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Review

Anatomical variations of the musculoskeletal system - A review of literatures

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Abstract

The musculoskeletal system developed from the mesoderm. However, some bones at the base of the skull and facial musculature are derived from the neural crest cells (ectoderm). The skeleton, joints and associated muscles, form the locomotor system which can be used either to move the whole or parts of the body in relation to its surroundings or to exert pressure or tension on external objects or internal organs. There are striking individual differences in the musculoskeletal system in spite of basic similarity of structures within specie, hence, the review of the anatomical variations of the musculoskeletal system. Textbooks descriptions however are meant to represent the condition in the majority of individuals. Muscles are subject to variation and books have been written about their variations. This review, consisting of literature search of journals and chapters in books aims at highlighting variation in the musculoskeletal system of humans which will contribute to knowledge in the teaching of gross and comparative anatomy. Anatomical variations is of both surgical and academic interest and important when studying entrapment syndrome and reconstructive surgery in patients with musculoskeletal conditions.

Key words: Musculoskeletal, Locomotor system, Anatomical variations, Academic, Surgery

INTRODUCTION

The musculoskeletal system which is mesodermal in origin provides support, stability, and movement to the body. It is made up of the bones of the skeleton, muscles, cartilage, tendons, ligaments, joints, and other connective tissue that supports and binds tissues and organs together. The musculoskeletal system's primary functions include supporting the body, allowing motion, and protecting vital organs (Mooar, 2007). The skeletal portion of the system serves as the main storage system for calcium and phosphorus and contains critical components of the hematopoietic system (Kahn and Scott, 2008).

The human skeleton consists of axial and appendicular skeleton which receive attachment of muscles. The axial skeleton consists of a series of vertebrae connected by thick intervening deformable intervertebral disc. The vertebral column includes cervical, thoracic, lumbar, sacral and coccygeal vertebrae. There are seven cervical, twelve thoracic, five lumbar, five sacral and one coccygeal vertebrae. There is a sternum (breast bone) made up of three parts; manubrium, body and xiphoid process. There are twelve pairs of ribs. Ribs one to seven are directly attached to the sternum and they are called true or vertebrosternal ribs. Ribs eight to ten are attached by means of a cartilage to the sternum and they are called false or vertebrochondrial ribs. Ribs eleven and twelve are not attached at all to the sternum, and they are called false or floating or vertebral ribs. The skull consists of the cranium and a facial portion. The facial portion includes the jaws and the parts which enclose the nasal cavity and orbits.

The appendicular skeleton consists of the upper and lower limbs girdles. The upper limb girdle consists of the clavicle and scapula and is connected to the axial skeleton via the sternoclavicular joint. The lower limb girdle consists of the two hip bones (formed by ilium, pubis and ischium which unite at the acetabulum) and articulate with the sacrum at the anterior and posterior sacroiliac joints posteriorly, and pubic symphysis anteriorly to form the pelvis. The upper limb bones include the humerus, radius and ulna, carpal, metacarpal and phalangeal bones. The lower limb bones include the femur, tibia and fibula, tarsal, metatarsal and phalangeal bones.

The nerve supply the head and neck musculature is derived from the cervical plexus, C1 – C4 spinal nerves and some cranial nerves (III, IV, V, VI, VII, IX, X, XI and XII). The nerve supply to the upper limb is derived from the brachial plexus C5 – T1 spinal nerves. The nerve supply to the thoracic musculature is derived from the intercostal nerves, T2 – T6 thoracic nerves. The nerve supply to the anterior abdominal wall muscles is derived from T7 – T12 thoracic nerves. The nerve supply to the posterior abdominal wall muscles is derived from the lumber plexus, L1 – L4 spinal nerves. The nerve supply to the pelvis, perineum and lower limb is derived from the sacral and coccygeal plexuses (L4 – S4 and S4, S5 and Co1 spinal nerves respectively).

Anatomical variations may influence predisposition to diseases, symptomatology, clinical examination, investigation and patient management including operative surgery (Willan and Humpherson, 1999). Over the years, there has been some misinterpretation in clinical diagnosis of normal variants and pathological abnomalties. However, Radiologists play a major role in differentiating normal variants and abnormal conditions with the use of medical imaging which is the technique and process of creating visual representations of the interior of a body for clinical analysis and medical intervention, and seek to reveal internal structures hidden by the skin and bones, as well as to diagnose and treat disease. Such imaging includes the use of technologies such as X-rays radiography, magnetic resonance imaging (MRI), medical ultrasonography or ultrasound, endoscopy and medical photography.

Anatomical variations of the muscular system

There are three types of muscles, namely, skeletal, cardiac, and smooth. Skeletal muscle is the striated voluntary muscle of the skeleton, tongue and eye ball. Cardiac muscle is the muscle of the striated involuntary muscle of the heart, while the smooth (visceral) muscle is the muscle found in the gastrointestinal tract, blood vessels and glands (Mooar, 2007). However, only skeletal and smooth muscles are part of the musculoskeletal system and only the skeletal muscles can move the body. Cardiac muscles are found in the heart and are used only to circulate blood. Skeletal muscles are attached to bones and arranged in opposing groups around joints (Mooar, 2007). Muscles are innervated, to communicate nervous energy by nerves, which conduct electrical currents from the central nervous system and cause the muscles to contract (Bárány, 2002). Anatomical variations have been reported in almost all regions of the muscular system.

Head and neck region

A duplicated omohyoid muscle was observed during a routine cadaver dissection. It was inserted along with the usual inferior belly of omohyoid into the transverse scapular ligament (Rai et al., 2007).

During dissection of the submental region, Ozgur et al., (2007) found that the anterior bellies of the right and left digastric muscles had four separate insertions. Two median accessory digastric muscles were located medially to the anterior bellies of digastric and inferior to the omohyoid deep to the platysma muscle. The four accessory muscles of the anterior bellies of digastric muscle originated from the digastric fossa and inserted into the hyoid bone.

Also during the gross anatomy dissections of the submental region, an anatomical variation of the left digastric muscle was found. This muscle had three bellies. Whereas the anterior and posterior bellies had their normal origin and course and were joined by an intermediate tendon, the accessory anterior belly originated from the digastric fossa and a thin tendon together with the anterior belly was inserted onto the hyoid bone (Sargon and Celik, 1994).

Anatomical variations in the musculature of the spine have the potential to cause functional and postural abnormalities which in turn could lead to chronic myofacial and skeletal pain. The levator scapulae muscle is inserted into the superior angle of the scapula. A unilateral case of a 71 year old Caucasian female in which the left levator scapulae muscle gave rise to an accessory head that inserted by way of a flat aponeurotic band to the ligametum nuchae, tendon of rhomboid major and the superior aspect of the serratus posterior muscle. It was also supplied by a branch of the dorsal scapular nerve (Loukas et al., 2006).

Upper limb region

The Biceps brachii muscle usually arises by two heads (long and short). However, Kumar et al., (2008) reported a case of a 3.33% third head of biceps brachii of a 56 year old male, when they studied both extremities of 48 formalin fixed cadavers. This variant third head arose from the anterior limb of the “V” shaped insertion of the deltoid muscle on the humerus. It was found to fuse with the common belly of the muscle well before the bicipital tendon and its aponeurosis and received twigs of the musculocutaneous nerve.

The extra heads of bicep brachii muscle have clinical significance as they might confuse surgeons who perform surgeries on the arm and might lead to iatrogenic injuries or the extra head might cause compression of vital neurovascular structures in the upper limb. Association of third head with unusual bone displacement following fracture has significance in surgical procedure (Sreedevi et al., 2013). The third head however, may offer extra strength to the Biceps during supination of the forearm and elbow flexion regardless of shoulder position (Swieter et al., 1980). The extra head of BB muscle is remarkable not only to anatomists but also to the clinicians, from the phylogenetic point of view as well as from the surgical view due to the partial entrapment of either the musculocutaneous or median nerve in certain cases (Meguid 2010).

A case of a four headed biceps brachii muscle with a double piercing by the musculocutaneous nerve in the right arm of an 87 year old female cadaver was reported (Vazquez et al., 2003). One of the supranumeracy heads originated from the humerus in the area between the lesser tubercle and the coracobrachialis and brachialis muscles and joined the long head at the level where the long head joined the short head. The 2nd supranumeracy head originated from the humerus at the point where the coracobrachials muscle inserted and joined the biceps brachii tendon and its bicipital aponeurosis at the inferior 3rd of the arm. They are supplied by the musculocutaneous nerve along with the long and short heads.

Fabrizio and Clemente (1997) reported the presence of 4th head of triceps brachii muscle found on the left side of a cadaver. This head originated from the proximal posteromedial aspect of the humeral shaft distal to the shoulder capsule. Tubbs *et al*., (2006) also demonstrated the presence of a fourth head of triceps brachii muscle found on the left side of a male cadaver. The head originated from the posterior aspect of the surgical neck of humerus.

Loukas et al., (2006) reported a case of an accessory brachialis muscle found during routine dissection at Harvard Medical School in 2003. It arose from the mid shaft of humerus and medial Intermuscular septum. Loukas et al., (2006) also reported a case of a right sided accessory head of pectoralis major muscle located inferior to its abdominal origin, found during a routine anatomy dissection at the American University of Caribbean School of Medicine. The muscle fibres arose from those of the serratus anterior muscle and travelled supralaterally towards the axilla.

El Domiaty et al., (2008) studied about forty-two upper limbs of embalmed cadavers (36 males, 6 females) to elucidate the prevalence of both the accessory heads of flexor pollicis longus of flexor digtorium profundus muscles origin, insertion and nerve supply in Egyptians. Accessory heads flexor pollicis longus were found to be present more frequently (61.9%) than it was absent, whereas the accessory head of flexor digitorum profindus was seen in only 14.24% of the cadavers examined. The insertion of accessory head of flexor pollicis longus was mainly into the upper third of the flexor pollicis longus tendon, while the accessory head of the flexor digitorum profundus joined the tendons of flexor digitorum profundus muscle to the index or middle or ring fingers.

In about 30 cadavers dissected and data obtained from published sources, four limbs showed complete agenesis of palmaris longus muscle. Reversal in the muscle tendon orientation was seen in two limbs and duplication in one limb (Pai et al., 2008).

Paul and Das (2007) reported a case of a variant abductor pollicis longus tendon which inserted into the base of the 1st metacarpal and proximal phalange. Also, multiple (3) tendons of abductor Pollicis longus muscle was reported in a 42 year old male cadaver (Paul and Dab, 2006).

Nayak *et al*., (2008) reported multiple variations of the extensor tendons of the forearm in which in a 51 year old male cadaver from the Department of Anatomy, Kasturba Medical College, Mangalore, India, there was complete absence of the extensor pollicis brevis, abductor pollicis longus having six slips of insertion with additional slip from brachioradialis. The extensor digitorum communis had five tendon slips.

Anomalous origin of the limbrical muscles was reported by Potu et al., (2008). In the research, the upper extremities of twenty-four South Indian (20 males, 4 females) cadavers were examined. Three instances of variant origins of the limbrical muscles (two instances of the 2nd and one instance of the 1st limbrical) were seen. The muscles were unusually long extending to the level of the proximal border of the flexor retinaculum. In two of the cases it took origin from the tendon of flexor digitorum profundus and its accessory belly, and in one case it took origin from the tendons of flexor digitorum profundus and superficialis muscles.

Lower limb region

Anatomical variations in the insertion of fibularis longus tendon was reported by Petil et al., (2007). In the research they observed additional slips in nine out of thirty cadaveric feet dissected to the neck of the 1st metatarsal, bases of the 2nd, 4th and 5th metatarsals in addition to its normal insertion.

Freeman et al., (2008) observed that nine out of the forty-six cadaveric Knees (19.6%) dissected, the plantaris muscle had a distinct interdigitations with the lateral head of gastrocnemius muscle and a strong fibrous extension to the patella in five of the specimens (10.9%).

A muscle such as the fibularis tertius is an ‘appearing’ muscle in the leg. It is absent in about 6.25% of the 400 cadaveric limbs studied. The palmaris longus and plantaris muscles are ‘disappearing’ muscles. The palmariis longus is absent in about 13.7% of the 771 cadaveric limbs studied, while the plantaris muscle is absent in about 6.6% of the 740 cadarevic limbs studied (Basmajian and DeLuca, 1985). Bloome et al., (2003) reported variations on the insertion of the tibialis posterior tendon from eleven fresh – frozen cadaveric feet (ten subjects). Three distinct bands of tibialis posterior tendons were seen in all specimens with variations on the insertion to the spring ligament (4/11), 5th metatarsal (7/11) flexor hallucis brevis (9/11) and fibularis longus (4/11).

Variations in the insertion of extensor hallucis longus muscle were studied in sixty adult human cadavers. Three different patterns of insertion were noticed. 65% of the muscle had a single tendon, 26.7% had two tendons and 8.3% had three tendons. Various sites of insertion order than the normal site were recorded, that is into the dorsal aspect of the proximal phalanx of the big toe and the capsule of the 1st metatarsophalangeal joint (AL saggaf, 2003).

Yalcin and Ozan (2005) reported some variations of the flexor digitorum brevis muscle in 33 embalmed cadaveric feet. They observed that the muscle belly for the 5th toe was much smaller than the others in 12 feet and was missing in 6 feet.

Pelvis and perineum region

Studies on the levator ani muscle showed in twenty-five cadaveric specimen (10 neonates, 15 adults) that smooth muscle fibres appear in the medial fibres of the muscle and that at this point, the muscle had two layers, deep pelvic layer formed of smooth muscle fibres and superfacial perineal part made up of skeletal muscle fibres (Shafik et al., 2002).

Anatomical variations of the skeletal system

In the skeletal system, anatomical variations may be seen in the presence of a cervical rib in about 0.5% of the subjects. It may unilateral or bilateral. If present, is attached to the transverse process of the 7th cervical vertebra and articulate with the 1st rib. Pressure of such a rib on the lowest trunk of the brachial plexus arching over it may produce paresthesia along the ulnar border of the forearm and wasting of the small muscles of the hand. Vascular changes even gangrene, may be caused by pressure of the rib on the overlying subclavian artery. This results in post-stenotic dilatation of the vessel distal to the rib in which a thrombus forms from which emboli are thrown off (Ellis, 1994).

Cohen et al.,(1997) described a case of superior transverse scapular ligament affecting a 58 year old man and his son who had calcification of superior transverse scapular ligament causing entrapment neuropathy of the suprascapular nerve and its attendant clinical symptoms of pain, weakness, atrophy of the supraspinatus muscle.

Rengachary et al., (1979) in their report of the anatomical variations observed in the suprascapular notch area, described six different types. These anatomical variations of the suprascapular notch and the superior transverse scapular ligament constitute potential predisposing factors to suprascupular nerve entrapment. Osuagwu et al., (2005) reported a case of complete ossification of the superior transverse scapular ligament in a Nigerian adult and concluded that in the diagnosis of suprascapular nerve entrapment syndrome, variations in the anatomy of the superior transverse scapular ligament must be considered as possible etiologic factors.

Anatomical variations of the musculoskeletal nerves

Nerves of the musculoskeletal system also present some anatomical variations. Tubbs et al., (2008) reported the contribution of the 4th cervical spinal nerve to the upper trunk of the brachial plexus without pre-fixation. In the report, posterior cervical triangles from sixty adult cadavers were dissected. Nine (15%) of the sixty sides were found to have extradural C4 contributions to the upper trunk of the brachial plexus and were excluded from the study. In approximate 20% (11 of the sixty sides) of normally composed brachial plexus (those with extradural contributions from only C5-T1) they found intradural C4 – C5 neural connections and concluded that such variations may lead to misinterpretation of spinal levels of pathological conditions of the spinal axis and should be considered in surgical procedure of this region such as rhizotomy.

Yan and Horiguchi (2000) used twenty-four adult cadavers (48 sides) to investigate the incidence of a branch arising from the ventral ramus of C4 spinal nerve with the phrenic nerve and subsequently joining the brachial plexus. They dissected six brachial plexuses with spinal cords and phrenic nerves. The incidence of C4 branch was 23% (11/48sides). Branches from C4 to the brachial plexus dividing into anterior and posterior divisions was on four sides (4/6 sides). These branches passed to the suprascapular nerve from the upper trunk of the plexus thus supporting the claim of Yan et al., (1999) that the human suprascapular nerve belongs to both anterior and posterior divisions of the brachial plexus.

An anatomical variation was also observed by Mahakkanukrauh and Somsarp (2002) in dual innervation of the brachialis muscle. The study was carried out on 45 male and 31 female Thai cadvavers. The dissections revealed that the brachialis muscle received innervations from the musculocutaneous nerve and that 81-6% were also innervated by a branch from the radial nerve. They concluded that the basis for the dual innervation may result from fusion of two different embryonic muscular primordial; the ventral (flexor) and the dorsal (extensor) muscle masses. A case of the human sternocleidomastoid additionally innervated by the hypoglossal nerve was observed in the right neck of an 82 year old Japanese female by Koizumi et al., (1993). It was reported that the nerve branch arose from the hypoglossal nerve at the origin of the superior root of the ansa cervicalis. The nerve fibre analysis revealed that the branch consisted of fibres form the hypoglossal nerve, the C1 and C2 nerves, and had the same component as the superior root of the ansa cervicalis. However, most part of the sternocleidomastoid muscle was innervated by the accessory nerve and a branch from the cervical plexus.

CONCLUSION

The musculoskeletal system refers to the system having its muscles attached to an internal skeletal system and innervated by cranial (head and neck) and spinal (rest parts of the body) nerves necessary for movement of humans to a more favorable position. Anatomical variations is of both surgical and academic interest, and important when studying entrapment syndrome and reconstructive surgery in patients with musculoskeletal conditions as complex issues and injuries involving the musculoskeletal system are usually handled by a physiatrist (specialist in physical medicine and rehabilitation) or an orthopaedic surgeon. A thorough knowledge of the anatomy of the musculoskeletal system, normal variations, abnormalities and its dynamic changes is essential to prevent performance of unnecessary invasive procedures.

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