The Scapula is a Sesamoid Bone

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Letter to the editor:

Gupta and Helm (2004) use finite element modeling to estimate load transfer to and across the scapula. But the finite element model must accurately predict the physical phenomenon it was designed to replicate. This is not the case in the Gupta-Helm model.

In their model, the scapularthoracic gliding plane (STGP) is perceived to experience considerable joint reactive forces, localized at the medial border, and that would exert compression on the undersurface of the scapula and the underlying ribs. However, the STGP joint is oriented towards the frontal or y,x plane and essentially loosely 'floats' on the chest wall. In a live subject, when the muscles are relaxed, it is possible to manually lift the scapula 1-2 cms off the chest and rotate it 5-10 degrees clockwise and counterclockwise. With the arm in an abducted position, any compression forces coming from the arm through the glenoid would be directed through the scapula essentially parallel to the plane of the STGP joint and would cause the scapula to slide off the chest wall and be projected in the direction posterior to the vertebral spine. The muscle that stops this medial migration is the serratus anterior (SA) that takes its origin from the more lateral surfaces of the ribs and interposes itself between the ribs and subscapularis and scapula and attaches to the scapula's medial border. Injury to the long thoracic nerve, not a rare injury that I have observed in patients of mine several times, causes paralysis of the SA muscle. This injury allows the medial border of the scapula to pull away from the chest wall or 'wing' and it is clinically apparent what direction the scapula would take if it were not functioning. Surprisingly, there may be some weakness but, otherwise, little loss of function when this injury occurs. It is clear from these observations that, unlike the mathematical model, in real life the SA does not force the medial edge of the scapula into the ribs, nor is it necessary for a fulcrum to exist between the scapula and the chest wall for the shoulder to function. Gupta and Helms perceive that the entire medial border of the scapula press against the ribs and is held there by the upper part of the

m. rhomboidius and the SA, but the rhomboids cannot resist posterior-medial migration of the scapula, which is the true direction of force of the abducted arm. There are no other muscles of consequence that could help. The SA could not possibly contract strongly enough to crush itself between the scapula and the ribs. The medal border of the scapula is tethered to the spine and thorax by its attached muscles but they can only keep it from flying into space and not compress the underlying ribs. As there are no external forces compressing the scapula to the thorax and the scapula is held by the tension of the SA and other muscles, there is no joint reactive compression force at the STGP. That's a good thing, as compression of the chest wall would restrict breathing. It is clearly a design advantage that restricts compression of the chest wall and it is reasonable to think that Mother Nature would favor this arrangement.

There are also problems calculating loads at the glenohumeral joint (GH). The GH is a small, shallow joint that is an essentially frictionless inclined plane and, therefore, can only transfer normal forces. In the fully abducted position, it is possible to conceive that the humeral head compresses directly into the glenoid normal to the joint surface. However, in many positions of normal function, in is mathematically impossible for any compressive load to cross the GH, as when one is doing push-ups, jabbing a punch, swinging a hammer, hand walking on parallel bars or swinging from rings or a tree limb. In that position, the joint is just about vertical and all the forces are directed parallel to the surface of the joint. As a frictionless inclined plane, it is incapable of transferring compression loads unless they are normal to the surface of the glenoid. The restricting joint capsule and other soft tissues can only pull on the scapula and that would separate it from the chest wall. Thinking about loads on the scapula as a free body problem does not reflect the realities of the anatomy and various forces and loads on the scapula. In order to keep the scapula from sliding off the chest wall, under any load, multiple muscles that may cross several joints must be active at the same time.

A model that is more consistent with the anatomy of the shoulder has been previously proposed (Levin, 1997). It is based on a concept that the scapula is, in reality, a sesamoid bone. It functions much like the hub of a bicycle wheel, with the wire spokes of the wheel replaced by a tension network of muscles and fascia. In a scapula-hub model, there is no fulcrum since the scapula is enmeshed in a spider web of muscles. Without a fulcrum, there are no levers. Without levers, there are only compression and tension forces. Loads are transmitted to the axial skeleton by tension just as in a bicycle wheel, where the compression load of the rim and hub interface through the tension spokes. The hub model of the scapula would function equally well for quadrupeds or bipeds with the arm in any position and the forces applied from any direction, not just in the abducted arm. {mosimage}

Gupta S., van der Helm, F.C.T., 2004. Load transfer across the scapula during humeral abduction. J of biomech 37, 1001-1009.

Levin, S. M. 1997. Putting the shoulder to the wheel: a new biomechanical model for the shoulder girdle. Biomed Sci Instrum 33, 412-417.