2. The Integrated Pelvis

Throughout our daily lives, humans transfer over 60% of bodyweight from the spine, across the pelvic articulations and hips to the lower limbs, during all weight bearing activities. In order to transfer these loads efficiently, motion and stability of the lumbar and pelvic articulations must be maintained at all times. Optimal stabilisation of the lumbo- pelvic region requires the integrated function of three systems:

1. Passive osteo-ligamentous system (form closure)
2. Active myo-fascial system (force closure)
3. Neural system (motor control) (Lee, 1999; Panjabi, 1992a)

In the lumbar spine, passive structures assisting load transfer and stability include the vertebral body, intervertebral disc, shape of the zygapophyseal joints, and ligaments (ligamentum flavum, supraspinous & interspinous ligaments). However, the components of the passive system provide little stability within the neutral zone of intersegmental motion (Panjabi, 1992a).

The pubic symphysis is a planar cartilaginous joint interposed with a fibrocartilaginous disc. It is supported by the superior pubic and inferior (arcuate) ligaments. The pubic symphysis is considered to be the most stable joint in the pelvis, and moves in reaction to forces placed across the joint rather than by direct muscle action. However, muscles attaching close to the pubic symphysis still have their affect on the joint and must be considered when there is an injury. Vertical translation (1-3mm) occurs during single leg support. Vertical shear forces tend to be increased, however, in the presence of stiffness at the hip joints (Williams, 1978). A small amount of anterior & posterior rotation occurs at the pubic symphysis during ambulation.

The pubic symphysis is stabilized superiorly by transversus abdominus, and inferiorly by pubococcygeus. Other muscles to consider in relation to the pubic symphysis are: rectus abdominus with its attachment from the pubic tubercle along the superior ramus, pyramidalis' attachment close to the pubic tubercle, pectineus, and the conjoint tendon are all in close relation to the pubic symphysis. Inferiorly, adductor longus originates from a flat tendon attaching to the pubic body. Gracilis and adductor brevis originate from the inferior pubic body and the inferior pubic ramus, and adductor magnus attaches to the inferior pubic and ischeal ramus plus the ischeal tuberosity. It is also interesting to note that fascial connections between the adductors and contralateral obliquus abdominis internus cross the pubic symphysis.

Other structures to consider in relation to anterior pelvic anatomy and pain/ injury in this region are:

1. psoas major- the lumbar plexus lies within the body of psoas major. Branches from the lumbar plexus such as ilioinguinal n., genitofemoral n., lateral cutaneous n. of the thigh, and obturator nerve all pass between or through fascicles of psoas major. Obturator nerve supplies the adductor group, and the anterior hip capsule. The femoral nerve (L2-L4 dorsal rami) descends within the substance of psoas, emerges at its lower lateral border, passes between it and iliacus, then behind the inguinal ligament and supplies the skin of the anterior thigh region.

2. sartorius muscle- is pierced by lateral femoral cutaneous nerve and is fascially connected to the inguinal ligament.

The Sacroiliac Joint (SIJ) is classified as a diarthroidal joint (i.e. synovial) surrounded anteriorly and posteriorly by a joint capsule with inner synovial membranes and hyaline cartilage lining both joint surfaces (only a thin layer of superficial hyaline cartilage lines the iliac surface). The SIJ is roughly L- shaped with a short cephalic arm and longer caudal arm that intersect at approximately S2 level.

The SIJ has adapted for transfer of large loads between the spine and pelvis during bipedal activity. Its articular surfaces are relatively flat and are aligned close to the vertical plane. Flat joint surfaces assist the transfer of loads, however SIJ alignment leaves the joint vulnerable to vertical shear loads (Snijders, Vleeming, & Stoeckart, 1993b). The development of complimentary ridges and grooves during puberty assists stability (Vleeming et al, 1990a), however motion is still possible at the SIJ, and occurs to assist shock absorption and load transfer. The pelvis is most stable for load transference when the innominate is posteriorly rotated, relative to sacral nutation; the closed pack or self-braced position (Hungerford & Gilleard, 2004; Sturesson et al, 1989).

Soft tissue components of SIJ structure augment joint stability while still allowing small amounts of movement to occur.

1. ligaments:- interosseous lig. & posterior SI lig.- lie directly posterior to the SIJ and form a strong link between the sacrum and ilium. They function to limit sacral nutation and inferior shear of the sacrum. As they tighten with nutation, these ligaments draw the PSIS's closer together. It is interesting to note that the interosseous lig. has a high elastin component that increases joint compression while allowing small amounts of movement to occur between joint surfaces.

- long dorsal SI ligament- from PSIS to S2,S3 sacral crests. This ligament limits sacral counternutation, and is commonly a source of pain, just below the PSIS.

- sacrotuberous lig.- attaches from the ischeal tuberosity to the inferior lateral angle (ILA) of the sacrum. Strong fascial connections exist between sacrotuberous lig. and the lateral portion of biceps femoris insertion onto the ischeal tuberosity. Often, biceps femoris attaches directly onto this ligament. Sacrotuberous lig. also has strong connections with the posterior layer of thoracolumbar fascia, and muscular attachments of gluteus maximus and piriformis into its upper portion. The sacrotuberous lig. limits sacral nutation, with assistance from sacrospinous ligament. Contraction of biceps femoris, gluteus maximus and piriformis may increase sacrotuberous ligament tension.

2. posterior layer of thoracolumbar fascia-

the T-L fascia has been considered in relation to its affect on the lumbar spine but its ability to increase force closure of the SIJ was only recently described by Vleeming et al (1995).T-L fascia attaches onto the sacrum and ilium. Fascial connections between gluteus maximus and contralateral latissimus dorsi via the T-L fascia are directed at 90º to the joint surface and so their combined action increase stabilisation of the joint. Connections with internal oblique and transversus abdominis, multifidus, erector spinae, and biceps femoris via sacrotuberous ligament, also affect force closure.

Stabilisation of the lumbo-pelvic region.

Stabilisation of the lumbo-pelvic region is maintained by activation of specific muscles, and the subsequent generation of forces onto interconnecting fascia and ligaments to produce lateral compressive forces that approximate the joint surfaces (force closure) (Hodges, 1998a; Vleeming et al, 1995a; Vleeming et al, 1995b).

Local or core muscles: Transverse abdominis (TrA), Lumbar multifidus, Diaphragm, Pelvic floor (pubococcygeus)

These muscles are optimally activated prior to motion, and respond with a pattern of tonic activity (postural stabilizers) (Hodges & Gandevia, 2000b; Hodges & Richardson, 1997a; Sapsford et al., 2001).

In the lumbar spine, feedforward activation of TrA and multifidus, tensions the middle and posterior layers of the thoraco-lumbar (T-L) fascia, increases intra-abdominal pressure (IAP), and increases tension on supraspinous and interspinous ligaments. Segmental stability and control of intersegmental motion is therefore increased (Richardson, et al, 1999). Co-contraction of the diaphragm and pubococcygeus assists maintenance of IAP. The inner unit muscles also assist stabilisation of the SIJ via connections to T-L fascia, sacrotuberous, and posterior SI ligaments.

Global muscles: include muscles that direct our posture e.g thorax over pelvis and pelvis onto hip, as well as muscles that create movement

-gluteus medius, minimus, gluteus maximus, adductors and hamstrings

- erector spinae, quadratus lumborum, biceps femoris

-anterior: obliquus internus abdominis, obliquus externus abominis

-piriformis, deep hip external rotators (obturator internus and externus, superior and inferior gemelli)

<u>Neural System:</u>

Optimal motor performance requires co-ordinated muscle action to maintain stability and effortless transfer of loads throughout motion. The nervous system maintains control of lumbo-pelvic stability via both feedforward and feedback mechanisms, plus modulation of muscle stiffness around the neutral zone to limit intersegmental motion. As previously mentioned, the inner unit muscles tend to be activated at a sub-maximal level, prior to onset of motion.

Lumbo-pelvic Dysfunction

Lumbo-pelvic dysfunction occurs in the presence of altered joint biomechanics, and/ or altered muscle activation and recruitment patterns.

Altered recruitment patterns of TrA, lumbar multifidus, and the pelvic floor have been shown to occur in patients with lumbar or pelvic pain (Avery et al, 2000; Hodges, 2000a; Hungerford et al, 2003; O'Sullivan et al., 1997c). Increased fatiguability and segmental wasting of multifidus also occur in the presence of low back pain (Hides et al, 1994; Roy, DeLuca, & Casavant, 1989). Pain inhibition and altered control of lumbo-pelvic posture may create imbalances in activation patterns of global muscles such as obliquus internus, gluteus maximus and medius (Kankaanpaa, et al, 1998; O'Sullivan et al., 1997c), and substitution with rectus abdomis, biceps femoris, iliopsoas, TFL, or adductor activity (Hungerford et al, 2003).

Treatment of lumbo-pelvic dysfunction requires a multifaceted approach including

1. Biomechanical assessment of joint motion at the lumbar spine, pelvis, and hips. This includes assessment for hypomobility and segmental hypermobility

2. Assessment of patients ability to control segmental motion, and load transfer through the lumbar spine & pelvis, plus postural assessment during functional activities and sports / employment specific tasks

3. Assess for neural deficits, neural mobility, disc pathology

4. Treatment of biomechanical joint dysfunctions- lumbar spine, pelvis, and hips

5. Specific retraining of muscle action and motor control in the lumbo-pelvic region, and flexibility of the lower limbs and trunk

Intra-pelvic motion

The physiological patterns of intra-pelvic motion may be described in relation to either the sacrum or innominate:

innominate movements: i.anterior / posterior rotation

ii. side flexion & contralateral rotation

sacral movements: i. nutation /counternutation (coronal axis- 2-6º)

ii. rotation & contralateral side flexion) = sacral torsion

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