Clinical Notes

Interpretation of modified FORCE CLOSURE model (Mark Comerford MCSP B.Phty MAPA)

The model of form & force closure as promoted by Vleeming et al (1993, 1995a&b, 1997) has influenced analysis and interpretation of stability function in the movement system. This model based largely on biomechanical force potential. This model suggests that a muscle can contribute best to joint and movement stability if it has the potential to deliver more force.

- Form closure: The shape, structure or form of a joint provides the stability.
- Force closure: Compressive forces and congruency between two surfaces of a joint provide the friction to enhance stability. (Vleeming et al. 1995, 1997, Don Tigny 1993)

This model can be further developed to take into consideration many recent developments of joint and movement stability. Lee (2001) has started to address some of these recent developments. This article attempts to further develop concepts of motor control and low threshold recruitment of local and global muscle stability systems.

Optimising form or force closure enhances the stability and load bearing ability of a joint complex. Minimising form or force closure reduces stability and ‘de-stabilises’ the load bearing ability, allowing for increased movement potential.

- Form closure is achieved passively at end range (osteo-ligamentous restraints) or by the shape of the supporting surface. The centre of mass of one bone is passively supported over the horizontal aspect of the body of the adjacent bone e.g. vertebral body on disc and body below, the femur on the tibial plateau in quiet standing.

- Force closure is achieved by the influence of an external force. There are four primary mechanisms of force closure:

(i) Segmental Stiffness

(ii) Compression Force Closure (low threshold & high threshold systems)
(iii) Positional Force Closure

(iv) Torsion Control (low threshold & high threshold systems)

These depend upon the activation of muscles across the joint system to: (i) generate sufficient segmental stiffness with low threshold recruitment of the local stability muscles to control abnormal inter-segmental motion, (ii) Increase compression across the joint either directly with muscles that cross the joint or indirectly with muscles located either side of the joint but having a mechanical connection, (iii) Produce close pack articular position or any other position that is intrinsically stable and (iv). Provide co-ordinated activation of one-joint muscles above and below a motion segment that eccentrically control rotational or torsional strain.

SEGMENTAL STIFFNESS

The local stabiliser muscles are not particularly force efficient. Nor are they mechanically advantaged to produce or control range of motion even if the range is quite small. Likewise, they are not direction specific and are not effective in controlling directional load even rotation. The primary role of the local stabilisers is to maintain low force continuous activity in all positions of joint range and in all directions of joint motion. This activity increases local muscle stiffness at a segmental level to control excessive physiological and translational motion, especially in the neutral joint position where passive support from the ligaments and capsule is minimal. Their activity often increases in an anticipatory action prior to load or movement, thus providing joint protection and support. Richardson et al (2002) have demonstrated that specific low threshold recruitment of transversus abdominis is more effective at stiffening the sacro-iliac joint that bracing with the global trunk muscles.

COMPRESSIVE FORCE CLOSURE

Any muscle that directly crosses a joint provides direct mechanical compression. Some muscles contribute to joint compression even though the do not cross the joint itself. Fascial and ligamentous structures can provide a direct mechanical connection between muscles that act either side of a joint and so that co-contraction of these muscles increases compression across the joint surface. Active or passive tensioning of these fascias and ligaments can increase compressive forces across the joint. This compression (force closure) can be applied longitudinally or transversely / contralaterally. Both local and global muscles can contribute to compressive force closure though global muscles are likely to be more force efficient. Also, a muscle that directly crosses a joint is likely to be more efficient than muscles that rely on a mechanical linkage and co-ordinated co-contraction. It is postulated that compressive force closure can be subdivided into low threshold (normal function) and high threshold (loaded function) systems. Consider the sacro-iliac joint with the posterior oblique sling as suggested by Vleeming et al (1995a). They suggest that co-activation of latissimus dorsi and the contra-lateral superficial gluteus maximus with the superficial layer of the thoraco-lumbar fascia acting as a mechanical linkage will increase compressive force closure of the sacro-iliac joint (gluteal side). This is obviously advantageous under high load function such as pushing, pulling, throwing and running when there is significant co-contraction of these two muscles. However, the relevance of
training these two muscles to stabilise the sacro-iliac joint has to be questioned when the sacro-iliac joint is stressed by low load normal functional activities such as normal walking, prolonged standing or sitting and lifting the unloaded arms overhead. In these normal low load functions there is minimal co-activation of latissimus dorsi and the superficial gluteus maximus. It would be more appropriate to recruit two muscles that are normally recruited in co-activation patterns for these low load functional activities. Such muscles do exist for the sacro-iliac joint. The posterior fibres of the internal obliquus link to the deep fibres of contra-lateral gluteus maximus via the middle layer of the thoraco-lumbar fascia with the same posterior oblique sling fibre orientation. Thus, there seem to be two sets of compressive force closure systems for the sacro-iliac joint. There is a high threshold (loaded function) system and a low threshold (normal function) system that can cope with the varying and diverse functional demands of a joint system.

POSITIONAL FORCE CLOSURE

Although all joints benefit passively from increased form closure at end range positions, some joint positions provide optimal congruency of joint surfaces along with increased tension in the passive ligamentous and capsular restraints than is provided by other positions. This position is referred to by Mennell (1972, 1992), Kaltenborn (1980), Evans (1988) and Magee (1998) as the ‘close packed’ or synarthrodal position of a joint. In its ‘close packed’ position a joint has maximal resistance to distraction and translation / shear and demonstrated greater load bearing stability. When muscle action is recruited to actively position and maintain a joint in its ‘close packed’ position then this is another process of force closure in action. Likewise direct muscle action can be used to position a joint in a position of diminished load bearing stability. This is a position of minimal congruency between the articular surfaces, with greatest potential for separation of joint surfaces and minimal resistance to translation / shear. The sacro-iliac joint is a good example of the influence of positional closure. The ‘close packed’ position is posterior rotation of the innominate. This can be actively achieved by contraction of the gluteal, abdominal, psoas major, and hamstring muscles to enhance load-bearing stability. Conversely, movement towards anterior rotation of the innominate is the ‘loose packed’ position and this can actively be produced by contraction of the iliocostalis, tensor fascia latae and rectus femoris muscles to diminish load-bearing stability.

TORSIONAL FORCE CLOSURE

The concept of torsional force closure relates to motor control of rotational or twisting forces around a joint complex. It is especially relevant for the pelvic and shoulder girdles linking the limbs to the trunk. In all functional movements there is a rotational interface between the rotating limbs and the trunk. Rotational forces and momentum are decelerated and controlled by the rotational global stabilisers. There are rotation control (global stabiliser) muscles between the trunk and the pelvis (oblique abdominals, superficial multifidus and anterior fasiculus of psoas) and between the trunk and the scapula (serratus anterior and trapezius). Likewise there are rotational control (global stabiliser) muscles between the lower limb and the pelvis (the three gluteals, iliacus, stability adductors and the deep hip intrinsics) and between the upper limb and the scapula (subscapularis, teres major & minor, infraspinatus and the deltoids). Independent (or isolated) strength or force output from any one of these groups is not adequate to decelerate rotation momentum and control strain at the pelvic or shoulder girdle in functional movements. Rather, it is
the efficient co-activation of rotation control muscles (with co-ordinated recruitment) either side of the pelvic and shoulder girdles that protects and controls the interface between the limbs and trunk.

As with compressive force closure there appears to be a low threshold (normal function) and high threshold (loaded function) system acting within torsion control. The low threshold torsion control system is related to the global stabiliser muscles listed above. The high threshold torsion control system involves the global mobiliser muscles that produce large range and high force rotation or side bending (pectoralis major, rhomboids, latissimus dorsi, iliocostalis, quadratus lumborum, tensor fascia latae piriformis and gracillis) for high load acceleration and deceleration of the limbs and hard change of direction.

**FORCE CLOSURE MECHANISMS: LOW LOAD ‘NORMAL’ FUNCTIONS**

This modified model of force closure mechanisms attempts to take into consideration the inter-relationship between biomechanical force potential and neuro-physiological recruitment strategies that influence normal low load function, which makes up approximately 85% of muscle activity. It tries to explain the relationship between local and global muscle function in maintaining stability for normal activity.

**References**


Evans P 1988 Ligaments, joint surfaces, conjunct rotation and close pack. Physiotherapy 74:105-114

Kaktenborn F M 1980 Mobilisation of the extremity joints: Examination and basic treatment techniques. Olaf Norlis Bokhandel, Oslo, Norway


Magee DJ 1992 Orthopedic physical assessment. 2nd edition. WB Saunders

Mennell J 1992 The Musculoskeletal System: Differential Diagnosis from Symptoms


