Atlas of Functional Shoulder Anatomy

Giovanni Di Giacomo • Nicole Pouliart • Alberto Costantini • Andrea De Vita
Editors

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Springer

Giovanni Di Giacomo
Concordia Hospital for Special Surgery
Rome, Italy

Nicole Pouliart
Vrije Universiteit Brussels
Universitair Ziekenhuis Brussel
Brussel, Belgium

Alberto Costantini
Concordia Hospital for Special Surgery
Rome, Italy

Andrea De Vita
Concordia Hospital for Special Surgery
Rome, Italy

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To my father Dr. Sergio Di Giacomo, and in memory
of my friends Dr. Richard B. Caspari, and Dr. Douglas T. Harryman, II
Giovanni Di Giacomo

To teachers and mentors who have inspired me
to keep delving deeper for knowledge
Nicole Pouliart

To my family, to my love Andrea and Stefano
Alberto Costantini

To my family and to my teachers Giovanni and Alberto
Andrea De Vita

We wish to express our grateful thanks to Mauro Fermariello for providing the scientific images,
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to the realization of the book images.

Foreword

Functional Anatomy of the Shoulder gives the shoulder surgeon a fresh look and feel for shoulder anatomy. The endless energy and the inquisitive nature that characterise Dr. Di Giacomo and his team are evident in every dissection and image in this book. His meticulous dissections and crisp photography give the reader a clear insight into the functional anatomical relationships of this elegant piece of machinery called the shoulder. He shows us how the stabilization and movement muscles provide power and motion and how it is that the ligament changes, which send signals to the brain, masterfully regulate the freedom of movement we enjoy throughout our lives with a minimal amount of pain and problems. The discerning clear photography of clean dissections gives new life to anatomical structures.

I have had the opportunity of viewing all the excellent images and listening to the Authors' descriptions of the biceps pulley and shoulder proprioception over the past several years. It pleases me that they have taken it upon their shoulders to share their expertise and enthusiasm. This is an exciting, essential book for everyone who is interested in the shoulder.

James C. Esch, MD
President, San Diego Shoulder Institute
Assistant Clinical Professor, Department of Orthopaedics
University of California
San Diego, School of Medicine
Tri-City Orthopaedics
Oceanside, CA, USA

Preface

Dr. Di Giacomo and his team have undertaken a very important task – the production of a book on shoulder anatomy that relates the static description of the anatomy to the dynamic function of the shoulder. This book has done an excellent job of showing the anatomy of the individual structures around the shoulder in a beautiful series of pictures and then relating this anatomy to the developing knowledge of how the shoulder functions as a dynamic, integrated whole. In addition, this book emphasizes the relation of shoulder anatomy and function to the larger kinetic chain that supports, guides, and provides force for shoulder function.

This book will serve two purposes. It is the newest and freshest addition to shoulder anatomy books, and it will serve to show the clinician the importance of a deep knowledge of functional anatomy as a basis for understanding how the shoulder works in function. With this knowledge, the clinician can better understand dysfunction – the combination of structural deficits that brings the patient to treatment. In addition, this knowledge of function will allow a framework of treatment that will restore the pertinent anatomy.

I am glad Dr. Di Giacomo's team has produced this work. It should become a standard reference for clinicians who will treat shoulder injuries. It will give doctors much more information with which they can effectively treat patients.

W. Ben Kibler, MD FACSM
Medical Director
Lexington Clinic Sports Medicine Center
Lexington, KY, USA

Contents

Part 3 - Glenohumeral Joint (muscle-tendon)

Part 4 - Glenohumeral Capsule

Part 5 - Neuromuscular Control and Proprioception of the Shoulder

List of Contributors

Klaus L. Baumann
Institute of Experimental Morphology, University of Hamburg, Hamburg, Germany

Alberto Costantini, MD
Arthroscopic Surgery Department, Concordia Hospital for Special Surgery, Rome, Italy

Andrea De Vita, MD
Assistant
Arthroscopic Surgery Department, Concordia Hospital for Special Surgery, Rome, Italy

Giovanni Di Giacomo, MD
Director
Arthroscopic Surgery Department, Concordia Hospital for Special Surgery, Rome, Italy

Todd S. Ellenbecker, DPT, MS, SCS, OCS, CSCS
Clinic Director
Physiotherapy Associates Scottsdale Sports Clinic, Scottdale, Arizona USA
National Director of Clinical Research, Physiotherapy Associates, Philadelphia, PA, USA

Zdenek Halata
Institute of Experimental Morphology, University of Hamburg, Hamburg, Germany
Department of Anatomy, First Faculty of Medicine, Charles University Prague, Prague, Czech Republic

W. Ben Kibler, MD FACSM
Medical Director
Lexington Clinic Sports Medicine Center, Lexington, KY, USA

Scott M. Lephart, PhD
Director
Neuromuscular Research Laboratory, Department of Sports Medicine and Nutrition,
School of Health and Rehabilitation Sciences, University of Pittsburgh, PA, USA

Hiroshi Minagawa, MD
Department of Orthopedic Surgery, Akita University School of Medicine, Akita, Japan

Nicole Pouliart, MD, PhD
Department of Human Anatomy, Vrije Universiteit Brussel
Department of Orthopaedics and Traumatology, Universitair Ziekenhuis Brussel, Brussel, Belgium

Aaron Sciascia, MS, ATC, NS
Program Coordinator
Lexington Clinic Sports Medicine Center, KY, USA

Part 1 - Scapulothoracic Joint

Andrea De Vita, W. Ben Kibler, Nicole Pouliart, Aaron Sciascia

1.1 Muscles for Scapulothoracic Control: Role of the Scapula

The scapula is anatomically and biomechanically involved in shoulder function and movement of the arm [1]. During the process of shoulder and arm movement to achieve a change in glenohumeral position and during movements required in athletic and daily activities, the two are linked (Fig. 1.1).

To obtain a correct three-dimensional (3D) movement of the shoulder girdle and upper arm the scapula rotates upwards, tilts to the back and rotates externally [2, 3], the clavicle elevates and retracts [3, 4] and the humerus elevates and rotates externally [5].

Scapula, shoulder and arm are either stabilised in or moved into a certain position to generate, absorb and transfer forces that accomplish work or athletic tasks. An alteration in the scapular position at rest or during arm movement is commonly associated with injuries that create clinical dysfunction of the shoulder. These alterations, which may be the result of injury or may exacerbate an existing injury, are called scapular dyskinesis [6], a generic term describing the loss of scapular motion and position control observed upon clinical examination.

The scapula has four roles in the shoulder complex. The first is as an integral part of the glenohumeral articulation, which cinematically is a ball-and-socket configuration. To maintain this configuration, the scapula must move in coordination with the moving humerus, so that the instant centre of rotation is constrained within a physiological pattern throughout the full range of shoulder motion [7, 8].

The second role of the scapula is to provide motion along the thoracic wall. Scapular retraction creates a stable base so that the abducted or elevated arm can perform tasks requiring actions such as reaching, pushing or pulling.

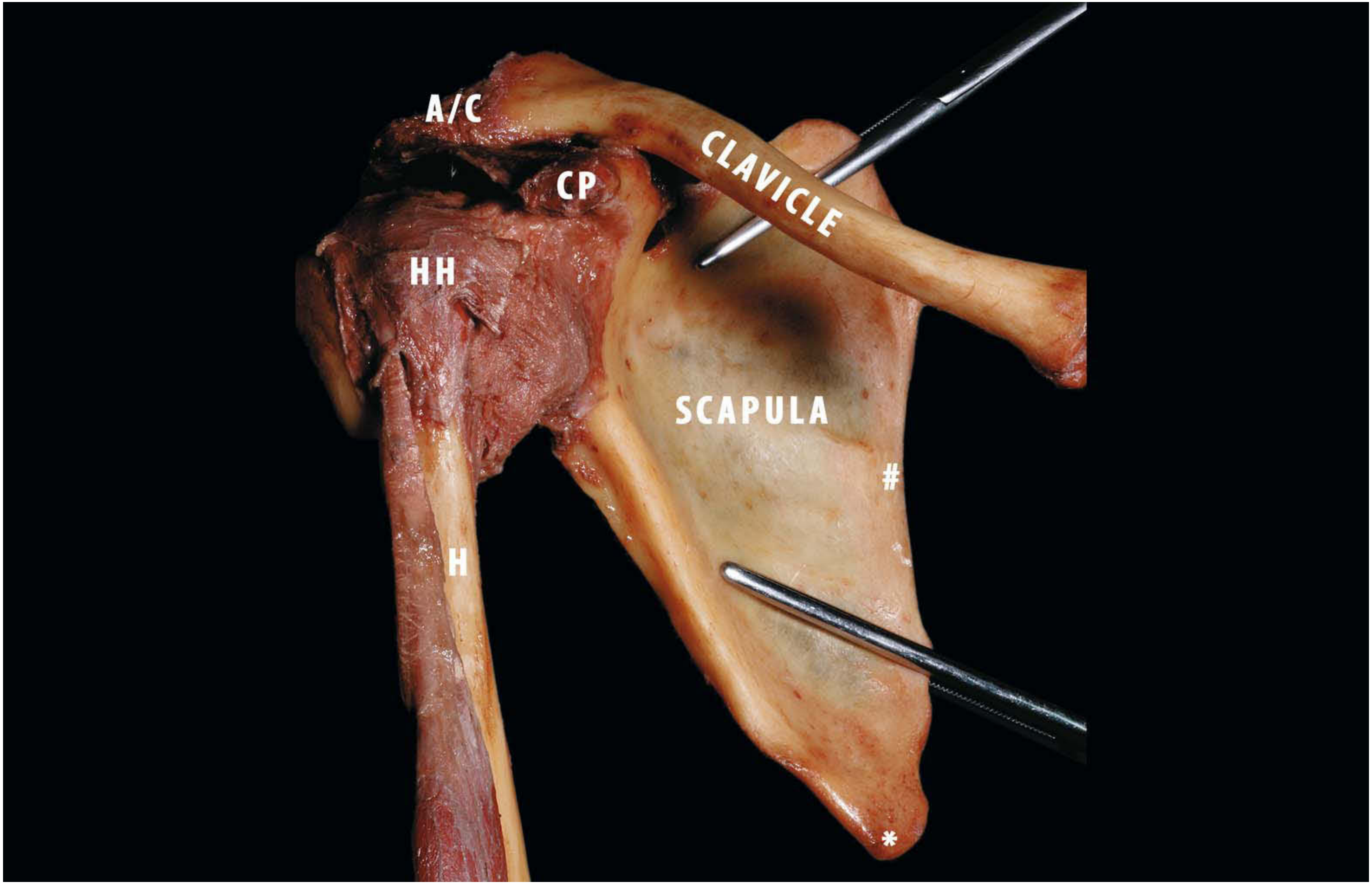
The third role of the scapula in shoulder function is the elevation of the acromion, which occurs during the cocking and acceleration phases of throwing or elevation of the arm, so as to separate it from the rotator cuff during movement and to decrease impingement and coracoacromial arch compression [9, 10].

The scapula's final role in shoulder function is to act as a link between proximal and distal parts of the body in order to transfer large forces and high energy from the legs, back and trunk to delivery points, such as the arm and the hand [11, 12].

It is absolutely necessary that the scapula have a good system of muscle activation in order to best perform these functions.

The serial muscle activation patterns stabilise the scapula and increase control over its movement and position as the arm is moved [1].

Fig. 1.1. Anterior view of the right shoulder. This view illustrates the three bones of the shoulder girdle: the scapula, the humerus (*H*), and the clavicle. The scapula is the link between the thorax and the superior arm (*HH* humeral head, *A/C* acromioclavicular joint, *CP* coracoid process, *inferior angle of the scapula; #medial border of the scapula)

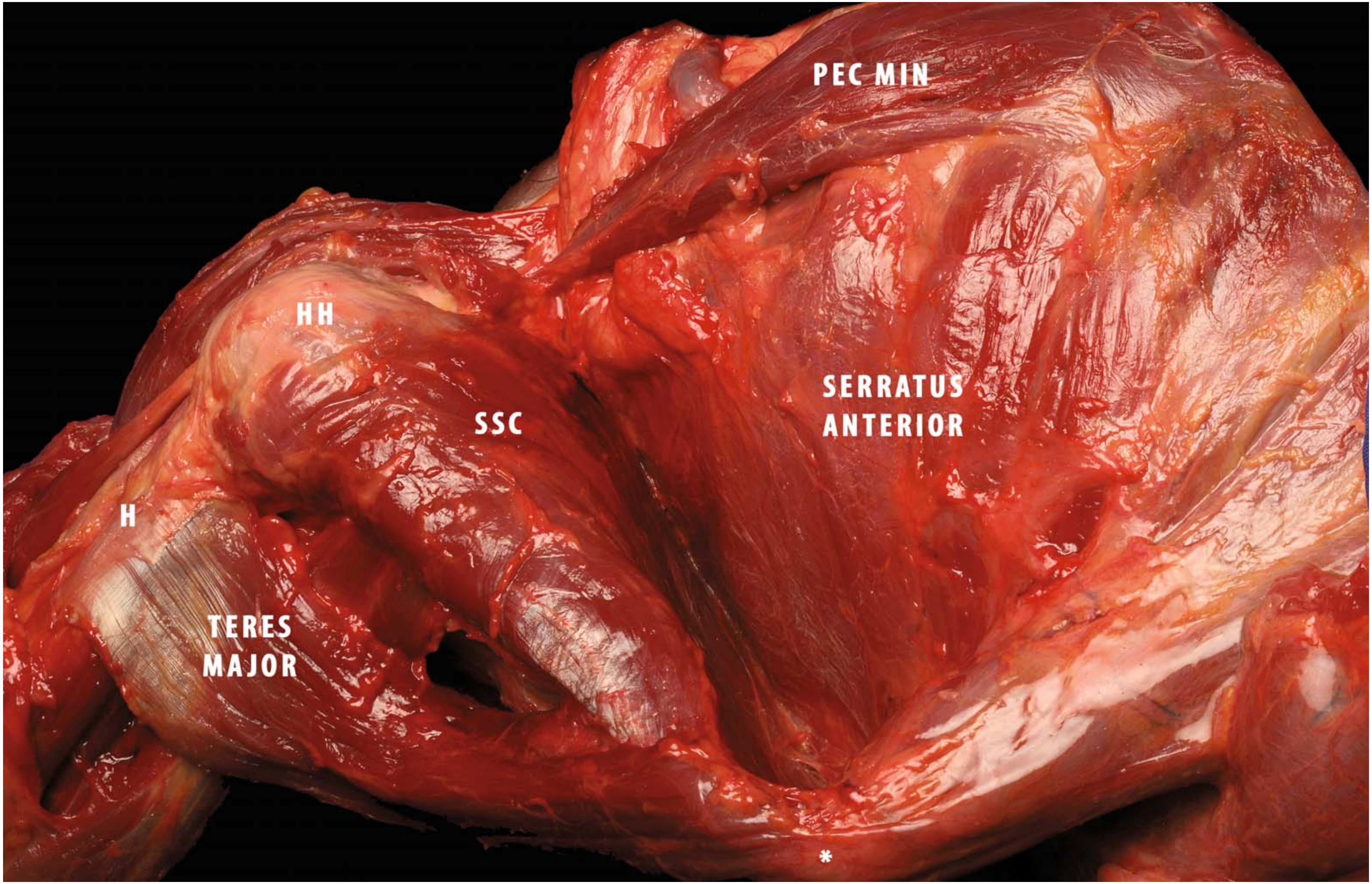

A/C
CP
CLAVICLE
HH
SCAPULA
#
H
*

1.1.1 Serratus Anterior Muscle

The serratus anterior muscle is a large muscle covering much of the lateral aspect of the thorax (Fig. 1.2). In bipedal animals, the serratus anterior complex acts together with the trapezius to provide a very strong, mobile base of support designed to optimise the glenoid position so that maximally effective use of the entire upper extremity is attained [17]. Its fleshy fibres arise from the outer surfaces of the upper nine ribs. There are three major functional portions to this muscle.

Concealed in the axilla by the pectoralis major muscle, the superior cylindrical mass accounts for 40-50% of the wet weight of the serratus anterior muscle. Attached to the main rotation axis at the superior medial border of the scapula, this large, powerful mass is a necessary anchor allowing the rotation required to lift the arm over the head. This portion of the serratus anterior muscle arises from the first, second and part of the third ribs, and the intervening fascia. It travels laterally, inserting in the superior medial angle of the scapula, where it forms the ventral part of the rotation axis. This scapular axis is completed by the trapezius muscles situated in the back and attached to the acromial spine base. The second portion of the serratus anterior is a long, thin, wide band of muscle originating from the third, fourth and fifth ribs and inserting in the vertebral border of the scapula. The fibres of this part of the muscle help to draw the scapula forward. The third functional part of the serratus anterior made up of the lower five slips. These originate from the sixth to the tenth ribs, run up and down along the chest wall and converge on the inferior angle of the scapula. These lower slips are subcutaneous and easily visible in muscular individuals. Innervation is supplied by the long thoracic nerve (C5, C6, C7) [18]. The blood supply to the serratus muscle is classically stated to come through the lateral thoracic artery. There is often a large contribution from the thoracodorsal artery, especially when the lateral thoracic artery is small or absent [19].

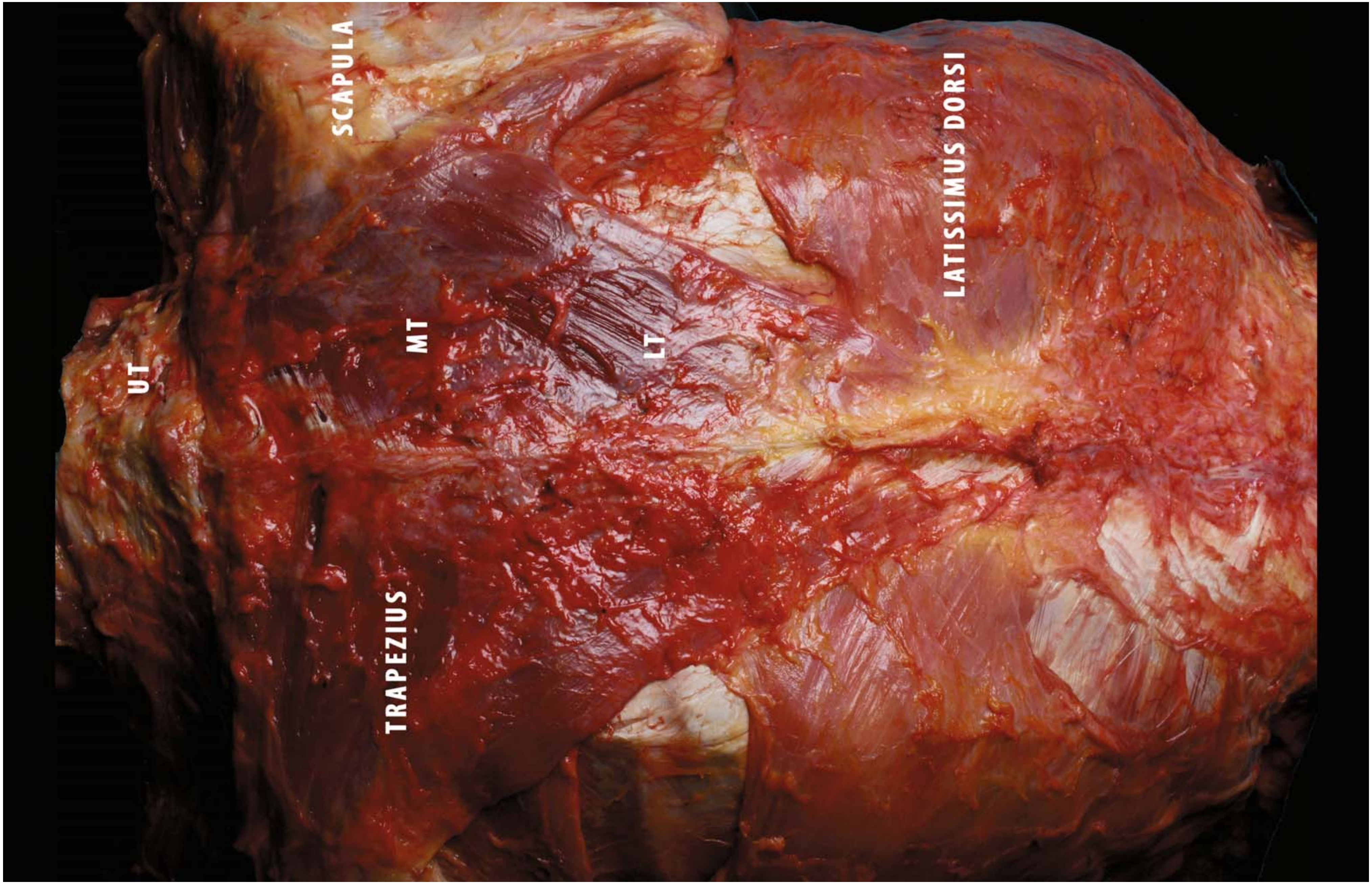
Fig. 1.2. Lateral view of the thorax (right side). This view illustrates the origin of the serratus anterior muscle from the ribs and its insertion to the medial border of the scapula. The inferior angle of the scapula (***)** is the common insertion for different scapulothoracic and glenohumeral muscles (*PEC MIN* pectoralis minor, *SSC* subscapularis muscle, *HH* humeral head, *H* humerus)


PEC MIN
HH
SSC
SERRATUS
ANTERIOR
H
TERES
MAJOR
*

1.1.2 Trapezius Muscle

The trapezius muscle is the largest and most superficial scapulothoracic muscle on the back of the thorax (Fig. 1.3). Many authors have been confused about the anatomical description and functions of this muscle. Little attention is paid to the morphology of the trapezius and its lines of action in biomechanics literature. Its origin comes from the nuchal ligament through the T-12 vertebra. The muscle is subdivided into upper, middle and lower portions. The upper portion originates from the occiput and the nuchal ligament, as far as C-6. Beyond the C-7 level all fascicles are directed to the clavicle. They are attached along the posterior border of the distal third of the bone, as seen in the case of the fascicle from the superior nuchal line. This last assumes the most anterior attachment, followed in sequence by the fascicles from the upper and then the lower half of the nuchal ligament. The fibres arising from the C-6 spinous process insert into the distal corner of the clavicle as far as the acromioclavicular joint. The middle and lower portions originate from the dorsal spines of the C-7 through T-12 vertebra. The lower cervical and upper thorax fibres (C7–T1) insert in the inner border of the acromion (C-7) and the spine of the scapula (T-1). The lower portion of the muscle inserts at the base of the scapular spine. The fascicles from T-2 to T-5 converge in a common aponeurotic tendon attached to the deltoid tubercle of the scapula. Fascicles from T-6 to T-12 insert in the medial border of the deltoid tubercle. The deep surface of the trapezius muscle touches the rhomboid and other muscles; on the back it is covered by fat and skin [20]. The blood supply usually derives from the transverse cervical artery or from the dorsal scapular artery. The accessory spinal nerve (CN XI) provides motor support, with some sensory branches contributed by C-2, C-3 and C-4 [19].

Fig. 1.3. Posterior view of the thorax. This view illustrates the trapezius muscle. The origin comes from the nuchal ligament to T-12. The wide origin of the large muscle is closely related to other muscles on the back of the thorax (*UT* upper trapezius, *MT* middle trapezius, *LT* lower trapezius)


SCAPULA
LATISSIMUS DORSI
UT
MT
LT
TRAPEZIUS

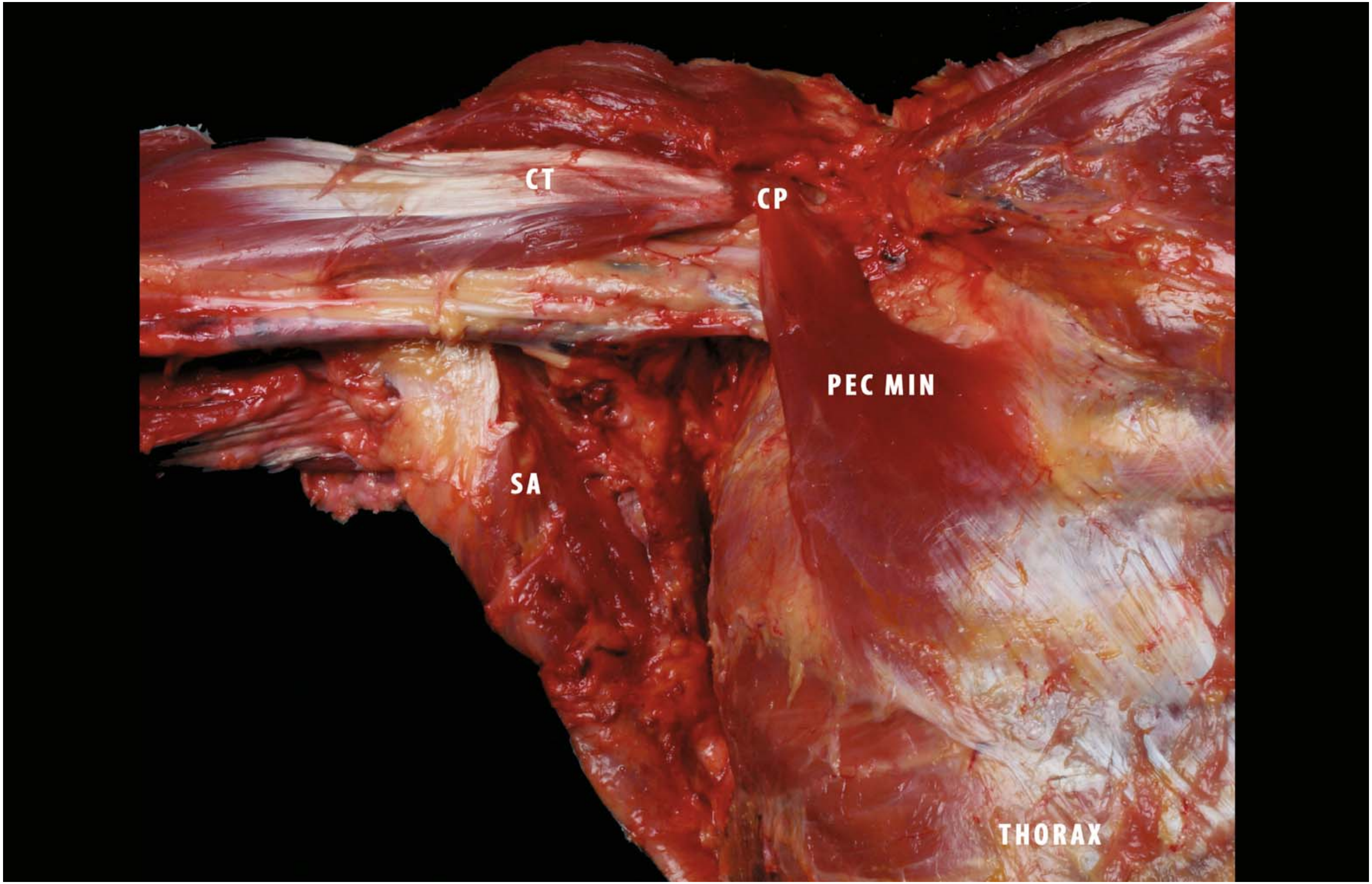
1.1.3 Pectoralis Minor Muscle

The pectoralis minor muscle is triangular. It is positioned under the pectoralis major muscle on each side of the thorax (Fig. 1.4). The origin of the pectoralis minor is at the external surfaces of the third, fourth and fifth ribs, and occasionally the second to sixth ribs. The muscle, running superolaterally, and the tendon insert in the medial and superior surfaces of the coracoid process of the scapula. The fibres of the tendon seem to continue into the coracoglenoid and/or coracohumeral ligaments (see Chapter 4, section 4.2.3). Several authors have reported frequent (15%) aberrant slips of the tendon to the humerus, glenoid, clavicle or scapula. Innervation is from the medial pectoral nerve, which passes through this muscle, which also receives motor supply from the lateral pectoral nerve. The blood supply comes through the pectoral branch of the thoracoacromial artery [19].

1.1.4 Biomechanics and Functional Anatomy

Scapular stabilisation on the thorax involves coupling of the upper and lower fibres of the trapezius muscle with the serratus anterior and pectoralis minor muscles [15]. Elevation of the scapula with arm elevation is accomplished through activation and coupling of the serratus anterior and lower trapezius muscles with the upper trapezius and pectoralis minor muscles [15, 16]. Divisions situated in the lower and in the middle part of the serratus anterior muscle are key contributors to normal and abnormal scapular motion and control [17, 21]. The serratus anterior muscle's insertion into the scapular vertebral border and inferior angle results in larger moment arms for production of scapular upward rotation and posterior tilting than in any of the other muscles linking scapula and thorax [21]. Thus, the serratus anterior muscle has been described as the prime mover of the scapula [20, 21]. This muscle has been historically identified

Fig. 1.4. Anterior view of the thorax (right side). This view illustrates the pectoralis minor muscle after removal of the pectoralis major muscle. The pectoralis minor is a triangular muscle on the deep surface of the pectoralis major. Its insertion is on the coracoid process (*CP*) with other tendons and ligaments (*CT* common tendon, *SA* serratus anterior muscle)

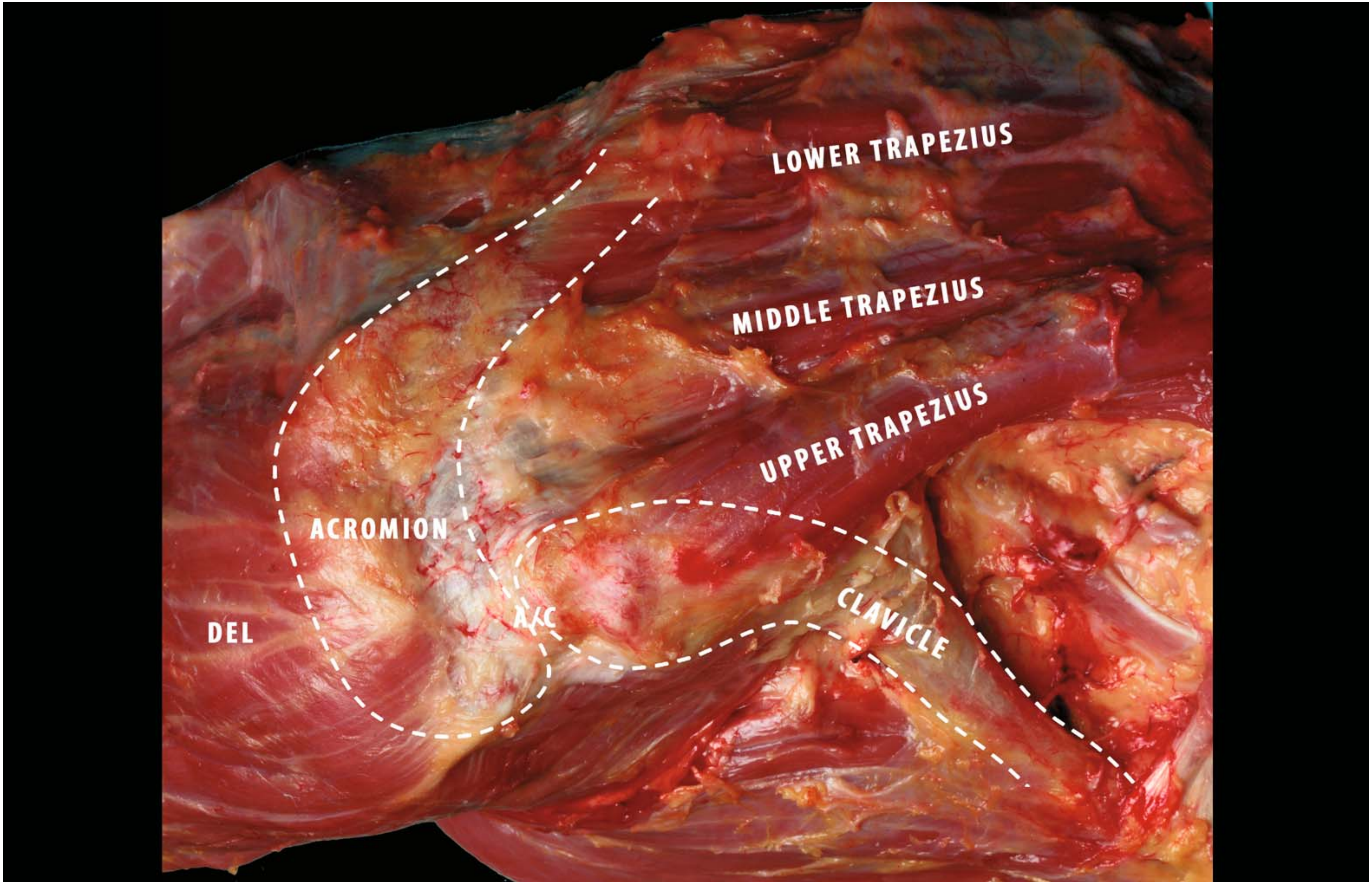

CT
CP
PEC MIN
SA
THORAX

as a protractor of the scapula owing to high EMG activity elicited during various push-up manoeuvres [23, 24]. The serratus anterior is actually multi-faceted, and it contributes to all components of 3D motion of the scapula during arm elevation [2, 25]. Specifically, this muscle can produce upward rotation, posterior tilt and external rotation of the scapula while stabilising the vertebral border and inferior angle of the scapula to the thorax and preventing scapular "winging" [22]. The serratus anterior also has a role as a stabiliser of the scapula. The highest level of serratus anterior activation occurs in both the cocking phase of the throwing motion [25, 26] and the earliest stages of arm elevation [27]. It appears that a prime role of the serratus in these activities is as an external rotator/stabiliser of the scapula in arm motion.

It is generally accepted that the three parts of the trapezius muscle, together with the serratus anterior muscle, are important in so far as they act as a force couple providing movement and dynamic stability of the scapula [16, 17, 28, 29]. However, within this force couple, the upper, middle and lower parts of the trapezius muscle are involved in different ways [20].

As the serratus anterior muscle contracts, its force tends to draw the scapula laterally around the chest wall, but lower fibres of the trapezius muscle, which operate at a constant length to stabilise the rotation axis, resist this displacement. The role of the upper part of the trapezius muscle is uncertain. It is evident from this pattern that the nuchal portion of the trapezius is not involved in elevating the scapula, as its fibres act on the clavicle and not on the scapula. Even so, its fibres are oriented transversely as if drawing the clavicle backwards or medially, but not upwards. In an anatomical study by Johnson et al. [20], the authors suppose that the transverse orientation of the fibres of the trapezius muscle can exert a medially directed moment on the clavicle on this axis, which would draw the lateral end of the clavicle medially and upwards. A consequence of this mechanism is that the sternoclavicular joint must sustain substantial compression loads and permit upward rotation of the scapula (in the same way as a fulcrum mechanism) (Fig. 1.5), enhancing the force of the serratus anterior muscle. The middle trapezius muscle fibres, although strong, lie very close to the rotation axis of the scapula.

Fig. 1.5. Superior view of the shoulder complex (right side). This view illustrates the insertion of the upper trapezius on the posterior border of the third distal of the clavicle. The *dotted line* shows the bony profile of the clavicle and the acromion. Biomechanical function of the upper portion of the trapezius helps to rotate the scapula upwards during arm elevation (*A/C* acromion/clavicular joint, *DEL* deltoid muscle)


LOWER TRAPEZIUS
MIDDLE TRAPEZIUS
UPPER TRAPEZIUS
ACROMION
A/C
CLAVICLE
DEL

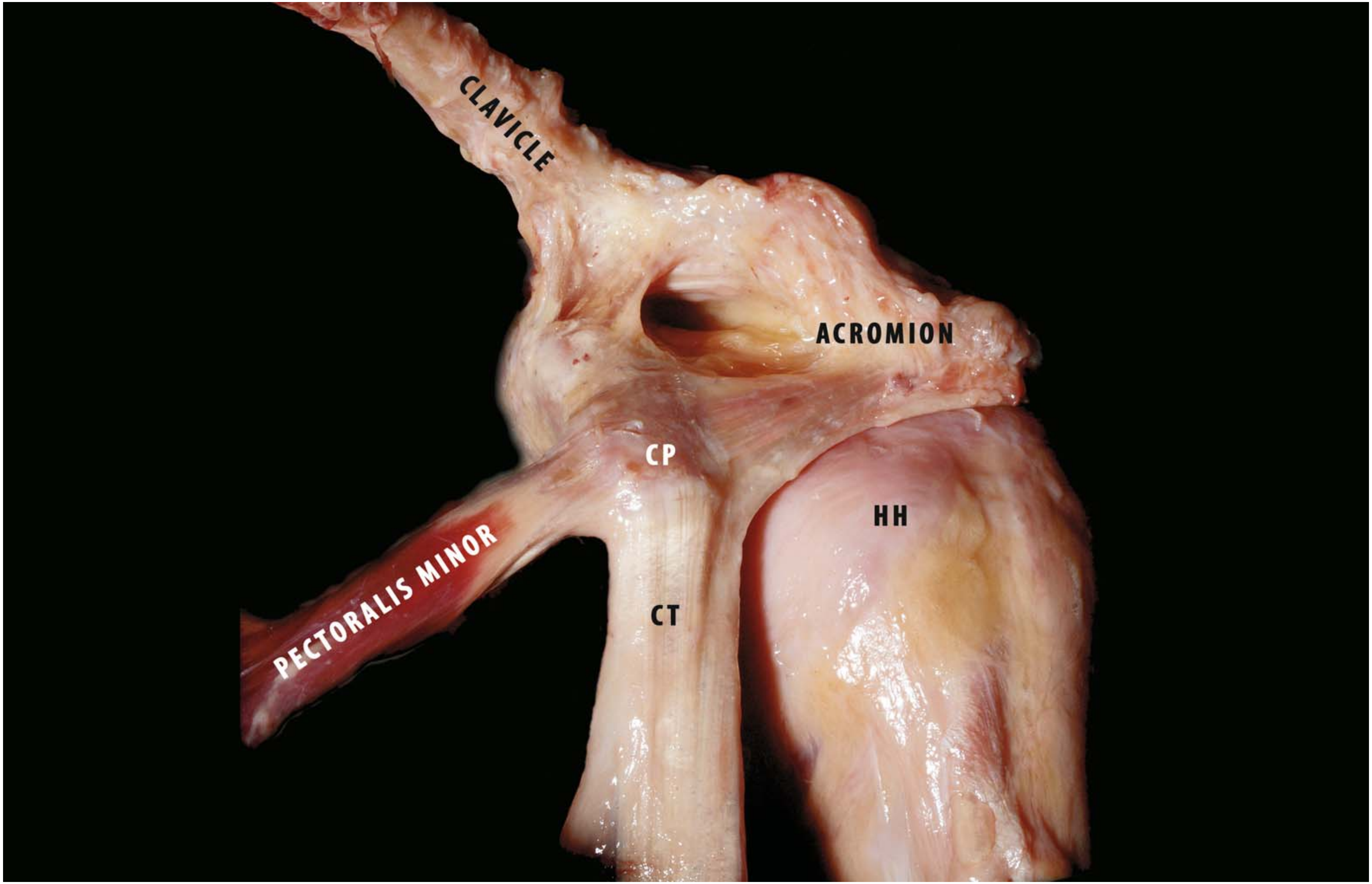
Therefore, their ability to generate an upward rotator moment is compromised by relatively short moment arms. On the basis of their data, several authors have concluded that the middle and lower fibres maintain horizontal and vertical equilibrium of the scapula rather than generating net torque. This stabilising role of the middle and lower trapezius muscle parts has also been suggested by several authors [29, 30–32].

The pectoralis minor muscle has an important role, in conjunction with the serratus anterior and trapezius muscles, in stability and motion of the scapula. The force couple created from three muscles is important to obtain the correct orientation of the scapula on the thoracic wall.

The main action of the pectoralis minor is the protraction of the scapula around the thorax. It works in conjunction with the serratus anterior muscle to keep the scapula close to the thorax as the latter draws it forward. Normally the pectoralis minor muscle elongates during arm elevation, allowing the scapula to rotate upwards and outwards and tilt backwards [33, 34] (Fig. 1.6). Optimal functioning of the stabilising muscles depends not only on the force production of these muscles in relation to synergists, antagonists, and prime movers of the joint, but also on the correct timing of muscle activation [32]. The scapular position that allows optimal muscle activation to occur is the retraction and external rotation. Scapular retraction is an essential and integral part of normal scapulohumeral rhythm in coupled shoulder motions and functions [14, 34, 35]. It results from synergistic muscle activation in patterns from the hip and trunk through the scapula to the arm, which then facilitates maximal muscle activation of the muscles attached to the scapula [1, 36]. The retracted scapula can then act as a stable base for the origins of all the rotator cuff muscles [1, 37].

Protraction has been shown to limit both muscle strength and motion [38, 39] Kebatse et al. [38] have shown that excessive scapular protraction, which is frequently seen in injured patients as part of scapular dyskinesis, decreases maximum rotator cuff activation by 23%. Smith et al. [40] report that maximal rotator cuff strength is achieved in association with a position of "neutral scapular protraction/retraction" and that positions of excessive protraction or retraction demonstrate decreased rotator cuff abduction strength. Kibler et al. [37] have shown that the strength of the supraspinatus increases by up to 24% in a position of scapular retraction in patients with shoulder pain.

Fig. 1.6. Anterolateral view of the left shoulder. View of insertion of the pectoralis minor muscle on the coracoid process (*CP*) on the anterior aspect of the shoulder. The pectoralis minor pulls the scapula in the anterior direction. During arm elevation the muscle is relaxed to permit correct positioning of the scapula around the chest wall (*CT* common tendon, *HH* humeral head)


CLAVICLE
ACROMION
CP
HH
PECTORALIS MINOR
CT