FIG.Stokdijk and colleagues have shown dif- fering ratios of external rotation to humeral elevation based on the specific plane of elevation.178 Strict frontal plane abduction had a higher ratio (i.e., greater external rotation per degree of abduction) than abduction in the scapular plane.These kine- matics (1) position the scapula relatively flush with the curvature of the thorax, (2) orient the glenoid fossa in the plane of the intended elevation of the arm (i.e., scapular, frontal, or sagittal), and (3) move the coracoacromial arch away from the advancing (abducting) humeral head--a strategy that likely reduces damag- ing impingement of structures within the subacromial space.94,118?The fifth kinematic principle of abduction states that the clavicle rotates posteriorly around its own long axis.Of interest, a similar in vivo study using motion sensors implanted into the bones of subjects diagnosed with subacromial impingement syndrome showed reduced posterior rotation of the clavicle throughout abduction in the scapular plane.106?The mechanism that drives the posterior rotation of the clavicle is based on a combination of interesting multijoint kinematics and forces transferred from muscle to ligaments.84,106,146 Fig.and/or plane of abduction studied as well as dissimilar experimental methodology.*?In summary, varying amounts of posterior tilting and net exter- nal rotation movements of the upwardly rotating scapula serve several useful functions during shoulder abduction.It has been hypoth- esized that posterior rotation of the clavicle is mechanically coupled with posterior tilting of the AC joint--motions that are essential to full-range shoulder abduction.112?The sixth kinematic principle of abduction states that the humerus naturally externally rotates during shoulder abduction (see Fig.5.36, main illustration).84,112,118,192 In vivo studies using motion sensors implanted into the bones of the healthy shoulder show that pos- terior rotation at the SC joint is the most predominant motion of the clavicle during scapular plane abduction.118 Data consis- tently show that most of the rotation occurs in the middle and late ranges of shoulder abduction.5.36, main illustration).118 The external rotation of the shoulder, which is relatively easy to verify clinically, allows the greater tubercle of the humerus to pass posterior to the acromion process and therefore avoid jamming against the contents within the subacromial space.The tension created within the stretched ligament rotates the crank-shaped clavicle in a posterior direc- tion, allowing the AC joint to allow full upward rotation.At the early phases of shoulder abduction, the scapula begins?*References 24, 65, 68, 69, 116, 118, 130?to upwardly rotate at the AC joint, stretching the relatively stiff coracoclavicular ligament (see Fig.The amount of external rotation that accompanies full active shoulder abduction likely falls within the 25-50-degree range, with the majority occurring before 70-80 degrees of abduction.118,126?The six kinematic principles associated with the fully abducting shoulder are summarized in Box 5.1.(A) At rest in the anatomic position, the acromioclavicular (AC) and sternoclavicular (SC) joints are shown with the coracoclavicular ligament represented by a slackened rope.This rotation places the clavicular attachment of the coracoclavicular ligament closer to the coracoid process, unloading the ligament slightly and permitting the scapula to continue its final degrees of upward rotation.Tension within the stretched ligament is transferred to the conoid tubercle region of the clavicle, a point posterior to the bone's longitudinal axis.(B) As the serratus anterior muscle rotates the scapula upward, the coracoclavicular ligament is drawn taut.5.38A shows in a very highly diagrammatic fashion the relatively slack- ened coracoclavicular ligament while at rest in the anatomic posi- tion.Realize that more principles could have been defined,

but these six provide a useful guideline for organizing and highlighting the kinematics across the multiple joints of the shoulder.Studies report 20 to 35 degrees of poste- rior clavicular rotation during abduction (see Fig.The inability of this ligament to significantly elongate restricts further upward rotation at this joint.This motion was described earlier in this chapter as one of the primary SC joint motions (see Fig.The application of this force rotates the crank-shaped clavicle posteriorly.The actual magnitudes and pattern of motion associated with each principle will certainly vary for any individual person or study.5.13).5.38B).