

Descriptive Anatomy of Lateral Digital Extensor Muscles of the Hand of the White-Footed Tamarin (*Saguinus leucopus* Günther, 1876).

Anatomía Descriptiva de los Músculos Extensores Digitales Laterales de la Mano del Tití Gris (*Saguinus leucopus* Günther, 1876).

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SUMMARY: The *Saguinus leucopus* is an endemic and monotypic primate of Colombia with quadrupedal arboreal locomotion, but the study of its morphological adaptations are still scarce, therefore the specific knowledge of its muscles will allow to understand these adaptations and to establish better medical and surgical procedures in order to preserve this species. For this purposes, the two forearms of 10 *S. leucopus* specimens were dissected, they were fixed within a formaldehyde solution, phenic acid and mineral oil mixture. Among the craniolateral muscles of the forearm two muscles were independent for digits IV and V. They presented form, origin and insertion suitable for individual extension of each digit, with innervation and irrigation by the cranial interosseous nerve and the homonymous artery respectively; they show similarities and differences with other primates, it allows to conclude that the development of these muscles could enable a particular anatomical and functional individualization in these digits extension, this feature makes possible its quadrupedal arboreal locomotion.

KEY WORDS: Antebrachial region; Extensor digiti quarti proprius muscle; Extensor digiti quinti proprius muscle; Myology; Primate.

INTRODUCTION

White-footed tamarin (*Saguinus leucopus*) is a neotropical endemic and monotypic primate of Colombia (Defler, 2010) categorized by the IUCN (International Union for Conservation of Nature and Natural Resources) as an endangered species due to a significant reduction in the population, mainly due to illegal animal trade as pets (Morales-Jiménez *et al.*, 2008). This situation makes them susceptible to arrive at the Wildlife Care and Assessment Center and zoos to be assessed by veterinarians, moreover, this species anatomical knowledge is scarce (Stevenson *et al.*, 2010), which hinders their medical and surgical care. In a study conducted by URRAS (Unidad de Rescate y Rehabilitación de Animales Silvestres), the clinical examination revealed that a third of the greatest abnormalities were in musculoskeletal system (Varela *et al.*, 2010). Therefore, knowing the muscle morphology is important to know its muscular adaptation for locomotion (Kardong, 2012), and establish better medical and surgical procedures. These primates have quadrupedal locomotion moving over trunks and branches of trees (Defler).

Therefore, they must work properly for the movement. The extensor digitorum lateralis muscle is among the craniolateral muscles of the forearm of domestic mammals. It serves to support the *extensor digitorum communis* muscle for the hand lateral digits, as it happens in the domestic dog for the three lateral digits (Budras *et al.*, 2007; Evans & De Lahunta, 2013), and in the domestic cat (König & Liebich, 2011), although in this the four lateral digits are reported (Barone, 2000). Furthermore, in humans posterior compartment of the forearm the *extensor digiti minimi* is reported due to the common pattern that only goes to this digit (Testut & Latarjet, 1984; Federative International Committee on Anatomical Terminology, 1998; Standring, 2008), but in other primates it is reported to the digit IV (Champneys, 1871; Hepburn, 1892; Primrose, 1900; Osman Hill, 1959; Kimura & Takai, 1970; Aziz & Dunlap, 1986; Ackermann, 2003; Cribillero *et al.*, 2009; Aversi-Ferreira *et al.*, 2010; Diogo & Wood, 2012), and it is even described as absent in Galagos (Stevens *et al.*, 1977; Ackermann).

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MATERIAL AND METHOD

Both *S. leucopus* forearms from five females and five males were dissected in an epicritic form. They were ethically obtained; they died by natural causes in Wildlife care and assessment centers of CORPOCALDAS (Colombia), and they weighed between 300 and 460 g. They were fixed with subcutaneous, intramuscular, and in cavities infiltrations with a solution of 10 % formalin, 5 % mineral oil, and 1 % phenic acid. They were immersed in plastic buckets the same mixture but without mineral oil solution. The terminology for quadruped animals present in the *Nomina Anatomica Veterinaria* for description (International Committee on Veterinary Gross Anatomical Nomenclature, 2012) was used, and photographic records were taken.

RESULTS



Fig.1. Superficial digital extensor muscles of the left forearm. The Superficial digital extensor muscles have been separated from interseptal origins to display separation. Common tendon originate in the most distal part of the lateral supracondylar crest and lateral epicondyle of the humerus (1). Extensor digitorum communis (2), extensor digiti IV proprius (3), extensor digiti V proprius (4); and respective tendons (2', 3', 4').



Fig. 2. Cranial view of the left forearm and hand of a *S. leucopus*. Extensor digiti IV proprius (1), Extensor digiti V proprius (2), Extensor digitorum communis (3), its tendons (1', 2', 3'), Retinaculum extensor (4), Dorsal extensor expansion (5).

In the ten *S. leucopus* specimens two independent lateral digital extensor muscles were found, they were between the craniolateral antebrachial muscles. These extensors are called the extensor digiti IV proprius muscle (extensor digiti quarti proprius) and extensor digiti V proprius muscle (extensor digiti quinti proprius), they are between the extensor digitorum communis muscle and extensor carpi ulnaris muscle.

The extensor digiti IV proprius is a unipennate and elongated muscle that is at the middle third of the intermuscular septum that limits with the extensor digitorum communis. This fibrous septum projects towards the proximal that forms a common tendon from the lateral epicondyle of the humerus with the extensor digitorum communis and the extensor digiti V proprius muscle (Fig. 1). The muscular belly of extensor digiti IV proprius goes from the middle of the forearm to the

proximal part of the carpal where its tendon passes along with the tendon of the extensor digiti V proprius through the more lateral compartment that forms the extensor retinaculum, and enters into the abaxial part of the dorsal extensor expansion that form at the level of the metacarpophalangeal joint of the digit IV (Fig. 2).

The extensor digiti V proprius is a fusiform and elongated muscle that arises in the lateral epicondyle of the humerus by a common tendon with the extensor digitorum communis and extensor digiti IV proprius. It also arises in the proximal third of the intermuscular septum that separates it from the extensor digitorum communis, and from the antebrachial fascia that covers it. Its muscular belly is in the two proximal thirds of the forearm, and develops a tendon to distal that inserts into the abaxial part of the dorsal extensor expansion of the digit V (Fig. 2).

These two muscles are innervated by independent muscular branches of the interosseous cranial nerve, which is the extension of deep branch of radial nerve when passes the supinator muscle. They are also irrigated independently by branches of the cranial interosseous artery (Fig. 3).

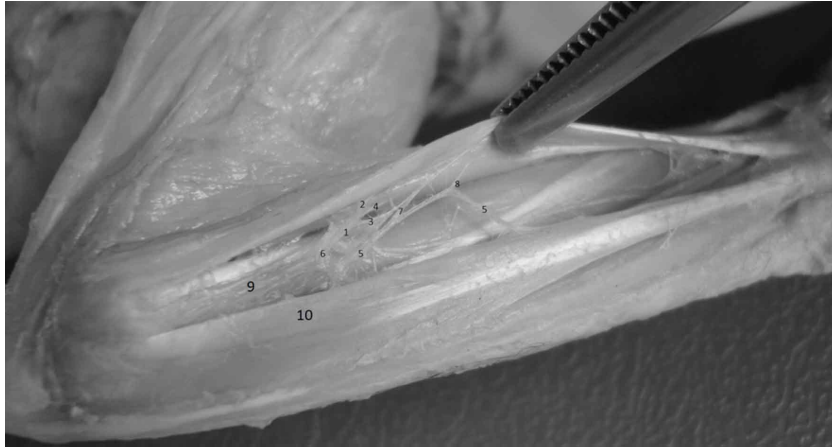


Fig. 3. Lateral view of the right forearm of a specimen. The superficial extensor muscles of the digits have been retracted to display its innervation through cranial interosseous nerve (1) with its branches to the extensor digiti V proprius (2), extensor digiti IV proprius (3), and extensor digitorum communis (4); as irrigation by interosseous cranial artery (5) and its muscle branches for the extensor digiti V proprius (6), extensor digiti IV proprius (7) and extensor digitorum communis (8). Supinator (9) and extensor carpi ulnaris muscles (10).

DISCUSSION

The presence of a separate muscle for the digit IV and one for the digit V has been reported in other species different from *S. leucopus*, such as in *Ateles geoffroyi*, in which the extensor digiti IV proprius arises deeply in the common digital extensor muscle. The extensor digiti V proprius described in *Cercopithecus aethiops* and *Cercopithecus talapoin* is divided into two muscles that supply the digits IV and V (Aziz & Dunlap). Two independent muscles have also been found in *Papio hamadryas*, where the extensor digiti IV proprius arises from the lateral epicondyle of the humerus and inserts on the dorsal aspect of the proximal phalanx (Ackermann), but it has also been found that in this species only one muscle leads to the digits IV and V (Champneys; Hepburn). In *Macaca mulatta* and *Macaca fascicularis* named independently, the descriptions report as a single muscular belly, in which the tendon is divided to digits IV and V (Ackermann; Kimura & Takai). This is an anatomical feature that occurs in *Macaca nemestrina* (Aziz & Dunlap), *Cebus libidinosus* (Aversi-Ferreira *et al.*), *Cebus albifrons* (Cribillero *et al.*), *Callimico goeldii* (Osman Hill), *Pongo pygmaeus* (Aziz & Dunlap; Diogo & Wood; Primrose), and *Macaca fascicularis* (Kimura & Takai). This division is also rarely present in humans (Standring; Testut & Latarjet) and other primates except *Pan troglodytes*, *Gorilla gorilla* (Aziz & Dunlap; Diogo & Wood; Hepburn), gibbons (Aziz & Dunlap; Diogo & Wood; Hepburn; Michilsens *et al.*, 2009), *Saguinus geoffroyi* (Aziz

& Dunlap), and *Saguinus oedipus* (Ackermann). In these, extensor digiti V proprius has only been found for the digit V, as happens with the common human pattern (Standring; Testut & Latarjet), it presents similarities to *S. leucopus*, although they do not have an individual muscle for the digit IV. An independent muscle has been found in *Nycticebus pygmaeus* for the digit V, but it has also been found corresponding to the digits IV and V (Diogo & Wood). The muscle is described as absent in *Galago senegalensis* (Stevens *et al.*) and *Galago crassicaudatus* (Ackermann), but its functional equivalent has been found in the extensor digitorum communis, similar to what happens in *Hylobates lar*, in which it has been fused to it (Michilsens *et al.*). These variations can occur in humans (Standring), but are not found in *S. leucopus*.

Regarding the origin of the *S. leucopus* extensor digiti V proprius, it differs from humans (Testut & Latarjet; Standring) because it arises from the intermuscular septum with flexor carpi ulnaris and differs from *C. libidinosus* (Aversi-Ferreira *et al.*), *P. pygmaeus* (Aziz & Dunlap) H. lar and *H. gabriellae* (Diogo & Wood) because its origin is reported from the antebrachial fascia. No origins were found in the ulna of the *S. leucopus*, which is a variant that has been reported in humans (Testut & Latarjet). In *Ateles* sp there is a description of an ulnar origin near the carpus (Ackermann); in *Symphalangus syndactylus* and *H. lar* its origin has been reported towards the middle of the ulna, and in *Pongo pygmaeus* in the proximal part of the ulna (Diogo & Wood). The *S. leucopus* innervation and irrigation of this muscle is similar to the one reported in humans (Testut & Latarjet; Standring) and differs from the irrigation in *C. libidinosus* as it is directly described in the radial artery (Aversi-Ferreira *et al.*).

In conclusion, the development of a single muscle to the digit IV and another for the digit V of the *S. leucopus*, suggests that this species has a particular anatomical and functional individualization in the extension of these digits, a feature, that enables them to use these digits to climb down off the branches and trunks of trees. This suggests that this condition is essential for the quadrupedal arboreal locomotion in a palmigrade way, as it demands longer an extension of the digits. This finding and anatomical description also suggests more anatomic studies to understand its role in the locomotor behavior of this animal.

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RESUMEN: El *Saguinus leucopus* es un primate endémico y monotípico de Colombia con la locomoción cuadrúpeda arbórea, sin embargo los estudios de sus adaptaciones morfológicas aún son escasos, por lo tanto, el conocimiento específico de sus músculos permitirá conocer estas adaptaciones y establecer mejores procedimientos médicos y quirúrgicos con el fin de preservar esta especie. Para estos fines, se diseccionaron los dos antebrazos de 10 especímenes de *S. leucopus*, los cuales fueron fijados con una solución en mezcla de formaldehído, aceite mineral y ácido fénico. Entre los músculos craneo laterales del antebrazo se encontraron dos músculos independientes para los dígitos IV y V. La forma, el origen y la inserción eran adecuadas para la extensión individual de cada dígito, con la inervación e irrigación por el nervio interóseo craneal y la arteria del mismo nombre respectivamente, presentando similitudes y diferencias con otros primates, lo que permite llegar a la conclusión que el desarrollo de estos músculos podría permitir una individualización anatómica y funcional particular en la extensión de estos dígitos, haciendo posible su locomoción cuadrúpeda arbórea.

PALABRAS CLAVE: Región antebraquial; Músculo propio del extensor del dedo Quarti; Músculo Extensor del dedo quinti proprius; Miología; Primate.

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