic vertebra (T10) on DV radiographs and the distance from the ventral surface of T10 to the nearest point on the sternum in RtL projections. Range of the FSI established in this work was 1.01 – 1.19 with a mean of 1.06 ± 0.01 (TABLES 4 a - c), comparable with the reference values (1.0 to 1.5) reported for brachycephalic dogs (Fossum, 2012). There was no significant mean difference between sexes and ages. The results compared to some favourable extent with previously published mean FSI values of 1.34 ± 0.09 (range: 1.23 - 1.48) by Nnaji *et al.* (2010), which was also within the brachycephalic reference range. Nnaji and his team worked with 12 (7 male and 5 female) puppies aged 6-20 weeks. The puppy mean FSI, 1.06 ± 0.01 , determined in this work varies a little from the result obtained by Nnaji

and his collaborators, probably due to procedural differences between the two studies. Diagnosis of pectus excavatum is usually straightforward based on clinical manifestations and radiological findings. Objective evaluation is used to grade the degree of the deformity by calculating the FSI and VI indices and the condition is mostly observed in the caudal part of the sternum evidenced by the reports of several investigators including Fossum (2012), Cho *et al.* (2012), and Hassan *et al.* (2018).

CONCLUSION

The three indices studied are used in both medical and veterinary sciences for diagnostic purposes (Haller *et al.*, 1987; Kilda *et al.*, 2007; Khanna, 2010; Poston, 2015). The results in the present investigation are reference values determined for the first time in the Nigerian Indigenous Dog. Therefore, the authors recommend that the reference indices be applied by veterinarians in small animal clinical practice for the radiologic evaluation of the thoracic size in the Nigerian Indigenous Dog. Similar investigations to the present work in other dog breeds, for comparative purposes, need to be conducted.

REFERENCE

- ARCHER, J.E., GARDNER, A., BERRYMAN, F., and PYNSENT, P. (2016): The measurement of the normal thorax using the Haller index methodology at multiple vertebral levels; *Journal of Anatomy* 229:577-581 doi: 10.1111/joa.12499.
- ATATA JA, ESIEVO KAN, ADAMU S, AND ABDUSALAM H (2018): Baseline haematological, serum biochemical and some urine parameters in Nigerian Indigenous Dogs; *Savannah Veterinary Journal* 1:1-5.
- BAUER, T. (1989): Thoracic wall. In: *Textbook of Veterinary Internal Medicine Vol 1* 3rd Ed, S.J. Ettinger, WB Saunders Co., Philadelphia.
- BLOOD, D.C. and STUDDERT, V.P. (2005): Puppy. *Saunders Comprehensive Veterinary Dictionary* (2nd edn). WB Saunders Co., Philadelphia p947.
- BLOOD, D.C., STUDDERT, V.P. and GAY, C.C. (2008): Pectus. *Saunders Comprehensive Veterinary Dictionary*; Saunders Elsevier, Philadelphia.
- CHO, S., HONG, S., CHUNG, Y., and KIM, O. (2012): Radiological assessment of pectus excavatum in a Perkingese dog; *Korean J Vet Serv* 35:251-254.
- CROITORU, D.P., KELLY, R.E. Jr, GORETSKY, M.J., LAWSON, M.L., SWOVELAND, B. and NUSS, D. (2002): Experience and modification update for the minimally invasive Nuss technique for *pectus excavatum* repair in 303 patients, *Journal of Pediatric Surgery* March 37(3): 437-445.
- DAUNT, S., COHEN, J., and MILLER, S. (2004): Age-related normal ranges for the Haller index in children; *Pediatric Radiology* 34: 326–330.

- DONNELLY, L.F., and FRUSH, D.P. (1999): Abnormalities of the chest wall in paediatric patients, *American Journal of Roentgenology December* 173(6):1595-1601.
- DONNELLY, L.F., FRUSH, D.P., FOSS, J.N., O'HARA, S.M., and BISSET, G.S. (2000): Anterior chest wall: Frequency of anatomic variation in children. *Radiology* 212(3):837-840.
- DOUGLAS, S.W., HERRTAGE, M.E., and WILLIAMSON, H.D. (1987): *Principles of Veterinary Radiology (4th edn)*. Bailliere Tindall, London.
- EINSIEDEL, E. and CLAUSNER, A. (1999): Funnel chest. Psychological and psychosomatic aspects in children, youngsters, and young adults, *Journal of Cardiovascular Surgery (Torino) October* 40(5):733-763.
- ELLISON, G. and HALLING, K.B. (2004): Atypical *pectus excavatum* in two Welsh terrier littermates; *Journal of Small Animal Practitioners* 45:311-314.
- ETTINGER, S.J. and SUTER, P.F. (1970): *Radiographic Examination in Canine Cardiology*. WB Saunders Co., Philadelphia.
- FARROW, C.S. (1996): Pectus deformities. *Radiography of the Cat*. Mosby Year Book, Inc., St Louis, USA.
- FONKALSRUD, E.W., DUNN, J.C., ATKINSON, J.B. (2000): Repair of *Pectus excavatum* deformities: 30 years of experience with 375 patients. *Annals of Surgery*; 231(3):443-448.
- FOSSUM, T.W., BOUDRIEAU, R.J., HOBSON, H.P. (1989): *Pectus excavatum* in 8 dogs and 6 cats; *Journal of Animal Hospital Association*; 25:595-601.
- FOSSUM, T.W. (2012): Surgery of the lower respiratory system. In: *Small Animal Surgery* 4th Ed. T.W. Fossum Mosby, St Louis pp 958-990.
- GARDNER, A., THOMPSON, M.S., HEARD, D.J., FONTENOT, .D, and GIBSON, N. (2007): Radiographic evaluation of cardiac size in flying fox species (*Pteropus rodricensus*, *P. hypomenalus* and *P. vampyrus*), *Journal of Zoo and Wildlife Medicine* 38(2):192-200.
- GOLLADAY, E.S. and GOLLADAY, G.J. (1997): Chest wall deformities, *Indian Journal of Pediatrics* May 64(3):339-350.
- GULANBER, E.G., GONENCI, R., KAYA, U., AKSOY, O., and BIRICIK, H.A.S. (2005): Vertebral Scale System to measure heart size in thoracic radiographs of Turkish Shepherd (Kangal) dogs, *Turkish Journal of Veterinary and Animal Sciences* 29: 723-726.

- GURKOK, S., GENÇ, O., DAKAK, M., GOZUBUYUK, A., GORUR, R., and BALKANLI, K. (2003): The comparison of measurements on chest x-ray for patients with *pectus* deformity. *Internet Journal of Thoracic and Cardiovascular Surgery* 5(2). Available at <http://www.ispub.com/ostia/index.php?xml>.
- HALLER, J.A., KRAMER, S.S., LIETMAN, S.A. (1987): Use of CT scans in selection of patients for *pectus excavatum* surgery: A preliminary report. *Journal of Pediatric Surgery* 22 (10):904–6.
- HALLER, J.A. Jr, SCHERER, L.R., TURNER, C.S., and COLOMBANI, P.M. (1989): Evolving management of *pectus excavatum* based on a single institutional experience of 664 patients, *Annals of Surgery* May 209(5):578-582.
- HALLER, J.A., COLOMBANI, P.M., HUMPHRIES, C.T., AZIZKHAN, R.G., and LOUGHLIN, G.M. (1996): Chest wall constriction after too extensive or too early operations for *pectus excavatum*. *Annals of Thoracic Surgery* 61(6):1618-1625.
- HASSAN, E.A., HASSAN, M.H., and TORAD, F.A. (2018): Correlation between clinical severity and type and degree of *pectus excavatum* in twelve bradycephalic dogs; *Journal of Veterinary and Medical Sciences* 80(5):766-771.
- HEBRA, A., SWOVELAND, B., EGBERT, M., TAGGE, E.P., GEORGESON, K., OTHERSEN, H.B. Jr, and NUSS, D. (2000): Outcome analysis of minimal invasive repair of *Pectus excavatum*: Review of 251 cases. *Journal of Paediatric Surgery*; 35(2):252-258.
- HOISE, S., SITKIEWICZ, T., PETERSEN, C., GOBEL, P., SCHAARSCHMIDT, K., TILL, H., NOATNICK, M., WINIKER, H., HAGL, C., SCHMEDDING, A., and WAAG, K.L. (2002): Minimally invasive repair of *pectus excavatum* – the Nuss procedure: A European multicentre experience. *European Journal of Paediatric Surgery August* 12(4): 235-238.
- KAGURAOKA, H., OHNUKI, T., ITAOKA, T., KEI, I., YOKOYAMA, M., and NITTA, S. (1992): Degree of severity of *Pectus excavatum* and pulmonary function in preoperative and postoperative periods. *Journal of Thoracic and Cardiovascular Surgery*; 104(5):1483-1488.
- KEALY, J.K. (1989): *Diagnostic Radiology of the Dog and Cat, 2nd edn.* WB Saunders Co., Philadelphia p258-265.
- KHANNA, G. (2010): Comparison of Haller Index values calculated with chest radiographs versus CT for *pectus excavatum* evaluation. *Pediatric Radiology* 40 (11): 1763–7.
- KILDA, A., BASEVICIUS, A., BARAUSKAS, V., LUKOSEVICIUS,

- S., and RAGAISIS, D.(2007): Radiological assessment of children with pectus excavatum; *Indian Journal of Paediatrics* 74:143-147.
- LINKLATER, K.A. and SMITH, M.C. (1997): Diseases and Disorders of the Sheep and Goats, Mosby Year Book, Europe Ltd, London.
- MCANULTY, J.F. and HARVEY, C.E. (1989): Repair of *pectus excavatum* by percutaneous suturing and temporary external coaptation in a kitten, *J Am Vet Med Assoc* 194:1065-1067.
- MILLER, K.A., WOODS, R.K., SHARP, R.J., GITTES, G.K., WADE, K., ASHCRAFT, K.W., SNYDER, C.L., ANDREWS, W.M., MURPHY, J.P., and HOLCOMB, G.W. (2001): Minimally invasive repair of *pectus excavatum*: a single institution's experience; *Surgery* October 130(4):652-657.
- NAKAHARA, K., OHNO, K., MIYOSHI, S., MAEDA, H., MONDEN, Y., and KAWASHIMA, Y. (1987): An evaluation of operative outcome in patients with funnel chest diagnosed by means of the computed tomogram. *Journal of Thoracic and Cardiovascular Surgery* April 93(4):577-582.
- NNAJI, T.O., IBEAGI, I.O., UDEGBUNAM, S.O. and UDEGBUNAM, R.I. (2010): Frontosagittal, ebral index and vertical diameter of thorax in mongrel dogs. *Animal Science. Reporter* 4(1):3-8.
- NNAJI, T., UBADIAGHA, U., and UDEGBUNAM, S. (2014): Frontosagittal and vertebral indices of West African Dwarf Goat. *Animal Research International* 11(2). Available at <https://www.ajol.info>. Accessed 20th May, 2019.
- OHNO, K., NAKAHIRA, M., TAKEUCHI, S., SHIOKAWA, C., MORIUCHI, T., HARUMOTO, K., NAKAOKA, T., UEDA, M., YOSHIDA, T., TSUJIMOTO, K., and KINOSHITA, H. (2001): Indications for surgical streatment of funnel chest by chest radiograph, *Pediatric Surgery International* Nov 17(8):591-595.
- OWENS, J.M. (1982): *Radiographic Interpretation for Small Animal Clinician*, Raltn Purina, St Louis.
- POSTON, P.M. (2015): The case for using the correction index obtained from chest radiography for evaluation of *pectus excavatum*. *Journal of Pediatric Surgery* 11: 1940– 1944.
- PRETORIUS, E.S., HALLER, J.A., and FISHMAN, E.K. (1998): Spiral CT with 3D reconstruction in children requiring re-operation for failure of chest wall growth after *pectus excavatum* surgery: Preliminary observations; *Clinical Imaging* 22(2):108-116.
- RAHAL, S.C., MORISHIN-FILHO, M.M., HATSCHBACH, E., MACHADO,

- V.M., APTEKMANN, K.P., and CORREA, T.P. (2008): *Pectus excavatum* in two littermate dogs, *Canadian Veterinary Journal* September 49(9):880-884.
- REEDER, M.M. and BRADLEY, W.G. (1993). Congenital deformities. *Reeder and Felson's Gamuts in Radiology: Comprehensive Lists of Roentgen Differential Diagnoses* 3rd Ed. Springer-Verlag New York Inc., NY.
- REBEIS, E.B., CAMPOS, J.R., FERNANDEZ, A., MOREIRA, L.F., and JATENE, F.B. (2007): Anthropometric index for *pectus excavatum*. Available at <http://www.scielo.br/scielo>
- SAPERSTEIN, G., HARRIS, S., and LEIPOLD, H.W. (1976): Congenital defects in domestic cats. *Feline Practice* 6(4):18-43.
- SAXENA, A.K., SCHAARSCHMIDT, K., SCHLEEF, J., MORCATE, J.J., and WILLITAL, G.H. (1999): Surgical correction of *pectus excavatum*: the Munster experience, *Langenbecks Arch Surg* April 384(2):187-193.
- SHIELDS, T.W. (1994): Chest wall deformities. In: *General Thoracic Surgery*, 4th Ed. R.C. Shamberger, Williams and Wilkins, USA.
- SHIRES, P.K., WALDRON, D.R., and PAYNE, J. (1988): *Pectus excavatum* in three kittens, *Journal of American Animal Hospital Association* 24:203-208.
- SMALLWOOD, J.E. and BEAVER, B.V. (1977): Congenital chondrosternal depression (*pectus excavatum*) in the cat, *Journal of American Veterinary Radiological Society* 18:141-146.
- SUTER, P.F. (1984): Injuries to thoracic wall and sternum. In: *Thoracic Radiology: A Text Atlas of Thoracic Disease of the Dog and cat*. P.F. Suter, Wettswil, Peter F Suter, Zurich, Switzerland pp 130-133.
- SUITA, S., TAGUCHI, T., MASUMOTO, K., KUBOTA, M., and KAMIMURA, T. (2001): Funnel chest: treatment strategy and follow-up. *Pediatric Surgery International* July 17(5-6): 344-350.
- TAYBI, H. and LACHMAN, R.S. (1990): Radiology of Syndromes, Metabolic Disorders, and Skeletal Dysplasias, 3rd Ed. Year Book Medical Publications, Chicago.
- UKAHA, R.O., ILOH, J.I. and TCHOKOTE, E. O. (2018): Determination of Vertebral Index in Thoracic Roentgenographs of the Rabbit (*Oryctolagus cuniculus*). *Asian Journal of Research in Animal and Veterinary Sciences* 1(2): 1-7, 2018.
- UKAHA, R.O., KENE, R.O.C. and AGWU, K.K. (2022): Radiomorphometric studies of the thorax in Nigerian indigenous dog:

Novel thoracic measurements. *Sokoto Journal of Veterinary Sciences* 20(2):75-86.

WALKER, M.A. (1986): The vertebrae. In: *Textbook of Veterinary Diagnostic Radiology* 3rd Ed. D.E. Thrall, WB Saunders, Philadelphia.

WRIGHT, J.A. (1982): A study of vertebral osteophyte formation in the canine spine II: Radiographic survey. *Journal of Small Animal Practitioners* 23:747-750.

WU, T.H., HUANG, T.W., HSU, H.H., LEE, S.C., TZAO, C., CHANG, H., and CHENG, Y.L. (2013): Usefulness of chest images for the assessment of pectus excavatum before and after a Nuss repair in adults. *European Journal of Cardiothoracicular Surgery* 43(2):283-287.

UKAHA, R.O. and ILOH, J.I. (2018): Determination of vertebral index in thoracic roentgenographs of the rabbit (*Oryctolagus cuniculus*). *Asian Journal of Research in Animal and Veterinary Sciences* 1(2):1-7.