

# Anatomy of Lumbosacral Plexus in Hoary Fox (*Lycalopex vetulus* - LUND, 1842)

Roseâmely Angélica de Carvalho Barros<sup>1</sup>, Luciano César Pereira Campos Leonel<sup>2</sup>, Carlos Eduardo de Carvalho Souza<sup>2</sup>, Lanussy Porfiro de Oliveira<sup>1</sup>, Thiago Sardinha de Oliveira<sup>1\*</sup>, Daniela Cristina de Oliveira Silva<sup>3</sup> and Zenon Silva<sup>1</sup>

<sup>1</sup>Biotechnology Academic Unit, Federal University of Goiás, Catalão-GO, Brazil.

<sup>2</sup>Faculty of Veterinary Medicine and Zootechny, University of São Paulo, São Paulo-SP, Brazil.

<sup>3</sup>Biomedical Sciences Institute, Federal University of Uberlândia, Uberlândia-MG, Brazil.

\*Corresponding author at: Laboratory of Human and Comparative Anatomy, Federal University of Goiás, Regional Catalão – Campus II, Avenida Castelo Branco, s/n, Setor Universitário, 75704-020, Catalão-GO, Brazil. Phone Number: +55 64 34415390

**Abstract**— *The anatomy of wild animals is an involving and interesting area of biological studies in many countries around the world, since the major interest of understands biology, especially animals in extinction risk. Therefore, the objective of this work was dissect and describe the anatomy of lumbosacral plexus of Hoary Fox, a typical and yet little known animal in the Neotropical Cerrado. For this, two male and two female specimens obtained from accidental death on the roadsides of Brazilian Southeast of Goiás were used, both fixed in aqueous solution of 10% formaldehyde and dissected under traditional techniques of macroscopic anatomy. The findings showed that lumbosacral plexus of Hoary Fox is formed by intersecting of L5, L6, L7, S1, S2 and S3. A lumbar plexus and a sacral one are easily identified in this animal. The boundary between them is the trifurcated nerve (L7). The lumbosacral plexus provides three major nerves to the pelvic limb: femoral, obturator and sciatic, besides some small muscular branches. Discussing with specific literature, the present work demonstrated unpublished data about the anatomic standard of Hoary Fox in lumbosacral plexus, an important system in this animal biological system.*

**Keywords**— *Comparative anatomy, lumbosacral plexus, Hoary Fox, Wild animals and Cerrado.*

## I. INTRODUCTION

The anatomy of wild animals is an involving and interesting area of biological studies in many countries around the world, since the major interest of understands biology, especially animals in extinction risk, in this sense many studies aimed understand the anatomy of wild mammals, however few literary quotations was made about neotropical canids biology, including some Brazilian animals in Cerrado biome, like Field Fox, one of seven lesser-known canids in the world [1].

Since wild animal's studies are developed, substantial information is discovered about the fragility of several species, mainly due to the destruction of environment which they live [2] and several species of neotropical mammals are subject of a significant number of studies, meanwhile the scientific world never focused animals that lives in areas of risk, perhaps the face of desire build sustainable development.

Hoary Fox (*Lycalopex vetulus* - LUND, 1842) is native animal of Cerrado, that although the second largest Brazilian biome, some components of its fauna are in danger of entering or already in process of extinction, since anthropic pressure on this biome growing stronger. According to Bocchiglieri *et al.* (2010) [3] the components Cerrado occupy all geographical patterns, composed of savannahs, fields and forests, therefore, Hoary Fox prefers clean fields and altitude. This animal is the smallest Brazilian canid and despite being considered a carnivore, eating small vertebrates or mainly insects, even eats fruits [1].

Is important note that Hoary Fox anatomy not presents the same level of knowledge as other species of the same biome, on the other hand, lumbosacral plexus is responsible for origin of all nerves destined to pelvic limbs and, therefore, the only responsible for movements control and is an important anatomical segment capable of arouses particular interest, especially to understand the related aspect of posture adaptations, locomotion, feeding and reproduction. Thus this work aimed to describe lumbosacral plexus of Hoary Fox, discussing the data obtained with specific literature.

## II. MATERIAL AND METHODS

The present paper is a descriptive anatomical study with two male and two female specimens of Hoary

Fox (*Lycalopex vetulus* - LUND, 1842), obtained from accidental death on roadsides of Brazilian Southeast of Goiás, under authorization of SISBIO n° 37072-2. Considering the descriptive approach of this work, statistical analysis is not necessary. All procedures were conducted in accordance with ethical principles and approved by the Institutional Ethics in Research Committee at the Federal University of Uberlândia (CEUA/UFU n° 067/12).

The study was made in the research laboratory of human and comparative anatomy from Federal University of Goiás – RC, where the specimens were fixed in aqueous 10 % formaldehyde solution to conservation and adopted consecrated techniques in Macroscopic Anatomy.

The anterior abdominal wall was opened in median sagittal plane and section of pelvis through pubic symphysis and lateral displacement of limbs, to facilitate access to abdominopelvic cavity. Once exposed the viscera of pelvic and abdominal cavity, it was removed to base of skull and exposed vertebral column as whole that the number of vertebrae could be verified. The next step was clean dorsal wall of abdominopelvic cavity until complete exposure of vertebral bodies and psoas muscles. Next, the muscles were carefully removed until vertebral bodies had been exposed. The lumbar vertebral bodies were carefully removed with the aid of osteotomies, tweezers, scalpel and scissors, until complete exposure of spinal cord involved by dura mater.

The Nikon® D7000 18-105 digital camera was used to photographic documentation and description nomenclature adopted is the standard of Nomina Anatomica Veterinaria (2012) [4], elaborated by the International Committee on Veterinary Gross Anatomical Nomenclature.

### III. RESULTS

The lumbosacral plexus of Hoary Fox consists interweaving of ventral branches at last three lumbar spinal roots and three first sacral ones, in thickness of

psoas major muscle. The lumbosacral plexus can easily be divided into lumbar plexus and sacral plexus. The border between them is bifurcated nerve or lumbosacral trunk corresponding to the nerve L<sub>7</sub>. The lumbosacral trunk or bifurcated nerve is named due after it shortly emergence and through intervertebral foramen, divides into two branches: cranial and caudal, cranial branch composing lumbar plexus and the caudal branch, sacral plexus. In Hoary Fox, bifurcated nerve would better know as a "trifurcated" nerve, overdue the division into three branches: cranial, middle and caudal. The cranial branch converges with L<sub>6</sub> to form lumbar plexus and femoral nerve; Middle branch joins caudal branch of L<sub>6</sub> to form cranial root of obturator nerve and finally, caudal branch contributes to the formation of sacral plexus (Figure 1 and Figure 2).

The lumbar plexus is restricted to intercommunications between the last three lumbar nerves, which in Hoary Fox are L<sub>5</sub>, L<sub>6</sub> and L<sub>7</sub>. The cranial nerves at L<sub>5</sub> not contribute to formation of lumbar plexus, although establishes interconnecting loops, frequently between L<sub>3</sub> and L<sub>4</sub>, which contribute to form ilioinguinal and genitofemoral nerves, respectively. The root L<sub>2</sub> follows as subcostal nerve and sometimes receives a small contribution of L<sub>1</sub>.

Sacral plexus is constituted by interlocking of ventral roots of S<sub>1</sub>, S<sub>2</sub> and S<sub>3</sub>, receiving strong contribution of L<sub>7</sub>. All ventral roots that forms lumbosacral plexus emerges separately through intervertebral foramina and only after traveling considerable space begin the process of interlacing, some closer and other distant (Figure 1 and Figure 2).

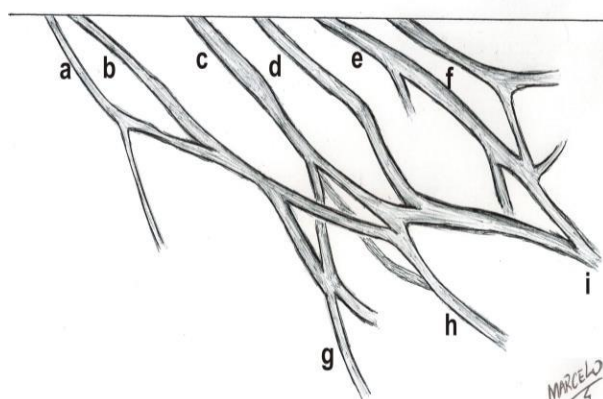
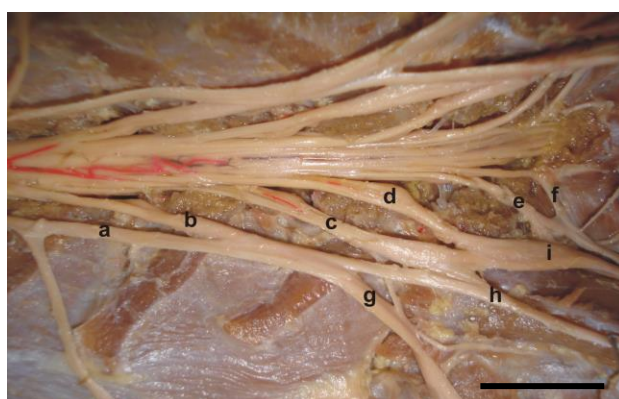


Fig.1: A- Photomicrography and B- Lumbosacral plexus scheme of right Hoary Fox (*Lycalopex vetulus*) antimer: a- L<sub>5</sub>, b- L<sub>6</sub>, c- L<sub>7</sub>, d- S<sub>1</sub>, e- S<sub>2</sub>, f- S<sub>3</sub>, g- femoral nerve, h- obturator nerve and i- sciatic nerve. —20%: 10.8 cm. Photography made by Roseâmely Angélica de Carvalho Barros and scheme illustration by Marcelo Vinícius Costa Amorim.

The root of L<sub>5</sub> forks in cranial branch and caudal branch after leaving the intervertebral foramen. Cranial branch follows as independent nerve to abdominal wall, while caudal branch joins with L<sub>6</sub>. In turn born and follows without branching, until joining with L<sub>5</sub> and then divides into cranial branch and caudal branch. The cranial branch follows as the femoral nerve, after receiving contribution of L<sub>7</sub>. However, caudal branch follows as cranial root of obturator nerve.

The root L<sub>7</sub> is divided into three branches: cranial, middle and caudal; hence the name of proposed trifurcated nerve. Cranial branch consist in femoral, median, obturator and flow sciatic nerve. The root S<sub>1</sub>

follows without dividing until joins caudal branch of L<sub>7</sub> to form cranial root of sciatic nerve.

The roots of S<sub>2</sub> and S<sub>3</sub> follow separate until branching into cranial branch and another caudal. The cranial branch makes sciatic nerve, while caudal branch joins S<sub>3</sub>. The pattern lumbosacral plexus formation is similar in four antimeres studied. The main nerves originating from lumbosacral plexus are: femoral, obturator and sciatic. Femoral nerve receives contribution of L<sub>5</sub>, L<sub>6</sub> and L<sub>7</sub>; as obturator nerve from L<sub>6</sub> and L<sub>7</sub>; meanwhile L<sub>7</sub>, S<sub>1</sub>, S<sub>2</sub> and S<sub>3</sub> contribute to form sciatic nerve. Several small muscular branches are born, also of the Lumbosacral Plexus (Figure 1 and Figure 2).

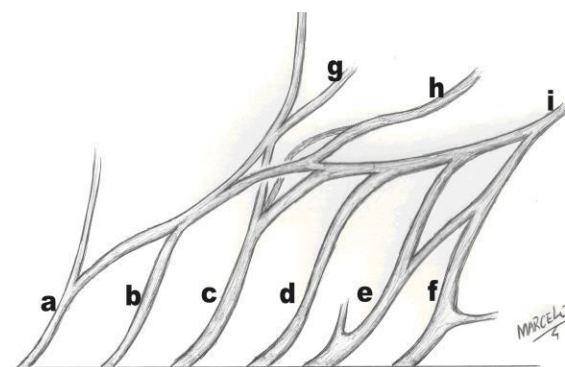
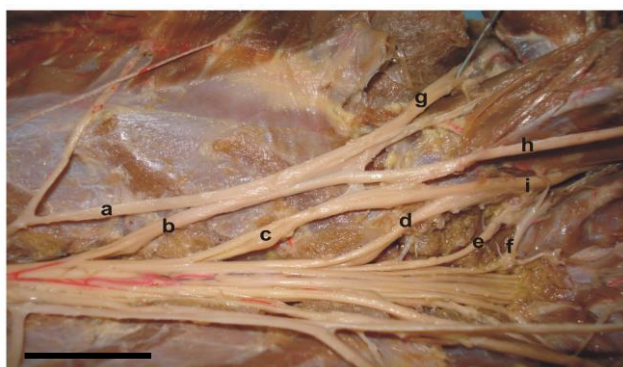


Fig.2: A- Photomicrography and B- Lumbosacral plexus scheme of right Hoary Fox (*Lycalopex vetulus*) antimer: a- L<sub>5</sub>, b- L<sub>6</sub>, c- L<sub>7</sub>, d- S<sub>1</sub>, e- S<sub>2</sub>, f- S<sub>3</sub>, g- femoral nerve, h- obturator nerve and i- sciatic nerve. . —20%: 10.8 cm. Photography made by Roseâmely Angélica de Carvalho Barros and scheme illustration by Marcelo Vinícius Costa Amorim.

#### IV. DISCUSSION

Regard the composition of Hoary Fox (*Lycalopex vetulus*), the involvement of iliohypogastric, ilioinguinal and genitofemoral nerves in the composition of lumbar plexus as a rule in humans is not recorded [5].

Hepburn (1892) [6] describing lumbar and sacral plexus anatomy in Gorilla, Chimpanzee, Orangutan and Gibbon, notes that lumbar plexus is similar to Man, exhibiting several loops. In Hoary Fox the structure in form of loops or intercommunications is rule, even the characteristic of plexus. In general, the literature do not show "loops" but of interlacing.

In gibbon, the only difference is the absence of loop between L<sub>1</sub> and L<sub>2</sub> [6]. In Hoary Fox there be "anastomoses" between cranial roots at L<sub>5</sub>, but do not contribute to formation of lumbar plexus. According to Hill (1972) [7] in Brachyteles, the first component loops of lumbar plexus occur between L<sub>1</sub>-L<sub>2</sub> and L<sub>2</sub>-L<sub>3</sub>; and *Macaca mulatta* cranial limit is T<sub>12</sub>, but more frequent find between L<sub>3</sub>-S<sub>1</sub> [8]. In Hoary Fox cranial limit is L<sub>5</sub>, an evident caudal displacement of plexus observed in relation to primates. Caudal displacement of Lumbar Plexus suggests lower characteristic in phylogeny, probably associated with a column formed by a larger

number of free vertebrae. Schultz and Straus (1945) [9] consider the presence of 13 thoracic vertebrae as a primitive trait, since in arboreal Mussaranhos there are 13 vertebrae, which can be considered alive ancestors of primates. Changes in musculoskeletal structure influence adjacent neural system, so the decrease in the number of vertebrae along phylogeny led to shortening of neural system [10-11].

For Howell and Straus (1932) apud Hartmann and Straus (1932) [12] is more convenient consider the Lumbar and Sacral Plexus as single entity, since lumbar and sacral roots contribute their formations. In the case of Hoary Fox, the separation in Lumbar Plexus and Sacral Plexus seems adequate, since the only communication between the two is trifurcated nerve and yet there is clear individuality regarding the branches destined for Lumbar and Sacral Plexus.

Bifurcated nerve is boundary between Lumbar and Sacral Plexuses [13]. Bergman et al. (2001) apud Izci et al. (2005) [14] reported that the border between lumbar and sacral plexuses is made by the presence of bifurcated nerve, as in Tamanduá Mirim [15].

Howell and Straus (1932) apud Hartmann and Straus (1932) [12] consider that Rhesus lumbosacral



plexus involves all seven lumbar nerves and the first two sacral. In dog, the lumbosacral plexus is composed of the last five lumbar and the first three sacral [16], lumbar plexus in dog being restricted to interconnections of L<sub>3</sub>-L<sub>5</sub>. According to El-Assy (1966) [17], lumbosacral plexus of primates is formed by all lumbar and first sacral; whereas according to Hill (1966) [18], in *Cercopithecus petaurista* there are seven lumbar nerves, but only the last five participate in the formation of lumbosacral plexus.

Urbanowicz and Zaluska (1969) [19] state that lumbar plexus in humans involves L<sub>1</sub>-L<sub>4</sub>, and in Rhesus and Cynomolgus from L<sub>1</sub>-L<sub>5</sub>. Wood James (1910) apud Urbanowicz and Zaluska (1969) [19] considers that participation of L<sub>5</sub> in the formation of lumbar plexus is a primitive trait, however, if anthropoids have features more progressive traits than humans, cause some monkeys have plexus formed only 3 or 4 lumbar nerves, therefore, there is cranial migration and reduction of the number of nerves. Zaluska and Urbanowicz (1972) [20] state that humans lumbosacral plexus is formed by the last two lumbar and three first sacral. For Castro *et al.* (2009) [21], in domestic animals, L<sub>3</sub>-S<sub>1</sub> make lumbosacral plexus, whereas Schwarze; Schröder (1970) [22] and Dyce *et al.* (2004) [23] related that the same plexus is formed by the last three or four lumbar and two first sacral. In Tamanduá Mirim, T<sub>18</sub>, L<sub>1</sub>, L<sub>2</sub>, L<sub>3</sub> and S<sub>1</sub>-S<sub>5</sub> contribute to lumbosacral plexus formation [15].

As observed there is no anatomical pattern for lumbosacral plexus, but rather depends on taxonomic group. In Hoary Fox, the lumbar plexus involves L<sub>5</sub>, L<sub>6</sub> and L<sub>7</sub>, while sacral plexus comprises S<sub>1</sub>, S<sub>2</sub>, S<sub>3</sub> and the connection between both is made by trifurcated nerve (L<sub>7</sub>).

The connection between Lumbar and Sacral plexus always done by bifurcated nerve [7], but according to Krechowiechi *et al.* (1972) [8] bifurcated nerve may be absent, whereas humans and gorillas always present. In Hoary Fox the connection between the two plexuses is always present, however the nerve is trifurcated and not bifurcated and its origin is in L<sub>7</sub>.

The connection between lumbar and sacral plexuses is closely associated with shortening of pre-sacral spine, however, lifestyle, especially locomotion strongly influences spinal shortening process, as changes in lumbosacral plexus [11].

Testut and Latarjet (1979) [24] and Piasecka-Kacperska and Gładkowska-Rzeczycka (1972) [11] consider that humans a pattern for lumbosacral plexus given the large number of variations, both in limits and number of component roots. In primates there is great variability in number of roots and nerves from the plexus [25]. In domestic carnivores, the highest number of roots is associated with largest number of lumbar vertebrae [23],

26]. In Hoary Fox six spinal segments, three lumbar and three sacral make up lumbosacral plexus, which is clearly divided into Lumbar Plexus and Sacral Plexus by trifurcated nerve and the seventh lumbar nerve.

## V. CONCLUSION

The present study demonstrated that anatomic standard of Hoary Fox presents lumbosacral plexus formed by intersecting of L<sub>5</sub>, L<sub>6</sub>, L<sub>7</sub>, S<sub>1</sub>, S<sub>2</sub> and S<sub>3</sub>. A lumbar plexus and a sacral one are easily identified in this animal. The boundary between them is the trifurcated nerve (L<sub>7</sub>). The lumbosacral plexus provides three major nerves to the pelvic limb: femoral, obturator and sciatic, besides some small muscular branches, showing particularities template compared to other mammals and detailed analysis of Hoary Fox anatomy

## FUNDING

This work was supported by grants from “Fundação de Amparo a Pesquisa do Estado de Goiás – FAPEG”.

## CONFLITS OF INTERESTS

The authors declare no conflicts of interest associated with this manuscript.

## ACKNOWLEDGEMENTS

The authors thank “Centro de Triagem de Animais Silvestres de Catalão” for animal management.

## REFERENCES

- [1] F. C. Azevedo, F. G. Lemos (2012). Rastros e Pistas: Guia de mamíferos de médio e grande porte do Triângulo Mineiro e Sudeste de Goiás. Uberlândia, Grupo de Mídia Brasil Central, pp.115.
- [2] P. Auricchio (1995), Primatas do Brasil. 1st ed., vol. 1. São Paulo: Terra Brasilis, pp.168.
- [3] Adriana Bocchiglieri, André F. Mendonça, Henriques R. P. Barros (2010). Composição e diversidade de mamíferos de médio e grande porte no Cerrado do Brasil central. Biota Neotropica (ISSN 1676-0611), 10(3), <http://dx.doi.org/10.1590/S1676-06032010000300019>.
- [4] International committee on veterinary gross anatomical nomenclature. Nomina anatomica veterinaria. 4. ed. New York, 1994: (Togheter with nomina histologica, 2. ed., 1992 and nomina embriologica veterinaria, 1992).
- [5] R. Warwick, P. L. Willians (1995), Gray anatomy. 37 ed., vol. 1. Rio de Janeiro: Guanabara Koogan.
- [6] David Hepburn (1892). The comparative anatomy of the muscles and nerves of the superior and inferior extremities of the anthropoid apes Part II. Journal of Anatomy and Pshysology, 26(3), 324-356.

- [7] Osman W.C. Hill (1972). Primates: Comparative anatomy and taxonomy V - Cebidae – Part B Edinburgh University Press, Edinburgh, pp. 537.
- [8] A. Krechowicki, D. Goscicka, S. Samulak, (1972). The lumbosacral plexus and lumbar enlargement in *Macaca mulatta*. *Folia Morphologica*, (31), pp. 11-19.
- [9] Adolph H. Schultz, William L. Strauss (1945). The numbers of vertebrae in Primates. *Proceedings of the American Philosophical Society*, 84(9), pp. 601-626.
- [10] K. Piasecka-Kacperska, J. Gładkowska-Rzeźczycka (1972). The sacral plexus in primates. *Folia Morphologica*, 31(1), pp. 21-33.
- [11] J. Gładkowska-Rzeźczycka, K. Piasecka-Kacperska (1973). Communications of the lumbar plexus with the sacral plexus in Primates. *Folia Morphologica* (Warsz.), 32(4), pp.413-419.
- [12] C. G. Hartmann, William L. Strauss Junior (1932). *Anatomy of the Rhesus monkey*. New York.
- [13] Osman W. C. Hill (1960). *Primates: Comparative anatomy and taxonomy IV - Cebidae – Part A* Edinburgh at the University Press.
- [14] Yusuf Izci, Doga Gürkanlar, Hasan Ozan, Engin Gönül (2005). The morphological aspects of lumbar plexus and roots: an anatomical study. *Turkish Neurosurgery*, 15(2), pp. 87-92.
- [15] J. R. Cardoso, P. R. Souza, V. S. Cruz, E. J. Benetti, E. Brito, M. S. Silva, P. C. Moreira, A. A. L. Cardoso, A. K. Martins, T. Abreu, K. Simões, F. R. Guimarães Estudo anatômico do plexo lombossacral de *Tamandua tetradactyla*. *Arquivo Brasileiro de Medicina Veterinária e Zootecnia*, 65(6).
- [16] Malcolm E. Miller, George C. Christensen, Howard E. Evans (1964). *Anatomy of the dog*. Philadelphia: W. B. Saunders, (40)4, pp. 746.
- [17] Y. S. El-Assy (1996). Beiträge zur morphologie des peripheren nervensystems der primate. *Gegenbaurs morphologisches Jahrbuch*, (108)1, pp. 476-567.
- [18] Osman W. C. Hill (1966). *Primates: Comparative anatomy and taxonomy VI - Catarrhini-Cercopithecoidea – Cercopithecinae*. Edinburgh at the University Press, pp. 115 -125 and 361-363.
- [19] Z. Urbanowicz, S. Zaluska (1969). Arrangement of lumbar plexus in man and macaca. *Folia Morphologica* (Wars), 28 (3), pp. 285-99.
- [20] S. Zaluska, Z. Urbanowicz (1972). Origin of the sacral plexus in man and in *Macacus*. *Acta Biologica et Medica*, v.17, n. 2, pp. 93-107.
- [21] Tiane F. Castro, Daniel A. S. Souza, Rodolfo P. Silva Filho (2009). Sistematização e distribuição da inervação lombar e sacral em *Arctocephalus Australis*. *Brazilian Journal Veterinary Research Animal Science*, (46), pp.404-411.
- [22] E. Schwarze, L. Schröder (1970). *Compendio de anatomia veterinária*. Zaragoza: Acribia, pp. 208.
- [23] K. M. Dyce, W. O. Sack, C. J. G. Wensing (2004). *Tratado de Anatomia Veterinária*. Rio de Janeiro, Elsevier, pp.856.
- [24] L. Testut, A. Latarjet (1979). *Anatomia humana*. 9 ed. Barcelona: Salvat, (3)1.
- [25] Daris R. Swindler, Charles D. Wood (1982). *An atlas of primate gross anatomy Baboon, Chimpanzee and Man – Robert E. Krieger Publishing Company* Malabar Florida, pp.224-225.
- [26] Robert Getty (1986). *Sisson/Grossman Anatomia dos animais domésticos*. 5 ed. Rio de Janeiro: Guanabara Koogan, (1-2)1.