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MUSCULAR ANATOMY OF THE THORAX AND THORACIC LIMB OF Caiman Crocodilus (LINNAEUS, 1758) (CROCODYLIA: ALLIGATORIDAE) BY MEANS OF DIGITAL DISSECTION AND THREE-DIMENSIONAL MODELS.

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ARTIGO ORIGINAL

ABSTRACT

The *Caiman crocodilus* , popularly known as *alligator* , is a species of crocodilian, which has a crest or "forehead" described as "in crescent shape", observed, immediately, dorsal in relation to the eyes, as well as above the dorsal region of the snout, with an ossified crust rostral to the orbicular region. The present study aimed to describe the muscular anatomy of the thorax with emphasis on the thoracoappendicular muscles, and *Caiman crocodilus* thoracic limb *,* with the aid of X-Ray (RX), Ultrasonography (US), and detailed manual dissection; identified the thickness of the muscle groups of the thorax and thoracic limb of the *Caiman crocodilus* , through Ultrasonography, and, at the end, three-dimensional models of the muscular anatomy of the thorax were built, with emphasis on the thoracoappendicular muscles, and the thoracic limb of the *Caiman crocodilus* , with finalization in three-dimensional PDF. Anatomical descriptions have greatly favored interventions in wild animals, as well as the use of imaging tests such as X-ray and US. In addition, 3D schematic models clarify topographical relationships and highlight muscle depth, for example. In this way, it is possible to identify anatomical differences and intervene in case of diagnoses and prognoses, such as in US, even in real time.

Keywords: Jacaretinga, Anatomy, Muscles.

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INTRODUCTION

The *Caiman crocodilus* , popularly known as *alligator* , is a species of crocodilian, which has a crest or "forehead" described as "in crescent shape", observed, immediately, dorsal in relation to the eyes, as well as above the dorsal region of the snout, with an ossified crust rostral to the orbicular region. Younger specimens have a yellow coloration, with black spots on the lateral regions throughout the entire body, however, the adult animals evolve to a dark olive color, measuring up to 2.8m in length (Mendonça & Coutinho, 2010). The main impacts related to anthropic interventions are the creation of dams, deforestation, and hunting (Da Silveira and Thorbjarnarson 1999; Campos 2003; Combrink et a*l.* 2017).

Research on the morphological and locomotor aspects of crocodilians require specific knowledge of the appendicular anatomy, as it is directly articulated with the axial part. It is a question of recognizing that crocodilians have different forms of displacement, and, therefore, different postures between slips and gallops. The anatomical and functional particularities of muscles, for example, as well as the locomotion itself, have been widely used in muscle reconstructions of fossil dinosaurs (Klinkhamer et. al*.* 2017).

Considering the phylogenesis of reptiles, as well as their differentiated morphology, in relation to other species, it is considered relevant to carry out morphofunctional descriptions of this class of tetrapod and ectodermal vertebrates. The muscular anatomy of crocodilians correlated to their functional aspects can contribute, both to conservation projects, and to preventive medicine, therapy, and handling of these animals, by expanding the specific knowledge base of the specimens. Also, it can be very useful in the reconstruction of fossils and/or dinosaurs.

Above all, crocodilians represent the most abundant carnivorous vertebrates, which are found in tropical and humid places. Thus, knowing the morphological pattern becomes relevant, with an emphasis on conservationist definitions, including rescue units (Da Silveira et a*l.* 2011; Xisto 2018).

The present study has aimed to describe the muscular anatomy of the thorax, with emphasis on the thoracoappendicular muscles and thoracic limb of the *Caiman crocodilus,* through digital dissection and three-dimensional models, as well as it has specifically aimed to describe the muscular anatomy of the thorax with emphasis in the thoracoappendicular muscles, and *Caiman crocodilus* thoracic limb*,* with the aid of X-Ray (RX), Ultrasonography (US), and detailed manual dissection; identified the thickness of the muscle groups of the thorax and thoracic limb of the *Caiman crocodilus* through Ultrasonography, and, in the end, three-dimensional models of the muscular anatomy of the thorax were constructed, with emphasis on the thoracoappendicular muscles, and the thoracic limb of the *Caiman crocodilus* , with finalization in Three-dimensional PDF.

MATERIAL AND METHODS

The present study was previously submitted to the Research Ethics Committee of the University Center of Patos de Minas, through the platform CEUA/UNIPAM (Committee in Ethics in the Use of Animals), being approved under protocol number 69/20. It is a descriptive and topographic field research. The chest muscle identification with emphasis on the thoracoappendicular muscles, and thoracic limb of the *Caiman crocodilus* was performed through digital and manual dissection, to contribute to the construction of 3D models, and finalization in three-dimensional PDF.

Five specimens of *Caiman crocodilus* belonging to the teaching collection of the Laboratory of Teaching and Research in Wild Animals (LAPAS), of the Federal University of Uberlândia (UFU), adult males, measuring an average of 1.50 m in length, were used.

Digital dissection was performed using X-Ray (RX) and Ultrasonography (US). RX allowed the visualization of bones, while US provided data on muscle groups. The animals were preserved in a 10% formaldehyde solution for detailed manual dissection.

The analyzes of muscle thicknesses at US were described in centimeters, with priority being given to the total thickness of the muscle groups (Vieira et. al*.* 2020; Mendes et. al*.* 2015), with an emphasis on the right antimere, for the presentation of data related to the results.

RX and US data were superimposed, as well as compared with detailed manual dissection, for better definition of the muscles, and of the fixation points of origin and insertion. Digital dissection performed on the thorax and thoracic limb of *Caiman crocodilus* contributed to the construction of three-dimensional schematic muscle models, and finalization with three-dimensional PDF (Cartwright et. al*.* 2013; Vieira et. al*.* 2020).

Detailed manual dissection of the thorax with emphasis on thoracoappendicular muscles and thoracic limb was performed on five specimens of *Caiman crocodilus*. It is considered that the combination of digital dissection with manual dissection increases the accuracy of specific structural identifications. The identification of soft tissues, and especially muscles, started in the superficial structures, until the deepest stratification. The muscle identification reference as well as the directional orientation terminology were based on publications of specimens and similar species (Klinkhamer et. al*.* 2017).

The data from the detailed manual dissection, as well as the digital dissections (RX and US) were superimposed and combined, to ensure with greater accuracy the individualization and identification of muscle structures, as well as their fixation points of origin and insertion. In this perspective, the muscles were edited in the professional modeling software *ZBrush* 2019 for *Mac*, and analyzed in groups, with emphasis, their motor agents. In this context, the topography was considered, as well as the relationships with the bones, mainly based on detailed manual dissection. Muscles were assigned different hues to differentiate identification and visualization in 3D transposition, and the final configuration was converted into a three-dimensional PDF file (Klinkhamer et. al*.* 2017).

RESULTS

1. DIGITAL DISSECTION

1.1 X-Ray

Chest X-ray was taken on the ventrodorsal and dorsoventral axis. The bone structures of the pectoral girdle and thoracic limb were identified, as well as the borderline terms considered for descriptions, as shown in **Figure 1**, with emphasis on the right antimere.

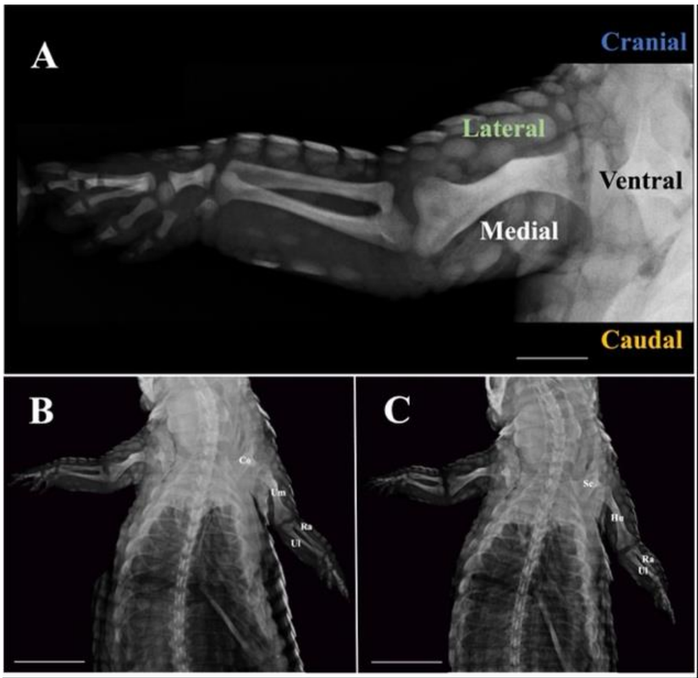

Fig. 1: X-Ray of the Chest, and thoracic limbs of *Caiman crocodilus,* with directional or borderline indications. **A:** Right thoracic limb (medial view): borderline indication - medial and lateral; and right hemithorax, with borderline indication - cranial, ventral and caudal. **B:** Ventrodorsal chest and thoracic limbs, with emphasis on the right antimere. **C:** Dorsoventral chest and thoracic limbs, with emphasis on the right antimere – Co: coracoid; Sc: scapula; Hu: humerus; Ra: radio; Ul: ulna. * *ScaleBar* = 3cm.

1.2 Ultrasound

The ultrasonography was performed on the chest in a ventral and dorsal view, as well as on the thoracic limb (arm and forearm), in a medial and lateral view, with a proximal and distal focus, both on the arm and on the forearm, as shown in **Figure 2**.

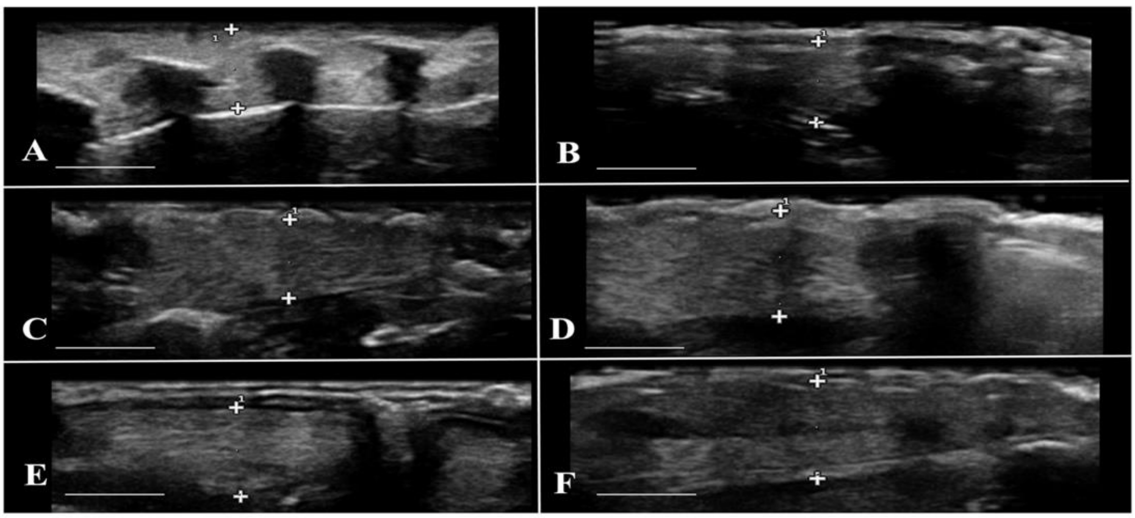

Fig. 2: **Ultrasound of the chest and forelimbs of *Caiman crocodiles* of *Caiman crocodiles,* with emphasis on the right antimere**. **A:** Ventral chest. **B:** Dorsal chest. **C:** Proximal right thoracic limb (arm) (medial view). **D:** Distal right thoracic limb (forearm) (medial view). **E:** Member thoracic right proximal (upper arm) (side view). **F:** Distal right thoracic limb (forearm) (lateral view). * *ScaleBar* = 3cm.

The average thickness of the Thorax muscle groups, with emphasis on the right antimere, was 0.98 cm in the ventral region and 1.01 cm in the dorsal region. In the right thoracic limb, medially, the average thickness was 0.90 cm proximally and 1.02 cm distally, respectively. Laterally, the average thickness was 1.12 cm proximally and 1.04 cm distally.

In the chest, in ventral view, the (+) muscle thickness measurement flag indicates in **Figure 2A**, the superficial and deep pectoral muscles, and, in dorsal view, in **Figure 2B,** the (+) muscle thickness measurement flag indicates the trapezius muscle, levator scapula, and dorsal muscles.

In the thoracic limb, the muscle thickness measurement flag (+) indicates in **Figure 2C and D,** the flexor muscle group, as well as, in **Figure 2E and F,** the extensor muscle group.

2. MANUAL DISSECTION

The muscles of the chest, pectoral girdle, and thoracic limb of the *Caiman crocodilus* are shown, considering the lateral and medial muscles of the arm, as well as the lateral and medial muscles of the forearm, as shown in **Figure 3,** with emphasis on the right antimere.

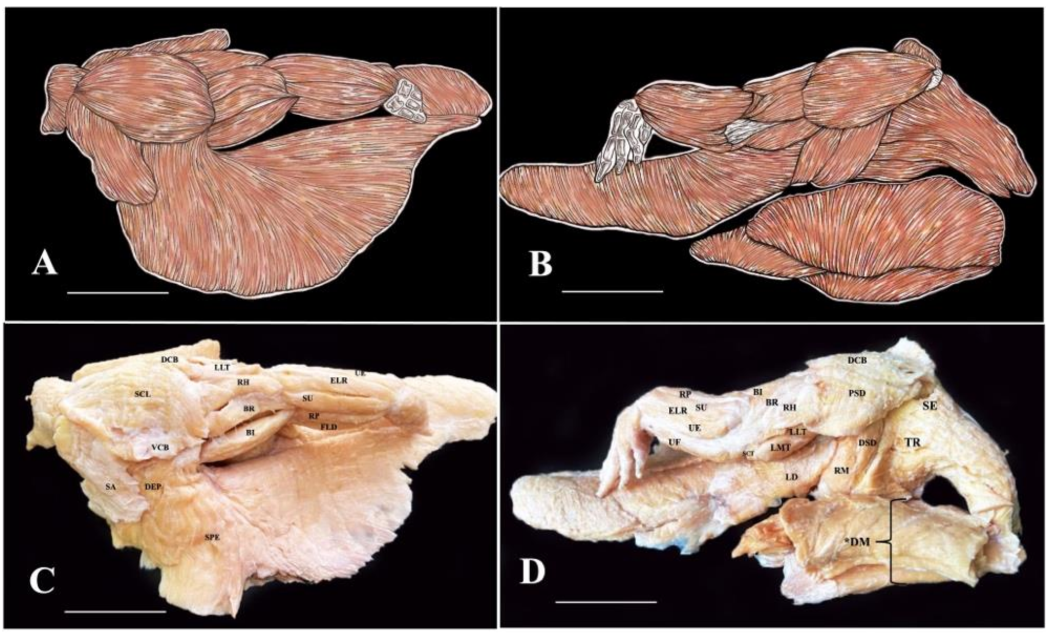

Fig. 3: A: Ventral photograph of the chest, pectoral girdle, and medial of the thoracic limb of *Caiman crocodilus,* with emphasis on the right antimere. SA: sternoatlantical; DPE: deep pectoral; SPE: superficial pectoral; VCB: ventral coracobrachialis; SCL: supracoracoid long; DCB: dorsal coracobrachialis; BI: biceps; BR: brachial; RH: radial humerus; LLT: long lateral triceps; SU: supinator; RP: round pronator; FDL: flexor digitorum longus; ELR: extensor digitorum longus radial; UE: ulnar extensor of the fingers. **B: Dorsal photograph of the chest, pectoral girdle, and lateral of the thoracic limb of *Caiman crocodilus,* with emphasis on the right antimere.** SE: scapula elevator; TR: trapezius; DM: dorsal muscles; DCB: dorsal coracobrachialis; PSD: proximal scapular deltoid, DSD: distal scapular deltoid; RM: round major; LD: latissimus dorsi; BI: biceps brachii; BR: brachial; RH: radial humerus; LLT: long lateral triceps; LMT: long medial triceps; SCT: short cranial triceps; UE: ulnar extensor of the fingers; UF: ulnar flexor of the fingers; ELR: extensor digitorum longus radial; SU: supinator; PR: pronator round. * *ScaleBar* = 3cm.

The identification and indication of fixation points of origins, insertions and muscular actions of the thorax and thoracic limb of the *Caiman crocodilus* is shown in **Tables 1, 2, 3, 4, 5, 6, 7, and 8.**

Table 1. Origin, insertion and action of the superficial dorsal muscles of the pectoral girdle of the *Caiman crocodilus.*

MUSCLE	SOURCE	INSERTION	ACTION
trapezius	thoracodorsal fascia cranial to the humerus (cervical and thoracic segment)	cranial margin of the scapula	cranial protraction and rotation of the scapula
Great Back	thoracodorsal fascia (continuous with trapezius)	distal to the proximal articular surface of the humerus, cranial to the triceps short intermediate	extension, retraction and elevation of the humerus
levator scapula	cervical level, perpendicular to the dorsal scapular deltoid	cranial and distal margin of the scapula	cranial rotation of the scapula

Table 2. Origin, insertion and action of the deep dorsal muscles of the pectoral girdle of *Caiman crocodilus.*

MUSCLE	SOURCE	INSERTION	ACTION
Deltoid proximal scapular	proximal surface of the cranial margin of the scapula	caudal to the vertex of the deltoid crest of the humerus	humeral abduction, shoulder stabilization
Bigger round	caudal and distal surface of the scapula	distal to the proximal articular surface of the humerus	humerus elevation, and shoulder flexion
Deltoid distal scapular	cranial and distal surface of the scapula	caudal to the vertex of the humerus deltoid crest (superimposed, perpendicularly, to the insertion of the proximal scapular deltoid)	shoulder extension
humeral scapula	proximal surface of the caudal edge of the scapula	caudal to insertion of latissimus dorsi and teres major	elevation, protraction and stabilization of the humerus

Table 3. Origin, insertion and action of superficial ventral muscles of the pectoral girdle of *Caiman crocodilus.*

MUSCLE	SOURCE	INSERTION	ACTION
superficial chest	superficial sternal margin	caudal to the biceps in its proximal portion	shoulder adduction and retraction
deep chest	deep sternal margin	caudal to the biceps in its proximal portion	shoulder adduction and retraction
sterno-atlantic	first and second cervical ribs	middle insertion on the cartilaginous margin of the sternum, between the origins of the pectoral muscles: superficial and deep	scapula stabilization
superficial costocoracoid	deep sternal margin	caudal margin, along the ventral surface of the coracoid	caudal rotation of the pectoral girdle, retraction of the coracoid or pectoral girdle
Long Supracoracoid	proximal ventral projection of the coracoid	distal to the proximal articular surface of the humerus, considering the insertion	shoulder extension

		position of the intermediate and short supracoracoid	

Table 4. Origin, insertion and action of the deep ventral muscles of the pectoral girdle of *Caiman crocodilus.*

MUSCLE	SOURCE	INSERTION	ACTION
ventral serratus	ribs in ventral and lateral location, immediately deep to the deep pectoralis muscle	middle and posterior margin of the scapula	pectoral girdle extension
deep costocoracoid	dorsal sternal margin	caudal margin, in the proximal ventral projection of the coracoid	caudal rotation of the pectoral girdle
Intermediate costocoracoid	proximal and ventral projection of the coracoid, deep to the long supracoracoid	average in relation to the proximal articular surface of the humerus, between the insertion of the long and short supracoracoid	shoulder extension
Short Supracoracoid	superimposed on the scapulocoracoid junction, lateral to the intermediate supracoracoid	proximal to the proximal articular surface of the humerus	shoulder extension, and thoracic limb adduction
Short ventral coracobrachialis	proximal to the sternal margin, along the coracoid process	central middle surface of the proximal humeral epiphysis, in a wide area, cranial to the deltoid crest	shoulder flexion and retraction
Short dorsal coracobrachialis	proximal and middle surface of the scapula	proximal to the proximal articular surface of the humerus, cranial to the insertion of the ventral coracobrachialis, and to the deltoid crest	shoulder stabilization, protraction and flexion of the thoracic member
subscapular	ventral surface of the scapula	bulge of the proximal articular surface of the humerus	shoulder stabilization

Table 5. Origin, insertion and action of the lateral brachial muscles of the *Caiman crocodilus.*

MUSCLE	SOURCE	INSERTION	ACTION
long lateral triceps	proximal, on the caudal margin of the scapula	olecranon	shoulder flexion, elbow extension
Short cranial triceps	in elongated projection, on the proximal epiphysis of the humerus, up to the limit with the short intermediate triceps	olecranon	elbow extension
Intermediate short triceps	proximal to the articular surface of the humerus, along the diaphysis of the humerus, cranial to the short caudal triceps	olecranon	elbow extension

Table 6. Origin, insertion and action of the medial brachial muscles of the *Caiman crocodilus*

MUSCLE	SOURCE	INSERTION	ACTION
Long medial triceps	medium on the caudal margin of the scapula with double tendon fixation, and proximal on the caudal margin of the coracoid	olecranon	shoulder flexion, forearm extension
short tail triceps	distal to the proximal articular surface of the humerus, along the medial shaft of the humerus	olecranon	forearm extension
brachial biceps	proximal projection of the cranial margin of the coracoid	radial tuberosity	shoulder extension and forearm flexion
brachial	diaphysis of the humerus, in an elongated surface, cranial to the biceps and caudal to the humeroradial	distal to the radial tuberosity	forearm flexion
Radial humerus	proximal to articular surface proximal to humerus, cranial to brachial	radial tuberosity	forearm flexion

Table 7. Origin, insertion and action of the lateral muscles of the forearm – craniocaudal direction of *Caiman crocodilus.*

MUSCLE	SOURCE	INSERTION	ACTION
Supinator	cranial epicondyle of the humerus	cranial diaphysis of the radius	forearm supination and flexion

Long Carpal Radial Extender	cranial epicondyle of the humerus	proximal dorsal edge of the radial carpal bone	wrist extension, flexion and stabilization of the humeroradial joint
Ulnar Long Carpal Extender	cranial epicondyle of the humerus	II metacarpal	wrist extension
Ulnar flexor	cranial epicondyle of the humerus	caudal diaphysis of the ulna	forearm flexion, and postural stabilization
Radial abductor	cranial epicondyle of the humerus	superimposed on the humeroradial joint	extension of the carpus and adduction of the fingers
Short radial carpal extender	Radial head: distal to the radius diaphysis Ulnar head: along the diaphysis, medial ulnar	Radial head: superimposed on the radiocarpal joint Ulnar head: superimposed on the radiocarpal joint	wrist extension and finger adduction

Table 8 . Origin, insertion and action of the Medial Forearm Muscles – craniocaudal direction of *Caiman crocodilus.*

MUSCLE	SOURCE	INSERTION	ACTION
Round pronator	caudal epicondyle of the humerus	tail shaft of the radius	forearm pronation, and radiohumeral joint flexion
Ulnar flexor of the carpus	caudal epicondyle of the humerus	pisiform bone prominence	flexion and abduction of the carpus, stabilization of the forearm
Long finger flexor (humeral head, ulnar)	caudal epicondyle of the humerus; and ulna shaft	central flexor tendon, proximal to the carpus on the middle palmar surface	finger flexion
Square pronator	along the cranial diaphysis of the ulna	along the radial shaft of the radius, in an area interspersed with the pronator teres	forearm pronation and stabilization

3. 3D PDF SCHEMATIC MODELS (*ZBRUSH* 2019 FOR *MAC)*

The *Caiman crocodilus* Thorax, pectoral girdle, and thoracic limb muscles, with emphasis on the right antimere, were edited in the professional modeling software *ZBrush* 2019 for *Mac* , and analyzed in groups, with an emphasis on the right antimere. In this context, the topography was considered, as well as the relationships with the bones, based on detailed digital and manual dissection. Different shades were used to highlight the stratification of the muscles and differentiate them, as shown in **Figures 4 and 5.** In addition, a realistic 2D manual representation of the muscles of the Chest, pectoral girdle and thoracic limb of the *Caiman crocodilus* was made, with an emphasis on the right antimere, demonstrated in transposition with the schematic models in 3D PDF.

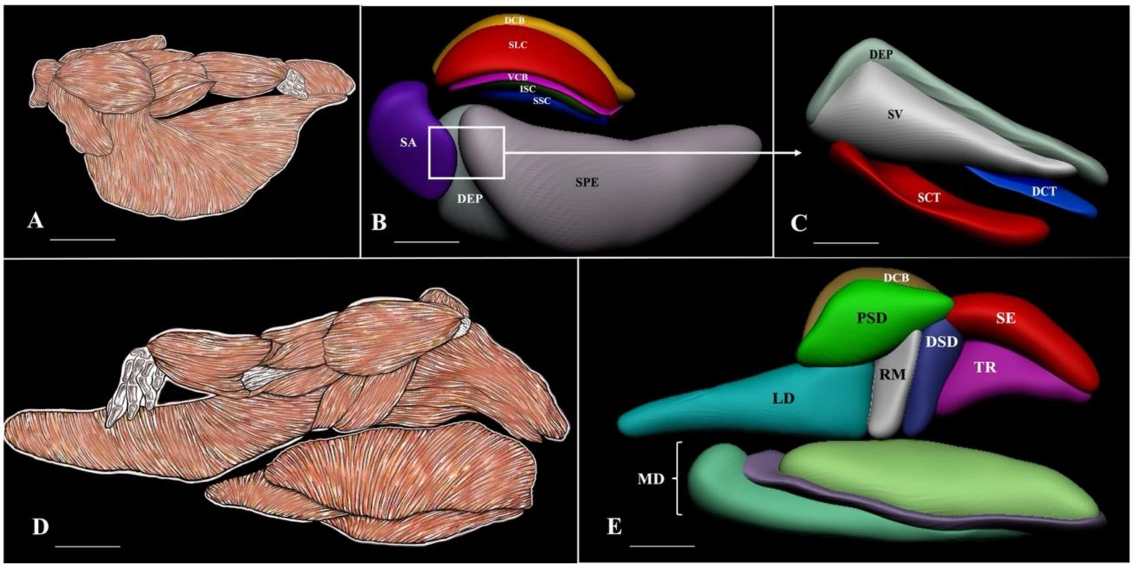

Fig. 4: A: Realistic 2D representations, and 3D PDF Schematic Models, of the Chest (*ZBrush* 2019 for *Mac)* and thoracic limb of the *Caiman crocodilus,* with emphasis on the right antimere. A: Realistic 2D representation - Ventral superficial view of the Thorax and thoracic limb of *Caiman crocodilus* (right antimere) **(**Teixeira, 2021); **B: Schematic 3D PDF model -** Superficial and deep ventral view of the Thorax and proximal thoracic limb (arm) of the *Caiman crocodilus* (right antimer). SA: sternoatlantical; DPE: deep pectoral; SPE: superficial pectoral; VCB: ventral coracobrachialis; LSC: long supracoracoid; DCB: dorsal coracobrachialis; ISC: intermediate supracoracoid; SSC: short supracoracoid. **C: Deep ventral view of the thoracic limb of *Caiman crocodilus* (right antimere).** DPE: deep pectoral; SV: serratus ventral; SCT: superficial costocoracoid; DCT: deep costocoracoid **C: 3D PDF schematic model -** Deep ventral view of the chest. **D: Realistic representation in 2D** - Superficial dorsal view of the Thorax and thoracic limb of the *Caiman crocodilus* (right antimere) **(**Teixeira, 2021). **E: B: 3D PDF Schematic Model -** Superficial and Deep Dorsal View of Thorax and Thoracic Limb of the *Caiman crocodilus* (right antimere): DCB:

dorsal coracobrachialis; PSD: proximal scapular deltoid; DSD: distal scapular deltoid; SE: scapula elevator; TR: trapezius; RM: round major; LD: latissimus dorsi; MD: dorsal muscles. *ScaleBar = 3cm.

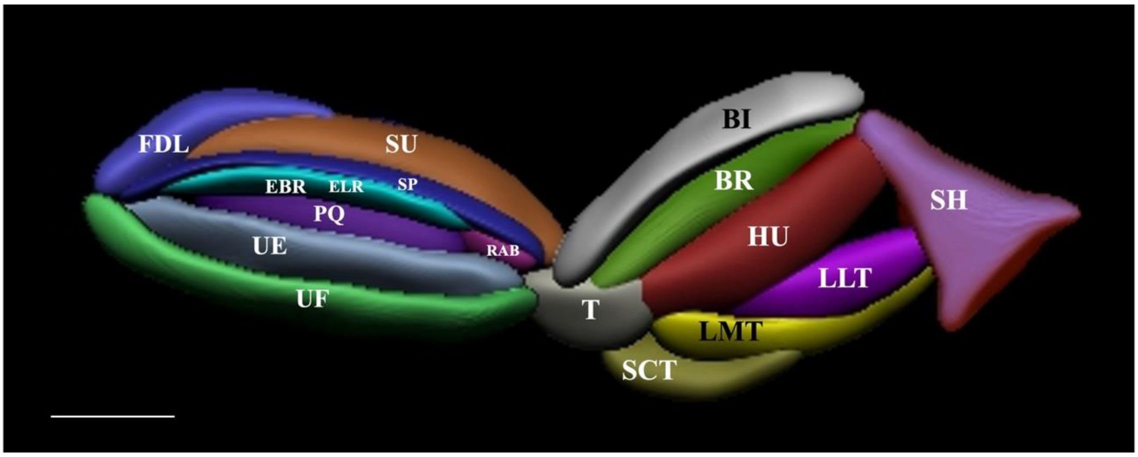

Fig. 5: Schematic 3D PDF model (*ZBrush* 2019 for *Mac)* of the flexor and extensor muscles of the proximal (arm) and distal (forearm) thoracic limb of the *Caiman crocodilus,* with emphasis on the right antimere. SH: scapulohumeral; BI: biceps brachii; BR: brachial; RH: radial humerus; LLT: long lateral triceps; LMT: long medial triceps; SCT: short cranial triceps; T: muscle tendon; FDL: flexor digitorum longus; PR: pronator round; ELR: extensor digitorum longus radial; EBR: extensor digitorum brevis radial; RAB: radial abductor; SP: square pronator; UE: ulnar extensor; UF: ulnar flexor. * *ScaleBar* = 3cm.

DISCUSSION

Differences in muscle anatomy are frequently found, and may represent important characteristics for certain actions and/or behaviors. The profile of the differences may indicate a simple variation, supernumerary structures or abnormal deviations, and also anomalous conditions, such as absent muscle bellies, poorly or highly developed, or differences in the areas of fixation of origin and insertion. Muscles identified as accessory or additional are considered anatomical variations. With the technology advancement, imaging diagnostics, as well as innovative equipment, are particularly capable of displaying high-quality sectioned images, as seen in computed tomography and ultrasonography. With the aid of images, analyzes and studies on muscle anatomy can be evidenced more precisely, in view of the distinction and correlation of soft tissues (Nascimento and Ruiz 2018).

Technological progress favors both evolution and the use of imaging as a way to make diagnoses. It is scientific proof about higher and better resolutions, enabling increasingly detailed analyses. A great advantage of ultrasound is that it does not represent a bodily "invasion", especially in structural observations, and complementary in clinical examinations (Yamada et al. 2009; Barcelos et al. 2012; Bellegard 2016).

The X-ray represents a resource considered essential for clinical interventions, considering its practical feasibility and agility in clarifying clinical situations. In addition, it represents the "gold standard", signaling the initial option of analysis, regarding the cost-benefit itself. In relation to crocodilians, radiography is very similar to what is observed in lizards. In a dorsoventral view, for example, foreign bodies are clearly identified, as well as aspects related to intestinal transit, and masses that are in the coelomic cavity. Horizontally, the respiratory system can also be assessed (Thrall 2007; Wisner and Zwingenberger 2015).

Wild animals, such as crocodilians, have many anatomical and physiological particularities, which are still poorly described. This makes the diagnosis and clinical and therapeutic prognosis of these animals difficult. Based on this assumption, imaging techniques, such as ultrasonography, have been very efficient in clinical examinations, mainly due to the ease of carrying out the examination, regardless of specific environments, and low harm to the examiner (Augusto, 2007; Valente, 2007; Bortolini et. al. 2013). Using ultrasound, it is possible to monitor reproductive functions, diagnose anatomical variations and/or anomalies, in addition to measuring tissue thickness, and assist in guided biopsies (Sainsbury and Gili 1991; STETTER 2006; Bortolini et. al. 2013).

In general, the descriptions of the thoracoappendicular anatomy of crocodilians do not show significant differences in relation to what is found in the pelvic region and hind limb. It is a specific locomotor evolutionary pattern of the *Archosauri*. Such differences, when found, have been indicated in the attachment points of muscle origin and insertion, especially in the pelvic limb, which is more requested in actions (Meers 2003; Remes 2008; Hutchinson 2000, 2006).

Digital Dissection is considered a complementary way, both in interpretations and in the analysis of biological systems. In addition, it is a "little" invasive and, therefore, non-destructive way, which favors access to researched data, including in three dimensions. In relation to the muscles, it allows the visualization and identification of the anatomical position and its topographic relationships. However, representations in two dimensions, that is, two-dimensional, which have been around for a longer time, tend to simplify or emphasize some points, privileging them, and, therefore, set precedents for different forms of interpretation (Curtis et. al. 2009; Lautenschlager 2014a). Above all, at any time, a digital anatomical dissection can be re-evaluated and re-examined (Lautenschlager et. al. 2014a; Klinkhamer et. al . 2017).

Several digital dissections of vertebrate animals have been published, mostly with an emphasis on cranial muscles (Miller et. al. 2008; Curtis et. al. 2009; Holliday et. al. 2013; Lautenschlager et. al. 2014b; Sharp and Trusler 2015) with greater adherence to computed tomography, ultrasound, and resonance in cases of using larger specimens (Jeffery et. al . 2011; Sharp and Trusler 2015; Klinkhamer et. al. 2017).

CONCLUSION

Anatomical descriptions have greatly favored interventions in wild animals, as well as the use of imaging tests such as X-ray and US. In addition, 3D schematic models clarify topographical relationships and highlight muscle depth, for example. Thus, it is possible to identify anatomical differences and intervene, in cases of diagnosis and prognosis, such as in US, even in real time.

THANKS

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