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Anatomical Description of the Southern Brown Howler Monkey (*Alouatta guariba clamitans*) Surface Musculature and Implications

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ABSTRACT

Introduction: southern brown howler monkey (*Alouatta guariba clamitans)* is a specie of New World primate present mainly in Brazilian territory and restricted to the Atlantic Forest biome, with its geographic distribution covering the Southeast, South to an extreme South of the state of Bahia to a small part in the province of Misiones, Argentina. Currently, the brown howler monkey is divided into two subspecies: *Alouatta guariba guariba* and *Alouatta guariba clamitans*. Studies on this species and other species of non-human primates from Atlantic Forest are extremely important to understand and prevent sanitary crises and fauna loss, as many of them share diseases with humans, such as yellow fever. This study aims to group the general surface musculature anatomy of the Southern brown howler monkey, as there are few studies of anatomy on these species. Additionally, a brief evaluation of the use of the plastination technique was performed in the anatomical description with its implications. For this, anatomical dissection of two adult male and one female specimens of *Alouatta guariba clamitans* was performed. The three specimens were dissected, evidencing the superficial musculature, with 100 muscles distributed at the body, being all identified and photographed. By the end of this study only one male specimen had completed the plastination process. This study had, for organization based on the muscle groups, the article The Anatomy of Common Marmoset by Casteleyn and Bakker, followed by the International Veterinary Anatomical Nomina.

Keywords: Brown howler monkey; New world primate; anatomy; Anatomical description.

Introduction

Southern brown howler monkey (*Alouatta guariba clamitans*, Cabrera, 1940) is a specie of New World primate belonging to the Atelidae family. In Brazil, it is characteristic from the Atlantic Forest biome and its distribution occurs from Jequitinhonha Valley, Bahia to São Lourenço do Sul, Rio Grande do Sul (GREGORIN, 1996; PRINTES *et al*., 2001 apud DE MORAES AGUIAR, 2003). Currently, the brown howler monkey is divided into two subspecies, *Alouatta guariba guariba* (Humboldt, 1812), present in the Northern, covering the South of Bahia and, possibly, parts of Espírito Santo and Minas Gerais, and *Alouatta guariba clamitans* (Cabrera, 1940), present in the Southern, covering the South of Espírito Santo to Rio Grande do Sul. An alternative distribution suggests that *Alouatta guariba guariba* is restricted to Southern of Bahia, while the other populations observed in Minas Gerais, Espírito Santos and South states are part of *Alouatta guariba clamitans* subspecies (KINZEY, 1982; RYLANDS *et al*., 1996 apud HARRIS, 2005).

The brown howler monkey lives in a polygynous social group with two to 13 individuals, generally having one or two adult males, one to four adult females and a variable number of immatures (MARAFIGA, 2013). This primate has as its main characteristic the anatomical changes present in its larynx and hyoid bone, that is particularly large, forming air sacs capable of emitting one of the loudest vocalizations among terrestrial animals (DUNN, 2015). According to IUCN Red List, the subspecie *Alouatta guariba guariba* is classified as critically endangered and *Alouatta guariba clamitans* as vulnerable.

Due to its flexible leaf-eating diet in small areas, brown howler monkey's populations are able to withstand certain ecological pressures, such as the fragmentation of its habitat, however, a greater exposure generated by this fragmentation makes it more susceptible to illegal hunting. Another important factor is the apparent vulnerability of these animals to yellow fever virus and parasitism, being more susceptible than humans and, in the case of yellow fever, developing fatal liver failure (DE AZEVEDO FERNANDES, 2021). Marafiga (2013) highlights that the yellow fever outbreak that occurred in 2008-2009 in Rio Grande do Sul caused a reduction in howler monkey's populations and may have affected the composition of social groups, with direct consequences on the future dynamics of these populations. The relationship between *Alouatta guariba* and yellow fever have a

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fundamental importance in the control and decision-making of this disease in Brazilian public health. This species is classified as "sentinel" by the Ministry of Health, being a biological indicator of a potential risk of this disease emergence in humans, enabling the adoption of prophylactic measures, such as vaccination (SANTOS, 2020).

Studies on howler monkeys and other primates from the Atlantic Forest are extremely important to understand and prevent sanitary crises and fauna loss, as many of them can share diseases with humans, such as yellow fever. Also, considering the scarcity of anatomical information for *Alouatta guariba clamitans*, anatomical description and comparative anatomy studies of these animals could provide crucial results for the well understanding of functional, behavioral, and phylogenetic morphology studies (AVERSI-FERREIRA, 2010).

This study aims to describe the general surface musculature anatomy of the Southern brown howler monkey with photographic records, once this knowledge is extremely fragmented in the literature. Additionally, it aims to evaluate the implications of such anatomical knowledge for other areas of research and education and to briefly discuss the use of the plastination technique in the conservation of biological materials for anatomical descriptions and comparative anatomy.

Material and Methods

For this study three adult specimens of Southern brown howler monkey (*Alouatta guariba clamitans*) were used, being two males and one female collected in 2017 in Santa Maria de Jetibá (Espírito Santo, Brazil) as part of the "Sentinelas da Mata" project. These three animals died from yellow fever infection and were donated to the UFES Plastination Laboratory (Maruípe campus, Espírito Santo, Brazil). It was stored frozen for two years until the beginning of the fixation process. The work was approved by the Animal Ethics Committee of the Universidade Federal do Espírito Santo, registered with the number 31/2019.

After 24 hours of defrosting at room temperature, the fixation step was followed, in which 10% formalin was injected, using syringes and an injection pump, throughout the body of the howler monkey, both in the superficial and deep musculature, as well as in the abdominal and thoracic cavities, in order to ensure a good fixation and penetration of the fixative substance in the tissues. Then, the specimens were placed on wooden bases and immersed in 10% formalin for at least two months. This positioning during fixation is of great importance, as the prolonged contact with formaldehyde causes rigidity of the soft tissues (BOON, 1988), making it difficult to reposition some structures after this step.

In the dissection stage, the first male specimen had the skin removed at the entire ventral and dorsal extension and at all the extension of the upper and lower limbs, except for the digits; at caudal region the skin was removed only in its proximal portion, close to the sacral region; at cervical region the skin was partially removed, showing the musculature around the hyoid bone; and at head region the skin was kept intact.

The second male specimen had the skin removed along the entire ventral and dorsal extension and at all the extension of the upper and lower limbs, except for the digits; at caudal region the skin was partially exposed, showing the muscles and the set of intrinsic tendons; at cervical region the skin was completely removed, the sternohyoid, thyrohyoid and omohyoid muscles on the animal's left side were also removed for better observation of the highly specialized and large hyoid bone and larynx, characteristic of males of these primates (DUNN, 2015) and the superficial platysma muscle was kept on the right side. The right abdominal rectus muscle was retracted to observe the organs of the digestive tract; however, this dissection was not connected with the objectives of this study.

As for the female, the same dissection pattern of the second male was followed (figure 1b). Despite using the same dissection pattern and the sexual dimorphism of some structures, some muscles were more easily observed in this specimen.

Due to the lack of information in the literature about the surface anatomy of Southern brown howler monkey (*Alouatta guariba clamitans*), some articles present in the literature of other New World primate and of human anatomy were used to identify the musculature of the specimens (NETTER, Atlas of human anatomy. 7th ed, 2019). This study had, for an organization based on the muscle groups, the article The Anatomy of Common Marmoset (CASTELEYN & BAKKER, 2019), followed by the International Veterinary Anatomical Nomina, 6th edition, 2017 (in Latin). The origins and insertions of the muscles were identified with dissection and corroborated with the associated bibliography such as The Muscular System of The Red Howling Monkey (SCHÖN, 1968). Due to the large amount of identified surface muscles and the difficulty of visualizing some of them by photography, not all of them were shown in the figures listed below.

Results

The total dissection of the two male specimens was completed after about 160 hours, in 6 months of work, during the second semester of 2020 and the female was completed in the first semester of 2021, with about 80 hours of dissection (figure 1). A total of 100 superficial muscles were observed, identified, and organized into groups by body region.

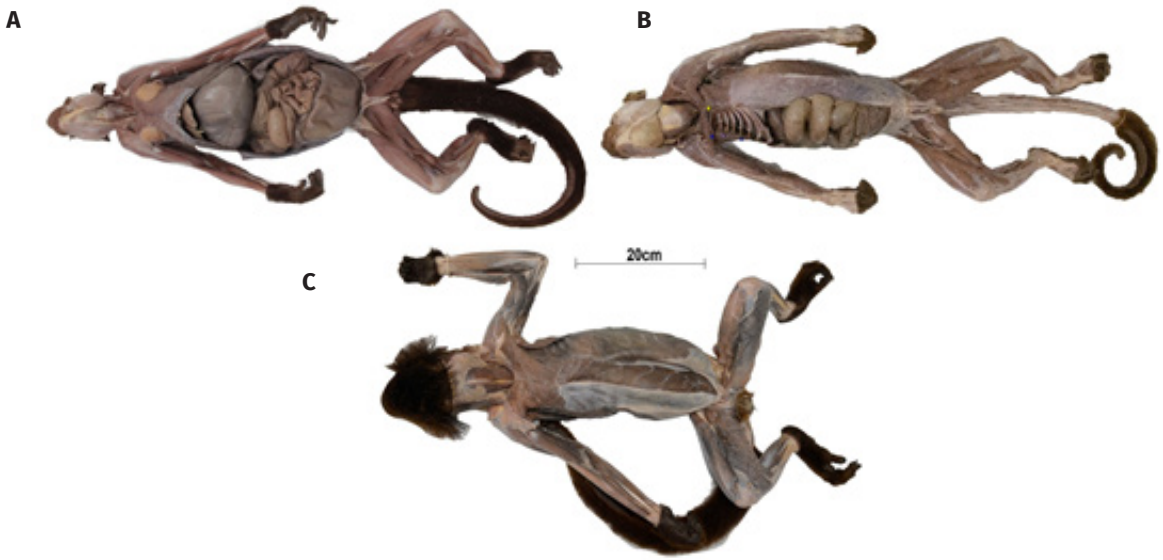

Figure 1. Ventral view of the three dissected specimens of Southern brown howler monkey (*Alouatta howler clamitans*). A) Female; complete abdominal opening evidencing the internal organs. B) Male; muscles of tail, abdominal and thoracic opening on the right side, evidencing internal organs and rib cage. C) Male; left *rectus abdominis* muscle.

Listed below (TABLE 1) are head and facial muscles, (TABLE 2) mastication muscles, (TABLE 3) neck muscles (figure 2); sexual dimorphism in the vocal apparatus of the female (figure 3); (TABLE 4) muscles of the cervical and dorsal and (TABLE 5) abdominal region (figure 4); (TABLE 6) muscles of the upper limbs (figures 5-6); (TABLE 7) lower limb muscles (figures 7-8); and (TABLE 8) prehensile tail muscles (figure 9).

Table 1. Facial/Head muscles.

Muscle	Origin	Insertion	Main actions
M. buccinator	Rostral part of the zygomatic arch and the maxilla.	Angle of mouth	Presses cheek against molar teeth, thereby aiding chewing, expels air
M. depressor labii inferioris	Mandible, anterior to the mental foramen	Skin of lower lip	Depresses lower lip
M. occipitalis	Nuchal line and epicranial aponeurosis	Epicranial aponeurosis and the adjacent bone of the supraorbital margin	Tenses scalp
M. frontalis			Elevates eyebrows and forehead; wrinkles forehead
M. levator labii superioris	Infraorbital region	Skin of upper lip	Elevates lip, raises angle of mouth
M. levator nasolabialis	Frontal process of maxilla and nasal bone	Skin of nasal bone and upper lip	Elevates lip and ala of nose
M. nasalis	Superior part of canine ridge of maxilla	Nasal cartilages	Draws ala of nose toward septum to compress opening
M. orbicularis oculi	Medial orbital margin, medial palpebral ligament, and lacrimal bone	Skin around margin of orbit; tarsal plate	Closes eyelids; orbital part forcefully and palpebral part for blinking
M. orbicularis oris	Median plane of maxilla superiorly and mandible inferiorly; other fibers from deep surface of skin	Mucous membrane of lips	Closes and protrudes lips (e.g., purses them during whistling)
M. platysma	Superficial fascia of deltoid and pectoral regions	Mandible, skin of cheek, angle of mouth, and orbicularis oris	Depresses mandible and tenses skin of lower face and neck
M. zygomaticus major	Zygomatic bone	Skin of angle of mouth	Elevates lip and angle of mouth
M. zygomaticus minor		Skin of upper lip	

Table 2. Mastication muscles.

Muscle	Origin	Insertion	Main Actions
M. masseter	Zygomatic arch	Ramus of mandible and coronoid process	Elevates and protrudes mandible; deep fibers retract mandible
M. temporalis	Floor of temporal fossa and deep temporal fascia	Ramus of mandible and coronoid process	Elevates mandible; posterior fibers retract mandible

Table 3. Neck muscles.

Muscle	Origin	Insertion	Main Actions
M. digastricus venter caudalis	Mastoid notch	Intermediate tendon to hyoid bone	Depresses mandible; raises hyoid bone and steadies it during swallowing and speaking
M. digastricus venter rostralis	Digastric fossa of mandible		
M. geniohyoideus	Mental spines	Hyoid bone	Elevates hyoid bone and depresses mandible
M. mylohyoideus	Mylohyoid line of mandible	Raphe and body of hyoid bone	Elevates hyoid bone, floor of mouth, and tongue during swallowing and depresses mandible
M. omohyoideus	Superior border of scapula near suprascapular notch	Inferior border of hyoid bone	Depresses and fixes hyoid bone
M. sternocleidomastoideus	Sternal head: manubrium of the sternum; Clavicular head: medial third of clavicle	Mastoid process and lateral half of superior nuchal line of occipital bone	Tilts head to one side, i.e., laterally flexes and rotates head so face is turned superiorly toward opposite side; acting together, muscles flex neck
M. sternohyoideus	Manubrium of sternum and medial end of clavicle	Body of hyoid bone	Depresses hyoid bone and larynx after swallowing
M. sternothyroideus	Posterior surface of manubrium	Oblique line of thyroid lamina	Depresses larynx and thyroid cartilage after swallowing
M. stylohyoideus	Styloid process	Body of hyoid bone	Elevates and retracts hyoid bone
M. thyrohyoideus	Oblique line of thyroid cartilage	Body and greater horn of hyoid bone	Depresses hyoid bone and elevates larynx when hyoid bone is fixed

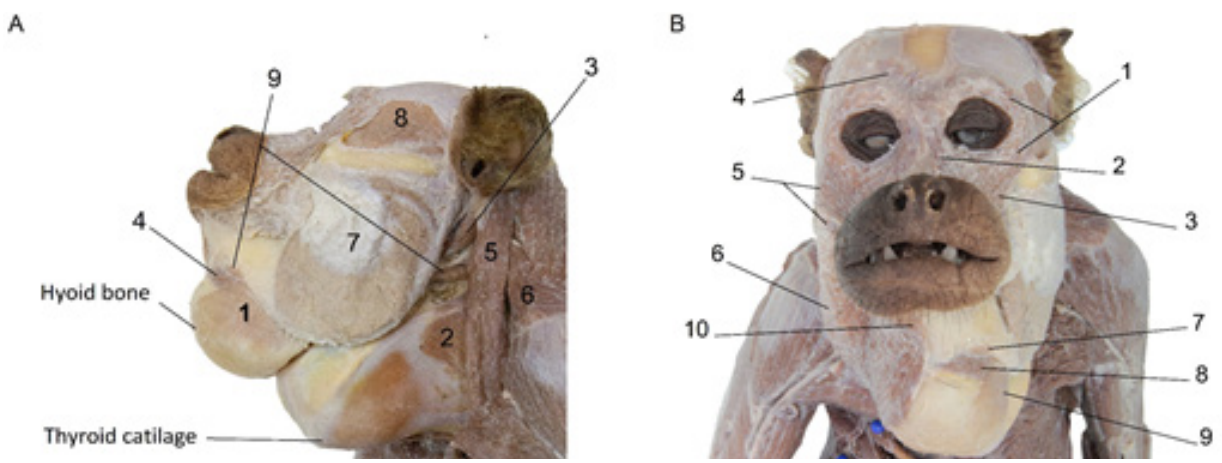

Figure 2. Facial/head, mastication, and neck muscles from Southern brown howler monkey. A) Male; lateral view of the left face evidencing hyoid bone, thyroid cartilage, and neck muscles. 1, *m. mylohyoideus*; 2, *m. sternothyroideus*; 3, *m. stylohyoideus*; 4, *m. geniohyoideus*; *5, m. sternocleidomastoideus*; 6, *m. atlantoscapularis anterior*; mastication muscles, 7, *m. masseter*; 8, *m. temporalis*; 9, *m. digastricus venter rostralis* located below the mandible and *m. digastricus venter caudalis*, located

below *m. stylohyoideus. Sternohyoideus, omohyoideus e thyrohyoideus* muscles were removed from its original region to evidence the thyroid cartilage. B) Male; frontal view evidencing the facial muscles and hyoid bone. 1, *m. orbicularis oculi*; 2, *m. nasalis*; 3, *m. levator labii superioris*; 4, *m. frontalis*; 5, *m. zygomaticus minor e m. zygomaticus major*; 6, *m. platysma*; 7, *m. digastricus venter rostralis*; 8, *m. geniohyoideus*; 9, *m. mylohyoideus*; 10, *m. depressor labii inferioris*.

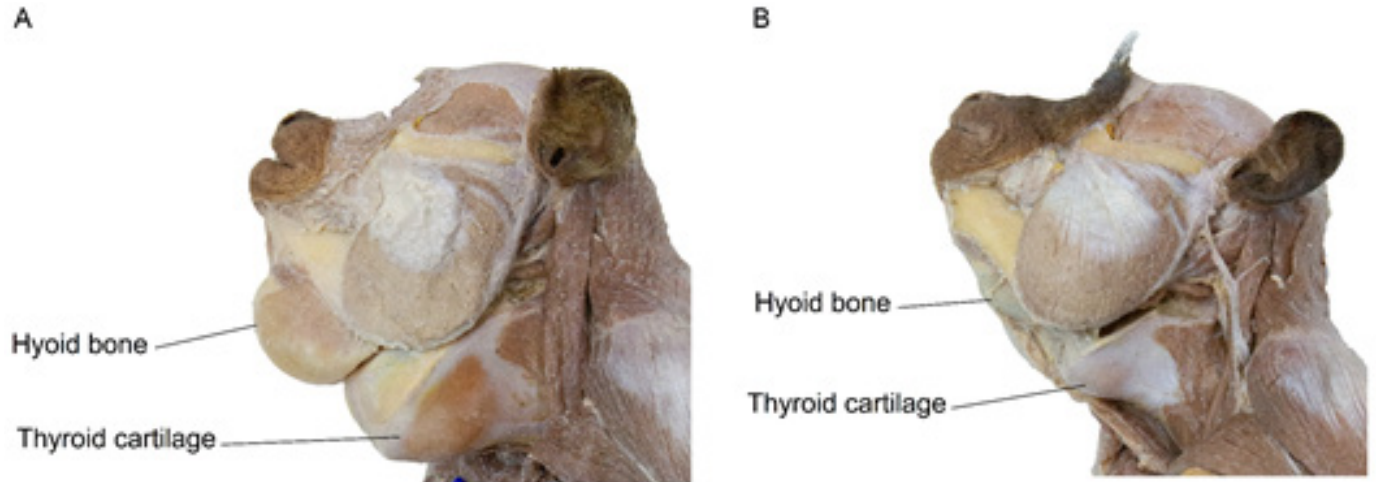

Figure 3. Lateral view of the dissected face from Southern brown howler monkey showing sexual dimorphism in the hyoid bone and thyroid cartilage. A = male; B = female.

Table 4. Cervical/Dorsal muscles.

Muscle	Origin	Insertion	Main Actions
M. atlantoscapularis anterior	Lateral third of clavicle, acromion, and spine of scapula	Atlas vertebrae	Laterally flexes and rotates head so face is turned superiorly toward opposite side; flexes neck
M. infraspinatus	Infraspinous fossa of scapula and deep fascia	Greater tubercle of humerus	Laterally rotates arm at shoulder; helps to hold head in glenoid cavity
M. latissimus dorsi	Spinous processes of TIV-LV, sacrum, thoracolumbar fascia and iliac crest	Humerus (intertubercular groove)	Extends, adducts, and medially rotates humerus
M. levator scapulae	Transverse processes of CI-CIV	Superior angle of scapula	Elevates scapula and tilts glenoid cavity inferiorly
M. rhomboideus thoracis	Minor: nuchal ligament and spinous processes of CVII-TI; Major: spinous processes of TII-TV	Medial border of scapula	Retract scapula, rotate it to depress glenoid cavity, and fix scapula to thoracic wall
M. scalenus dorsalis	Transverse processes of the fifth and sixth cervical vertebrae	First four ribs	Laterally flexes head
M. splenius capitis	Nuchal ligament, spinous processes of the last cervical and first two thoracic vertebrae	Mastoid process of temporal bone and lateral third of superior nuchal line	Bilaterally: extends head; Unilaterally: laterally bends (flexes) and rotates face to same side
M. teres major	Dorsal surface of inferior angle of scapula	Medial lip of intertubercular sulcus of humerus	Adducts arm and medially rotates shoulder
M. teres minor	Lateral border of scapula	Greater tubercle of humerus	Laterally rotates arm at shoulder; helps to hold head in glenoid cavity
M. trapezius	Superior nuchal line, external occipital protuberance, nuchal ligament, and spinous processes of CV-TX	Lateral third of clavicle, acromion, and spine of scapula	Elevates, retracts, and rotates scapula; lower fibers depress scapula
M. atlantoscapularis anterior	Lateral third of clavicle, acromion, and spine of scapula	Atlas vertebrae	Laterally flexes and rotates head so face is turned superiorly toward opposite side; flexes neck

Table 5. Abdominal muscles.

Muscle	Origin	Insertion	Main Actions
M. obliquus externus abdominis	External surfaces of 5th to 12th ribs	Linea alba, pubic tubercle, and anterior half of iliac crest	Compresses and supports abdominal viscera; flexes and rotates trunk
M. rectus abdominis	Pubic symphysis and pubic crest	Xiphoid process and costal cartilages 5-7	Compresses abdominal viscera and flexes trunk

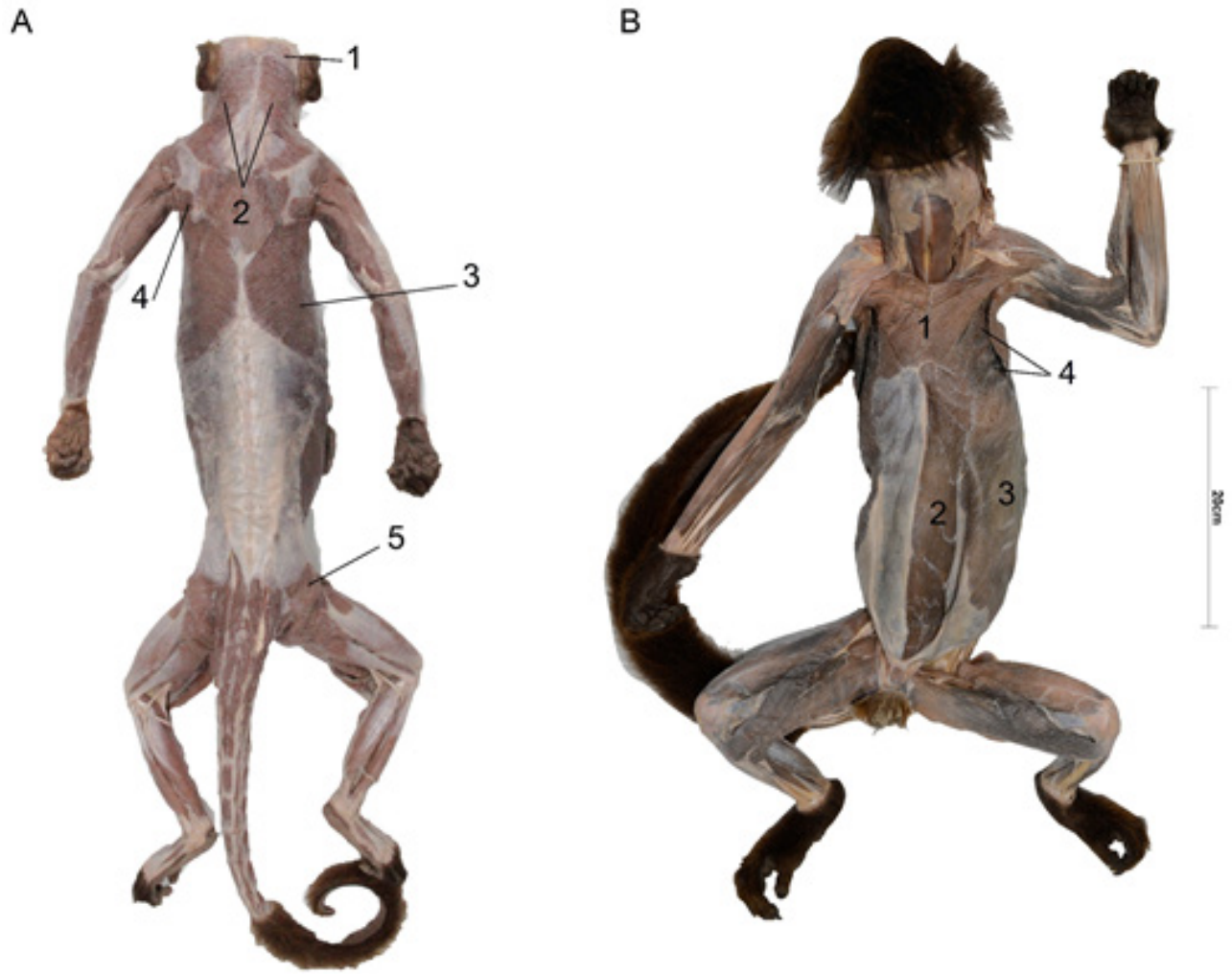

Figure 4. A) Dorsal view from the Southern brown howler monkey evidencing its surface musculature. 1, *m. occipitalis*; 2, *m. trapezius* in its whole extension; 3, *m. latissimus dorsi*; 4, *m. teres major*; 5, *m. gluteus* [*glutaeus*] *superficialis*. B) Ventral view from the Southern brown howler monkey evidencing its surface musculature. 1, *muscles from pectoralis* group; 2, *m. rectus abdominis*; 3, *m. obliquus externus abdominis*; 4, *m. serratus ventralis thoracis.*

Table 6. Upper limb muscles.

Muscle	Origin	Insertion	Main actions
M. abductor digiti I [pollicis] longus	Posterior surfaces of ulna, radius, and interosseous membrane	Base of 1st metacarpal bone	Abducts thumb and extends it at carpometacarpal (CMC) joint
M. abductor digiti minimi	Pisiform and tendon of flexor carpi ulnaris	Medial side of base of proximal phalanx of 5th digit	Abducts 5th digit
M. anconeus	Lateral epicondyle of humerus	Lateral surface of olecranon and superior part of posterior surface of ulna	Assists triceps in extending elbow; abducts ulna during pronation
M. biceps brachii	Short head: apex of coracoid process of scapula; Long head: supraglenoid tubercle of scapula	Tuberosity of radius and fascia of forearm via bicipital aponeurosis	Supinates flexed forearm; flexes forearm at elbow

M. brachialis	Distal half of anterior humerus	Coronoid process and tuberosity of ulna	Flexes forearm at elbow in all positions
M. brachioradialis	Proximal 2/3 of lateral supracondylar ridge of humerus	Lateral surface of distal end of radius	Flexes mid pronated forearm at elbow
M. coracobrachialis	Tip of coracoid process of scapula	Middle third of medial surface of humerus	Helps to flex and adduct arm at shoulder
M. deltoideus	Lateral third of clavicle, acromion, and spine of scapula	Deltoid tuberosity of humerus	Anterior part: flexes and medially rotates arm at shoulder; Middle part: abducts arm at shoulder; Posterior part: extends and laterally rotates arm at shoulder
M. extensor carpi radialis brevis	Lateral epicondyle of humerus	Base of 3rd metacarpal bone	Extends and abducts hand at wrist
M. extensor carpi radialis longus	Lateral supracondylar ridge of humerus	Base of 2nd metacarpal bone	Extends and abducts hand at wrist
M. extensor carpi ulnaris	Lateral epicondyle of humerus and posterior border of ulna	Base of 5th metacarpal bone	Extends and adducts hand at wrist
M. extensor digiti I [pollicis] brevis	Posterior surfaces of radius and interosseous membrane	Base of proximal phalanx of thumb	Extends proximal phalanx of thumb at CMC joint
M. extensor digiti I [pollicis] longus	Posterior surfaces of middle third of ulna and interosseous membrane	Base of distal phalanx of thumb	Extends distal phalanx of thumb at (metacarpophalan geal) MCP and (interphalangeal) IP joints
M. extensor digitorum [digitalis] communis	Lateral epicondyle of humerus	Extensor expansions of medial four digits	Extends medial four digits at MCP joints; extends hand at wrist joint
M. extensor digitorum [digitalis] lateralis	Lateral epicondyle of humerus	Tendon of the extensor digitorum communis to the fifth finger	Extends fifth finger at MCP joint; extends hand at wrist joint
M. flexor carpi radialis	Medial epicondyle of humerus	Base of 2nd metacarpal bone	Flexes hand at wrist and abducts it
M. flexor carpi ulnari	Humeral head: medial epicondyle of humerus; Ulnar head: olecranon and posterior border of ulna	Pisiform bone, hook of hamate bone, and 5th metacarpal bone	Flexes hand at wrist and adducts it
M. flexor carpi ulnaris	Humeral head: medial epicondyle of humerus; Ulnar head: olecranon and posterior border of ulna	Pisiform bone, hook of hamate bone, and 5th metacarpal bone	Flexes hand at wrist and adducts it
M. flexor digitorum [digitalis] superficialis	Medial epicondyle of humerus, ulnar collateral ligament, and coronoid process of ulna	Bodies of middle phalanges of medial four digits	Flexes middle phalanges of medial four digits; also weakly flexes proximal phalanges, forearm, and wrist
Mm. interossei	Adjacent sides of two metacarpals	Extensor expansions and bases of proximal phalanges of 2nd to 4th digits	Abduct digits; flex digits at MCP joints and extend IP joints
M. palmaris longus	Medial epicondyle of humerus	Distal half of flexor retinaculum and palmar aponeurosis	Flexes hand at wrist and tightens palmar aponeurosis

M. pectoralis	Medial half of clavicle; sternum; superior six costal cartilages; aponeurosis of external abdominal oblique	Lateral lip of intertubercular sulcus of humerus	Flexes, adducts, and medially rotates arm at shoulder
M. pectoralis profundus			
M. pectoralis transversus			
M. pronator teres	Medial epicondyle of humerus and coronoid process of ulna	Middle of lateral surface of radius	Pronates forearm and flexes elbow
M. serratus ventralis thoracis	Upper eight ribs	Medial border of scapula	Rotates and protracts scapula; pulls it anteriorly toward thoracic wall
M. triceps brachii	Long head: infraglenoid tubercle of scapula; Lateral head: posterior surface of humerus; Medial head: posterior surface of humerus, inferior to radial groove	Posterior surface of olecranon of ulna and fascia of forearm	Extends forearm at elbow; is chief extensor of elbow; steadies head of abducted humerus (long head)

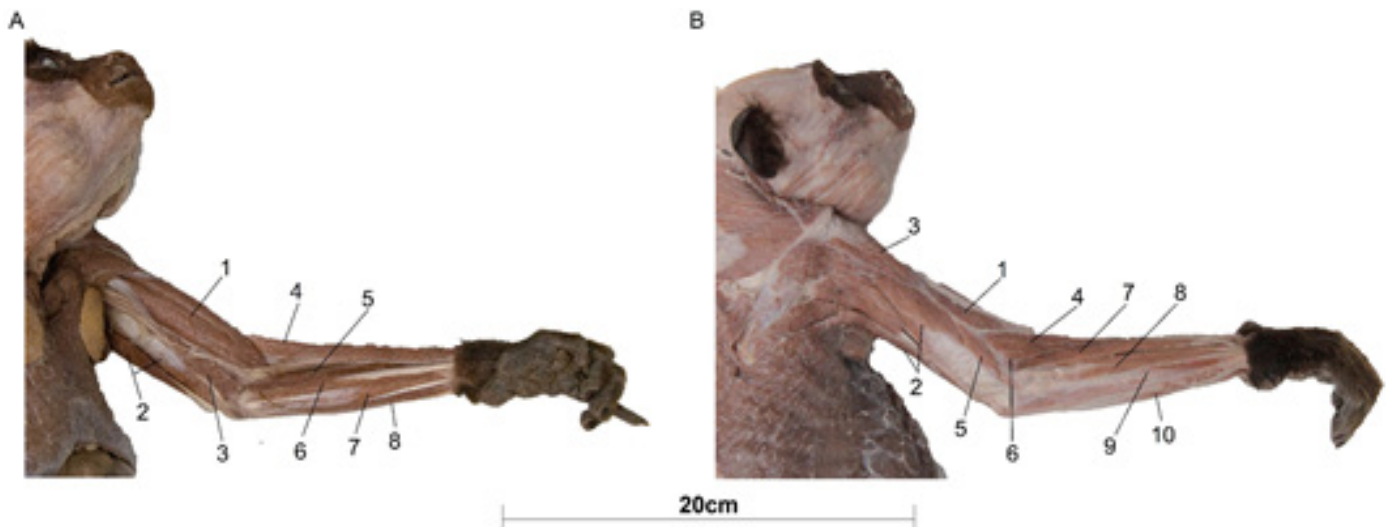

Figure 5. Upper limbs from the Southern brown howler monkey evidencing its surface musculature. A) Anterior view of the female's left upper limb. 1, *m. biceps brachii*; 2, *m. triceps brachii*; 3, *m. brachialis*; 4, *m. brachioradialis*; 5, *m. flexor carpi radialis*; 6, *m. palmaris longus*; 7, *m. flexor digitorum* [*digitalis*] *superficialis*; 8, *m. flexor carpi ulnaris*. B) Posterior view of the female's right upper limb. 1, *m. biceps brachii;* 2, *m. triceps brachii*; 3, *m. deltoideus*; 4, *m. brachioradialis*; 5, *m. anconeus*; 6, *m. extensor carpi radialis longus; 7, m. extensor carpi radialis brevis; 8, m. extensor digitorum [digitalis] communis; 9, m. extensor carpi ulnaris*; 10, *m. flexor carpi ulnaris.*

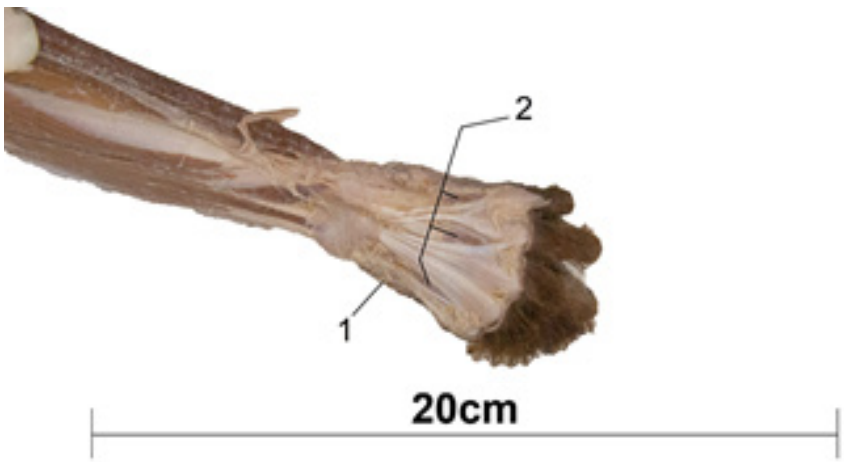

Figure 6. Dorsal view of the right hand from the Southern brown howler monkey

Table 7. Lower limb muscles.

Muscle	Origin	Insertion	Main actions
uctor digiti V	Medial and lateral tubercles of tuberosity of calcaneus, plantar aponeurosis, and intermuscular septa	Lateral side of base of proximal phalanx of 5th digit	Abducts little toe
M. adductor hallucis	Oblique head: bases of metatarsals 2-4; Transverse head: plantar ligaments of metatarsophalangeal joints of digits 3-5	Base of proximal phalanx of 1st digit	Adducts great toe
M. adductor longus	Body of pubis inferior to pubic crest	Middle third of linea aspera of femur	Adducts thigh at hip
M. adductor magnus	Inferior ramus of pubis, ramus of ischium, and ischial tuberosity	Adductor part: gluteal tuberosity, linea aspera, medial supracondylar line; Hamstring part: adductor tubercle of femur	Adducts thigh at hip; Adductor part: also flexes thigh at hip; Hamstring part: extends thigh
M. biceps femoris	Long head: ischial tuberosity; Short head: linea aspera and lateral supracondylar line of femur	Lateral side of head of fibula; tendon at this site split by fibular collateral ligament of knee	Flexes leg at knee and rotates it laterally; extends thigh at hip
M. extensor digitorum [digitalis] brevis	Dorsal side of calcaneus	Tendon of the extensor digitorum longus	Extends lateral four digits
M. extensor digitorum [digitalis] longus	Lateral condyle of tibia and superior 3/4 of anterior surface of interosseous membrane and fibula	Middle and distal phalanges of lateral four digits	Extends lateral four digits and dorsiflexes foot at ankle
M. extensor hallucis brevis	Dorsal side of calcaneus	Proximal phalanx of the hallux	Extends great toe
M. fibularis [peron(a)eus] brevis	Inferior 2/3 of lateral surface of fibula	Dorsal surface of tuberosity on lateral side of 5th metatarsal	Everts foot and weakly plantarflexes foot at ankle
M. fibularis [peron(a)eus] longus	Head and superior 2/3 of lateral surface of fibula	Head and superior 2/3 of lateral surface of fibula	Everts foot and weakly plantarflexes foot at ankle
M. flexor digitorum [digitalis] superficialis	Posterior surface of tibia	Base of distal phalanx of four digits	Flexes four lateral digits and plantarflexes
M. gastrocnemius	Lateral head: lateral aspect of lateral condyle of femur; Medial head: popliteal surface of femur, superior to medial condyle	Posterior surface of calcaneus via calcaneal tendon	Plantarflexes foot at ankle; flexes leg at knee joint
M. gluteus [glutaeus] superficialis	Ilium posterior to posterior gluteal line, posterior surface of sacrum and coccyx, and thoracolumbar fascia	Most fibers end in iliotibial tract that inserts into lateral condyle of tibia; some fibers insert on gluteal tuberosity of femur	Extends flexed thigh at the hip and assists in its lateral rotation; abducts and assists in raising trunk from flexed position
M. gracilis	Body and inferior ramus of pubis	Superior part of medial surface of tibia	Adducts thigh at hip; flexes leg at knee and helps to rotate it medially
Mm. interossei	Adjacent sides of metatarsals 1-5	First: medial side of proximal phalanx of second digit; Second to fourth: lateral sides of digits 2-4	Abduct digits 2-4, flex metatarsophalangeal joints, and extend phalanges
M. rectus femoris	Anterior inferior iliac spine and ilium superior to acetabulum	Base of patella and by patellar ligament to tibial tuberosity	Extends leg at knee joint; also steadies hip joint and helps iliopsoas to flex thigh at hip
M. sartorius	Anterior superior iliac spine and superior part of notch inferior to it	Superior part of medial surface of tibia	Flexes, abducts, and laterally rotates thigh at hip joint; flexes knee joint

M. semimembranosus	Ischial tuberosity	Posterior part of medial condyle of tibia	Extends thigh at hip; flexes leg at knee and rotates it medially
M. semitendinosus		Medial surface of superior part of tibia	
M. soleus	Posterior aspect of head of fibula, superior fourth of posterior surface of fibula, soleal line and medial border of tibia	Posterior surface of calcaneus via calcaneal tendon	Plantarflexes foot at ankle; steadies leg over foot
M. tensor fasciae latae	Anterior superior iliac spine and anterior iliac crest	Iliotibial tract that attaches to lateral condyle of tibia	Abducts, medially rotates, and flexes thigh at hip; helps to keep knee extended
M. tibialis cranialis	Lateral condyle and superior half of lateral tibia and interosseous membrane	Medial and inferior surfaces of medial cuneiform and base of 1st metatarsal	Dorsiflexes foot at ankle and inverts foot
M. vastus lateralis	Greater trochanter and lateral lip of linea aspera and gluteal tuberosity	Base of patella and by patellar ligament to tibial tuberosity	Extends leg at knee joint
M. vastus medialis	Intertrochanteric line, greater trochanter, and medial lip of linea aspera of femur		

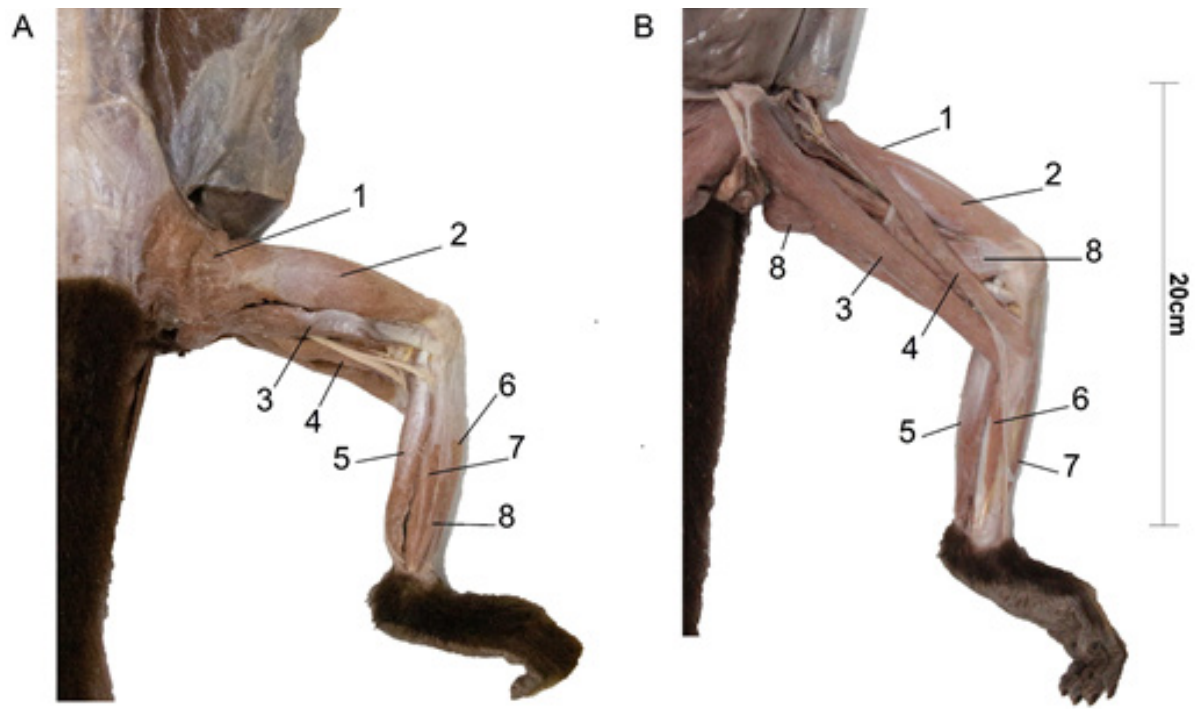

Figure 7. Lower limbs from the Southern brown howler monkey evidencing its surface musculature. A) Posterior view of the female's right lower limb. 1, *m. tensor fasciae latae*; 2, *m. vastus lateralis*; 3, *m. biceps femoris*; 4, *m. semitendinosus*; 5, *m. gastrocnemius*; 6, *m. tibialis cranialis*; 7, *m. fibularis [peron(a)eus] longus*; 8, *m. extensor digitorum [digitalis] longus.* B) Anteromedial view of the female's left lower limb. 1, *m. rectus femoris*; 2, *m. vastus medialis*; 3, *m. gracilis*; 4, *m. sartorius*; 5, *m. gastrocnemius*; 6, m. *soleus*; 7, *m. tibialis cranialis*; 8, *m. semimembranosus.*

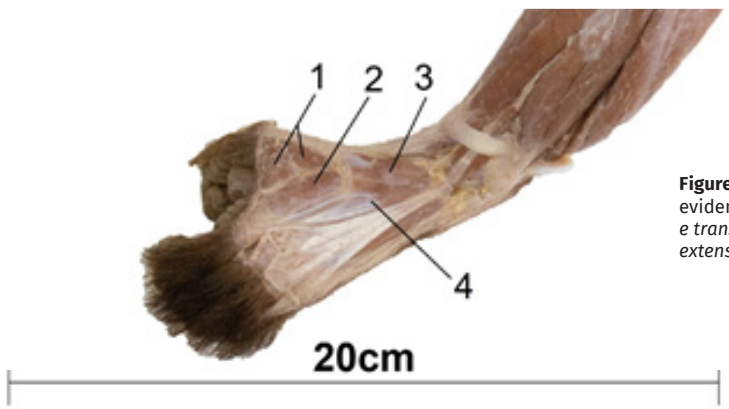

Figure 8. Dorsal view of left foot from the Southern brown howler monkey evidencing its surface musculature. 1, *m. adductor hallucis caput obliquum e transversum*; 2, first *interosseus dorsal*; 3, *m. extensor hallucis brevis*; 4, *m. extensor digitorum [digitalis] brevis.*

Table 8. Caudal muscles.

Muscle	Origin	Insertion	Main actions
M. coccygeus	Ischial spine and sacrospinous ligament	Inferior sacrum and coccyx	Supports pelvic viscera; draws coccyx forward
M. sacrocaudalis [-coccygeus] dorsalis lateralis	Lumbar vertebra and the articular processes of the sacrum	Last caudal vertebrae	Extension and lifting of the tail
M. sacrocaudalis [-coccygeus] dorsalis medialis	Dorsolateral to the caudal edge of the caudal vertebrae	Last caudal vertebrae	Extension of the tail
M. sacrocaudalis [-coccygeus] ventralis lateralis	Ventral surface of the last lumbar vertebrae and sacrum	Last caudal vertebrae	Flexion of the tail
M. sacrocaudalis [-coccygeus] ventralis medialis	Ventromedial to the caudal edge of the caudal vertebrae	Last caudal vertebrae	Flexion of the tail
Mm. intertransversarii dorsales caudae	Lateral aspect of the transverse process of the cranial region of the tail	Border of the transverse processes of the caudal vertebrae	Prehensile tail movements

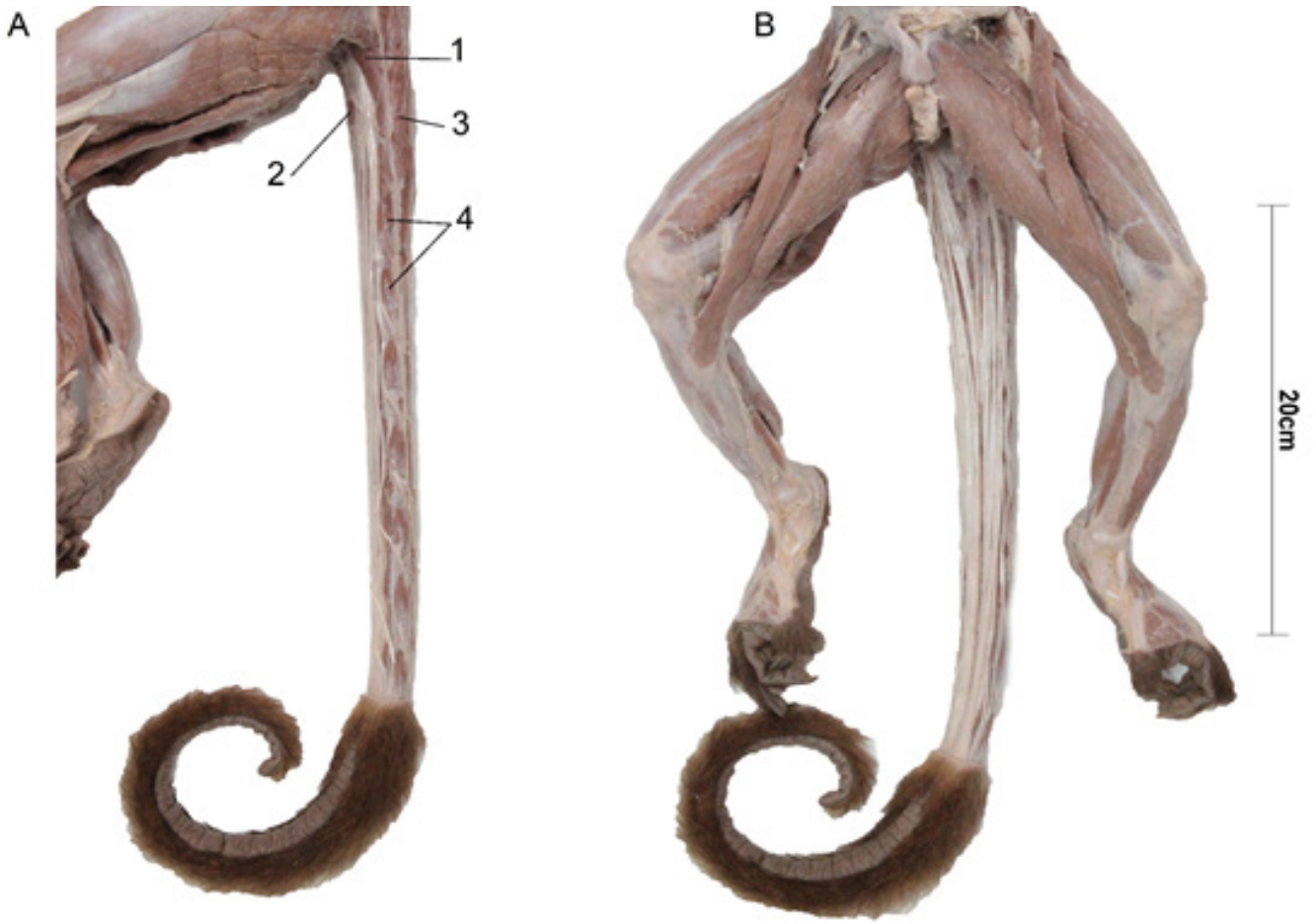

Figure 9. The prehensile tail from the Southern brown howler monkey evidencing the intrinsic musculature. A) Lateral view of the tail. 1, *m. coccygeus*; 2, *m. sacrocaudalis [-coccygeus] ventralis lateralis*; 3, *m. sacrocaudalis [-coccygeus] dorsalis lateralis*; 4, *mm. intertransversarii*. B) Ventral view of the tail with associated tendons.

Discussion

Importance of anatomical studies

The study of muscular anatomy or myology is not restricted to descriptions and identifications. The correlation between primate's anatomy and life habits iscrucial for a complete understanding of the functional morphology and phylogeny of these and other mammals (GIBBS *et al.*, 2000, 2002 apud AVERSI-FERREIRA, 2010).

Following the behavioral changes of animals, locomotor apparatus and musculature are modified in the same proportion. An example of this is the upper limb musculature from arboreal animals, that are extremely developed and specialized for this

environment. Therefore, evolutionary studies with primates and other animals must pay attention to the myological features for a more complete understanding of evolutionary changes (YE, Z.-Z.; PENG, Y.-Z.; ZHANG, Y.-P., 1989) Grand (1968) already identified correlations between life habits of New World primates and their anatomical characteristics through observations of live animals, dissections, and illustrations. In his article, he illustrates the walk of a black howler monkey (*Alouatta caraya*, Humboldt, 1812) and correlates the locomotor characteristics of the specimen with its anatomy, developing a discussion about the functional morphology of these animals.

Lemelin (1995) reinforced this idea in his work with anatomical characteristics of New World primates and their implications for their lifestyle habits, especially in relation to the subfamily Atelinae, a sister group of the howler monkey, which are characterized by the flexor and *intertransversarii caudae* muscles, developed for its arboreal locomotion using its prehensile tail. In the same work, Lemelin concludes that behavioral data together with the myology of the primates studied support the hypothesis that the prehensile tail developed in parallel in some groups of New World primates Aversi-ferreira (2010) had the same conclusion when analyzing flexor musculature of forelimb from *Cebus libidinosus* (Rylands *et al*., 2000; Primates, Cebidae), a species of capuchin monkey. In his work, he realized that ecological pressures and adaptations shaped the myology of the *Cebus* genus, associated with its characteristic neurological capacity, facilitating its arboreal locomotion.

Dunlap (1985) in his study, argues, based on the myology of the forelimb, that the Cebus genus represents a good model for studies in fossil hominids, due to its structures with "ancestral conditions", like himself defines. In the same work, he also suggests that myological characteristics of the forelimb may support the hypothesis that genus *Aotus* (owl monkey) is phylogenetically closer to Ateline-*Alouatta* than to Callitrichidae family: "Maximum parsimony tree analyzes of our data on forelimb myology suggest the interesting hypothesis that *Aotus* is closely phylogenetically linked to the Ateline-*Alouatta* lineage, not to *Callicebus*. A close link between the genera *Callitrichine* and *Callimico* was also supported by the analyses." (DUNLAP, 1985).

Comparative anatomy

Some preliminary observations could be made in the process of identifying specimens' musculature. When compared to each other, two males showed morphological variations in relation to proportion and appearance of some structures, such as the *pectoralis* muscle and the musculature associated with thyroid cartilage, which could be attributed to freezing time, exposure to formalin, age of the individuals, among other factors.

Likewise, when compared to the female, the specialized structure for vocalization of the two males (figure 4), as well as the musculature associated with thyroid cartilage and hyoid bone, presents a considerable difference (figure 5), due to the high degree of sexual dimorphism present in this species, specifically in this apparatus (DUNN, 2015). This dimorphism is associated with the vocalization that dominant males emit to demarcate territory and for reproductive purposes. Despite this dimorphism, juveniles and females are also capable of producing this vocalization (DE MORAES AGUIAR, 2003). As noted by Miranda (2004), female of Southern brown howler monkeys (*Alouatta guariba clamitans*, Cabrera, 1940) not only emit this vocalization, but can in some cases form matriarchal groups when an adult female becomes dominant.

A notable feature observed in the surface musculature of the *Alouatta* genus is the presence of *atlantoscapularis* muscle group that connects spine and scapula. This group is formed by the anterior *atlantoscapularis* muscle, which extends between the atlas and the shoulder girdle and is located superficially to M. *trapezius*, which together, form the dorsal edge of the posterior cervical triangle (SCHÖN, 1968). This muscle is homologous to *levator scapulae ventralis* in cats and humans (RICHMOND, 2001). Posterior *atlantoscapularis* muscle originates in the atlas but inserts more internally into the cranial edge of the scapula and, in *Alouatta*, is particularly well developed compared to other muscles of the scapular region. This is most likely due to the development of hyoid bone and larynx large proportions in these animals, requiring a more robust musculature to support the weight of the head (YOULATOS, 2000).

Conclusion

The results observed after the process of dissection and identification of surface musculature from the three specimens in this work could be helpful for future studies involving comparative anatomy and functional myology, as well as in phylogenetic and evolutionary aspects of the howler monkey and general New World primates. These specimens will be preserved with the plastination technique and exhibited at the Museum of Life Sciences at Universidade Federal do Espírito Santo, located on the campus of Goiabeiras, Vitória, Brazil.

References

CASTELEYN, Christophe & BAKKER, Jaco. (2019). The Anatomy of the Common Marmoset. 10.1016/B978-0-12-811829-0.00002-9.
International Committee on Veterinary Gross Anatomical Nomenclature (I.C.V.G.A.N.). Nomina Anatomica Internacional. 6a edição. Rio de Janeiro, 2017.
VON HAGENS, Gunther; TIEDEMANN, Klaus; KRIZ, Wilhelm. The current potential of plastination. Anatomy and embryology, v. 175, n. 4, p. 411-421, 1987.
BOON, M. E. *et al*. Formaldehyde fixation and microwave irradiation. The Histochemical Journal, v. 20, n. 6-7, p. 313-322, 1988.
AVERSI-FERREIRA, Tales Alexandre *et al*. Comparative anatomy of the arm muscles of the Japanese monkey (Macaca fuscata) with some comments on locomotor mechanics and behavior. Journal of medical primatology, v. 45, n. 4, p. 165-179, 2016.
NETTER, Frank H.. Atlas de anatomia humana. 7ª ed. RIO DE JANEIRO: Elsevier, 2019.
SANTOS, Daniel Oliveira dos *et al*. Histopathologic patterns and susceptibility of neotropical primates naturally infected with yellow fever virus. Veterinary Pathology, v. 57, n. 5, p. 681-686, 2020.
MARAFIGA, A. *et al*. Composição e dinâmica de grupos de bugios-ruivos (Alouatta guariba clamitans Cabrera, 1940) em área impactada por febre amarela no Rio Grande do Sul. Anais..., 2013, Brasil., 2013.
MIRANDA, João MD *et al*. Formas Não Usuais para a Obtenção de Água por Alouatta guariba clamitans em Ambiente de Floresta com Araucária no Sul do Brasil. Neotropical Primates, v. 13, n. 2, p. 21-23, 2005.
DE AZEVEDO FERNANDES, Natália CC *et al*. Differential yellow fever susceptibility in new world nonhuman primates, comparison with humans, and implications for surveillance. Emerging infectious diseases, v. 27, n. 1, p. 47, 2021.
DE MORAES AGUIAR, Lucas *et al*. Dieta, área de vida, vocalizações e estimativas populacionais de Alouatta guariba em um remanescente florestal no norte do estado do Paraná. NEOTROPICAL, v. 11, n. 2, p. 78, 2003.
HARRIS, Eugene E. *et al*. Cytochrome b sequences show subdivision between populations of the brown howler monkey (Alouatta guariba) from Rio de Janeiro and Santa Catarina, Brazil. Neotropical Primates, v. 13, n. 2, p. 16-21, 2005.
YE, Z.-Z.; PENG, Y.-Z.; ZHANG, Y.-P. Comparative study of musculature in goldon monkey (Rhinopithecus). Human Evolution, v. 4, n. 1, p. 63-71, 1989.
DUNLAP, S. S.; THORINGTON, R. W.; AZIZ, M. A. Forelimb anatomy of New World monkeys: myology and the interpretation of primitive anthropoid models. American Journal of Physical Anthropology, v. 68, n. 4, p. 499-517, 1985.
AVERSI-FERREIRA, T. A. *et al*. Comparative anatomical study of the forearm extensor muscles of Cebus libidinosus (Rylands *et al*., 2000; Primates, Cebidae), modern humans, and other primates, with comments on primate evolution, phylogeny, and manipulatory behavior. The Anatomical Record: Advances in Integrative Anatomy and Evolutionary Biology, v. 293, n. 12, p. 2056-2070, 2010.
LEMELIN, Pierre. Comparative and functional myology of the prehensile tail in New World monkeys. Journal of Morphology, v. 224, n. 3, p. 351-368, 1995.
RICHMOND, Frances JR; SINGH, Kan; CORNEIL, Brian D. Neck muscles in the rhesus monkey. I. Muscle morphometry and histochemistry. Journal of neurophysiology, v. 86, n. 4, p. 1717-1728, 2001.
MIRANDA, João MD *et al*. Social structure of Alouatta guariba clamitans: a group with a dominant female. Neotropical primates, v. 12, n. 3, p. 135-138, 2004.
SCHÖN, Miguel A. The muscular system of the red howling monkey. Bulletin of the United States National Museum, 1968.
YOULATOS, Dionisios. Functional anatomy of forelimb muscles in Guianan Atelines (Platyrrhini: Primates). In: Annales des Sciences Naturelles-Zoologie et Biologie Animale. Elsevier Masson, 2000. p. 137-151.
WALTER, Tony. Plastination for display: A new way to dispose of the dead. Journal of the Royal Anthropological Institute, v. 10, n. 3, p. 603-627, 2004.
SORA, Mircea-Constantin *et al*. Slice plastination and shrinkage. Mat. Plast, v. 52, p. 186, 2015.

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