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CLINICAL AND RESEARCH REVIEW

'The core': Understanding it, and retraining its dysfunction

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Summary "Core stability training" is popular in both the therapeutic and fitness industries but what is actually meant and understood by this concept? And does everyone need the same training approach?

This paper examines the landscape of 'the core' and its control from both a clinical and research perspective. It attempts a comprehensive review of its healthy functional role and how this is commonly changed in people with spinal and pelvic girdle pain syndromes.

The common clinically observable and palpable patterns of functional and structural change associated with 'problems with the core' have been relatively little described.

This paper endeavors to do so, introducing a variant paradigm aimed at promoting the understanding and management of these altered patterns of 'core control'.

Clinically, two basic subgroups emerge. In light of these, the predictable difficulties that each group finds in establishing the important fundamental elements of spino-pelvic 'core control' and how to best retrain these, are highlighted.

The integrated model presented is applicable for practitioners re-educating movement in physiotherapy, rehabilitation, Pilates, Yoga or injury prevention within the fitness industry in general.

Introduction

Despite a lot of research around the subject, there is apparent confusion in understanding what goes wrong with 'the core' and how to properly retrain it. The noted researcher, McGill (2009) opines: "There's so much mythology out there about the core. The idea has reached trainers and through them the public that the core means only the abs. There's no science behind that".

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'Core confusion' and/or reductionism of 'core' as synonymous with the abdominals and by association, the 'need to strengthen them' utilizing 'high load' (strength/effort) training starts to permeate research design and outcomes (George et al., 2011; Escamilla et al., 2010). The misunderstanding becomes further entrenched.

Most people with spino-pelvic pain syndromes generally have relatively low level function and *cannot organize the basic elements of 'core control'*. Subjecting them to individual muscle group and 'high load' training strategies is likely to further imprint perturbed motor patterns and in many, symptom development or exacerbation.

Debate around 'core stability' has begun to surface (McNeill, 2010), questioning the concept and the real value of 'training the core' (Allison and Morris, 2008; Allison et al., 2008; Lederman, 2010).

A historical perspective on 'core'

In spite of all the interest in 'the core' it is difficult to find a succinct definition of it.

Long before 'the core' became fashionable, Ida Rolf conceptualized the myofascial system as 'intrinsic' and 'extrinsic'. The intrinsic are the 'core', inner 'being' muscles. The extrinsic are the 'sleeve' — the large/superficial 'doing' muscles (Linn, 2004). She saw that inappropriate substitution by the 'extrinsics' for the 'intrinsics' — "living in their extrinsics", was a sign of somatic immaturity or dysfunction (Smith, 2008). These are useful concepts to keep in mind.

The concept of 'core stability' probably emanated from Australian research into postural control in both healthy and chronic low back pain (CLBP) populations. They were interested in the role of the motor system — how the nervous system organizes the appropriate responses to support the spine, give us the postural control to counteract gravity and balance while at the same time, also co-coordinating important functions such as breathing and continence. The evidence suggests that when spinal pain is present, the strategies used by the central nervous system may be altered (Hodges, 1999, 2000, 2001). Much of their research involved studying the feedforward anticipatory role played by the intra-abdominal pressure (IAP) *mechanism*, an important aspect of the antigravity postural control and spinal stabilization system. They studied the roles of various muscles contributing to a ***synergy of muscles*** responsible for generating intra-abdominal pressure (IAP) — transversus abdominis, the diaphragm, the pelvic floor muscles (PFM) and lumbar multifidus.

Hence it is appropriate to adopt the term '**stabilization synergy**'. This affords 'intrinsic' *control from the inside* — the 'core' of our being.

These researchers found that in healthy populations the individual elements of the 'stabilization synergy' *spontaneously **co-activate** in advance* of limb movement: — transversus abdominis (Hodges and Richardson, 1996, 1997); the diaphragm (Hodges et al., 1997a; Hodges and Gandevia, 2000a,b); the pelvic floor (Hodges et al., 2007; Smith et al., 2007a); deep fibres of lumbar multifidus (Moseley et al., 2002). Yet, in CLBP and chronic pelvic girdle pain (CPGP), the pre-activation response of ***all*** these muscles was variably ***delayed and/or diminished*** during movement (Hodges and Richardson, 1998, 1999a; Hungerford et al., 2003; O'Sullivan et al., 2002a).

However, their findings have been somewhat misinterpreted, such that transversus abdominis has been singled out as '*the* core muscle' — transversus and 'core' have become inextricably linked. This myth-conception is propagated as the panacea for just about everything from helping back pain, enhancing performance, to improving your shape. Transversus abdominis dysfunction is only a part of the problem.

Joseph Pilates work has become linked with 'the core' although he didn't use the term. His interest was "physical fitness and the complete coordination of body mind and spirit — good posture, flexibility and vitality" (Pilates and Miller, 1945). He worked with the physically elite — gymnasts, dancers and circus performers, and many of his exercises are 'high load' strengthening with a strong focus on activating the abdominals (into lumbar flexion) and gluteals with the breath.

Many of the moves are difficult to perform properly and also risk provoking lumbo-pelvic pain symptoms e.g. 'The Roll up', 'The Teaser'.

Later disciples of his method use the term 'the powerhouse' "… *to describe the collective muscles of your abdominals, gluteals (buttock muscles) and lower back musculature. We define the powerhouse as the centre of strength and control for the rest of your body. Pilates practitioners also refer to this region as your 'girdle of strength' or your 'core muscles'*" (Ungaro, 2002).

One starts to understand how the confusion begins to occur — the shift in seeing 'the girdle' and the 'abdominals' in becoming synonymous' with 'core'. Note also that this notion of the 'powerhouse' alludes to a more '***extrinsic***' locus of control.

The risk is that the 'inner locus of control' gets bypassed.

Examining the healthy 'core'

'Core' structure

'Core' is often simply construed as the muscles that wrap around and 'pull in the midriff' — the transversus trap. 'Core' is more complex.

The pelvis is the main centre of weight shift and 'load transfer' in the body. The body's centre of gravity is anterior to the second sacral segment (S2) in the standing anatomical position (Neumann, 2002) hence our mechanical 'core' is principally around the front of the sacrum. Yet, as the diaphragm and anterolateral abdomen are critical in 'core support' and movement control, structurally, 'the core' reaches from the ischial tuberosities up to the mid thorax where the diaphragm and transversus abdominis attach superiorly.

Energy expenditure is minimized when the head, thorax and pelvis are aligned in relation to the line of gravity — known as the 'neutral' spinal posture. The rib cage, anterolateral abdominal wall (ALAW) and the pelvic ring form a framework of 'hoop bracing' to the spinal column and enclose an internal body chamber capable of volume change through expansion

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and contraction. The diaphragm divides this chamber into the thoracic and thoraco-abdominal-pelvic cavities — the latter being our 'core'. A balanced postural and functional relationship between the thorax and pelvis affords 'ideal' internal dimensions of 'the core' promoting optimal function between the thoracic and pelvic diaphragms.

'Core' functional mechanisms

In essence, healthy antigravity postural support and spino-pelvic movement control can be distilled as consisting of three ***inter-dependent*** *functions*:

1. The **breathing mechanism** — plays a fundamental role in the generation of IAP
2. **Postural control mechanisms of the axial column** — a duality of:
   - Balanced yet adaptable *co-activation* between the axial flexor and extensor muscle systems (Cholewicki et al., 1997) — helped by
   - Appropriate levels of IAP for postural support
3. Sound posturo-movement control of the **proximal limb girdles** — particularly the pelvis as its control directly influences trunk flexor/extensor activation patterns. Space constraints do not allow an in-depth exploration of this aspect, which has been addressed elsewhere (Key et al., 2008; Key, 2010a).

Coordinated activity *between* these 3 functional systems is achieved by *synergistic co-activation* of many muscles, to provide adaptable and complex *patterns of control*. ***The 'intrinsic system' contribution is significant*** — those of the 'abdominal canister' (diaphragm, PFM, transversus abdominis) and also lumbar multifidus, the interspinales and intertransversarii, psoas, medial fibres of quadratus lumborum and the internal oblique (Hodges, 2003). Clinically, the iliacus and deep hip rotators are also important. Excluding the intrinsic spinal extensors, these 'deep' muscles form a *continuous inner myofascial sleeve surrounding the thoraco-abdominal-pelvic cavity* — collectively termed the 'Lower Pelvic Unit' (LPU) (Key, 2010a,b) (Fig. 1).

Variable patterns of activity within this provide the adaptive underlying support in the modulation of these basic *'mechanisms of core control'*.

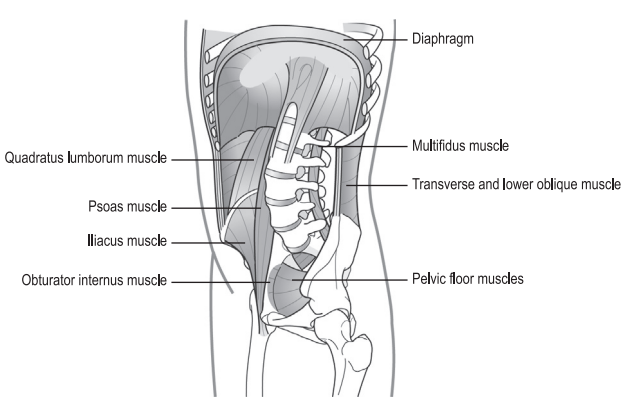

Figure 1 Schematic depiction of the myofascial elements of the Lower Pelvic Unit which contribute to 'intrinsic' mechanisms of spino-pelvic support and control.

Breathing and postural control in particular, are inextricably linked and are important elements common to both mechanisms in the *generation of appropriate levels of IAP*.

'The core' regulates internal pressure changes

The ability to appropriately pressurize the thoraco-abdomino-pelvic cavity and modulate its volumes and shape not only underlies breathing and postural control but also a range of other functions e.g. functional expiratory patterns — vocalisation, singing, laughing, sneezing; and acts of elimination — coughing, nose blowing, vomiting, defecation, birthing etc.; — while also maintaining continence during impact activities like running and jumping.

Like a suction pump, the diaphragm plays a crucial role in generating these internal pressure change mechanisms. IAP in variable measure is behind them all. The creation of each distinct function is achieved by differing timing onset and proportional activity levels between the three principal elements — the thoracic and pelvic diaphragms and transversus abdominis.

Breathing and postural control: the root mechanisms of 'core control'

Breathing is our most fundamental motor pattern. At birth we have an abdominal breathing pattern — where diaphragm descent creates a negative intra-thoracic pressure drawing air into the lungs. To 'get up' against gravity we need to develop postural control — the underlying platform supporting all our movements. In the developmental sequence, breathing becomes integrated into our evolving patterns of posturo-movement control. Breathing and postural control are inextricably linked — each supports the other.

Consider the apparent 'effortless' yet protracted upright posture adopted by the meditating Buddha — an endurance activity sustained by breathing (Ong, 2007). This co-dependency between posture and breathing is considered.

Breathing sub serves the postural control mechanism:

- Breathing transiently changes the volume and shape of the trunk creating slight postural disturbance which when we are upright is counteracted by small angular displacements through the lower trunk and legs (Hodges et al., 2002). The sensori-motor activity from these adjustments constantly 'refuels' the postural reflex mechanism.
- A healthy breathing pattern is principally one of ***lateral expansion*** of the lower rib cage. *This only occurs if there is sufficient generation of IAP* acting through the zone of apposition between the diaphragm and lower pole of the thorax 'to push the ribs out' (Urmey et al., 1988; De Troyer, 1997). This 'respiratory generated IAP' simultaneously contributes towards the postural support and stabilisation system.

Postural control supports the breathing mechanism:

- By providing a *spatially appropriate and stable base of support for* the lower spinal column and pelvis and so, stability for the diaphragm's crural attachments

- In 'healthy posturo-movement', the thorax is aligned in a balanced relationship to the pelvis, affording spatial stability of the lower pole of the thorax and so for the diaphragm's costal attachments enabling optimal conditions for its descent.

If the posture is 'good' so too is the breathing pattern and conversely, if the breathing pattern is healthy, so is the posture (Cumpelik 2008). In dysfunction, altered posture and compromised breathing patterns always go together and are found almost universally in our clients.

Lewit (2008) speculates that in essence, healthy breathing and postural patterns *depend upon balanced activity levels and good coordination between the diaphragm, and the ALAW — in particular transversus abdominis*. This is further explored.

'Core control' and the intra-abdominal pressure mechanism

The spine like any column, risks buckling through non-axially applied loading stresses — particularly those in the sagittal plane. Yet the spine is but the 'backbone of the trunk' and other mechanisms come into play to assist its support and control.

IAP has long been regarded as important for the stabilization and support of the back when exposed to lifting heavy loads. Early lifting studies mostly looked at maximal effort with Valsalva's manoeuvre with a closed glottis (Hemborg and Moritz, 1985; Hemborg et al., 1985a,b; Goldish et al., 1994). The focus then was on trunk muscle strength rather than 'control'.

Later studies showed that low levels of IAP were also an important part of the dynamic antigravity *postural **control** and support mechanism* during daily 'functional activities' — moving a limb (Cresswell et al., 1992, 1994; Hodges and Gandevia, 2000a,b; Kolar et al., 2010); lifting and lowering (Cresswell and Thorstensson, 1994).

IAP is generated when the diaphragm descends creating a simultaneous ***reflex co-activation*** of the transversus abdominis and the pelvic floor muscles. This positive intra-abdominal pressure is an automatic, anticipatory or 'pre-movement' stabilizing response which acts like an inflated balloon providing *internal 'pneumatic support'* for the anterior spine and pelvis and tensioning of the thoracolumbar fascia (Bartelink, 1957; Tesh et al., 1987; Cresswell et al., 1992; Hodges et al., 2001b). It is important that the *activity levels and timing onsets* between the diaphragm and transversus with the PFM are well balanced. Problems arise when any element is overactive or underactive thus disturbing the balanced pattern of coordination and leading to 'system blow outs' and loss of optimal control — postural, breathing, continence etc..

In healthy function, the amount of IAP generated is *at a level appropriate to the task* — **to enable *postural support and regular breathing patterns* during functional activities** (Grillner et al., 1978; Hodges and Gandevia, 2000b; Kolar et al., 2010). Hence IAP increases in proportion to the reactive forces created by limb movement (Hodges and Gandevia, 2000b; Beales et al., 2010b) and more so with increasing respiratory demand (Beales et al., 2010a). It varies phasically with each step when walking (Grillner et al., 1978). A 'heavy lift' requires strong muscle splinting of the body wall and high levels of IAP as in Valsalva's manoeuvre (McGill and Sharratt, 1990) where breathing is temporarily sacrificed.

It isn't possible to generate IAP without associated trunk muscle co-activation and conversely trunk muscle co-activation is normally associated with IAP generation — *each increases proportionally to the other* and the higher the forces, the stiffer the spine (Cholewicki et al., 2002). In dysfunction, this proportionality is lost - increased and dominant 'outer myo-fascial squeeze' suffocates the 'core response'.

Spinal stiffness also changes throughout the breathing cycle due to fluctuating IAP and trunk muscle activity (Shirley et al., 2003). Holding the breath at the end of inspiration during loading generates higher levels of IAP and spinal stiffness (Hagins et al., 2004, 2006). However a regular breathing pattern under loading conditions results in '*more optimal*' IAP levels reducing the risk of undue spinal compression (Beales et al., 2010b).

IAP also expands the lower rib cage three dimensionally — in particular laterally. Thus it 'opens the centre' body, helping to maintain the optimal spatial alignment between the thorax and pelvis and helping preserve the body's longitudinal integrity. Through it we can change the volumes of the body cavities — contributing also to changes in body shape in posturo-movement.

Importantly in healthy control, IAP is not a 'rigid holding'! Instead, it affords a *buoyancy and resilience to axial antigravity control*. This promotes adaptable, flexible intersegmental control, and three-dimensional postural weight shifts and adjustments *throughout the whole spine* — necessary for optimal control and balance.

Significantly, IAP provides ***internal stability*** to support in particular, the actions of psoas (Kolar, 2007), and the large superficial 'extrinsic' trunk muscles involved in more dynamic postural control — providing ***internal counter support*** against the 'yanking' and 'squeezing' effects of their activity. This is important during functional load transfer between the pelvis and trunk as in the supine Active Straight Leg Raise (ASLR) test (Beales et al., 2009a).

Microgravity studies are illuminating. Weightlessness of the abdominal contents dramatically removes tension in the abdominal wall allowing the sternum and ribs to move upward changing the rib cage shape and motion. When the resistance provided by the abdominal fulcrum decreases, the diaphragm's ability to generate IAP in the zone of apposition and expand the lower rib cage is compromised — and the scalenes and parasternal intercostals show increased tonic activity (Paiva et al., 1993). Conversely, in hyper gravity states, IAP increased and the lateral rib cage invariably expanded and assumed a more caudal position. These researchers concluded that "IAP thus appears to be a major determinant of the configuration of the related lower rib cage".

So, when 'up' against gravity, low levels of IAP are always present but *vary in magnitude to* accommodate the respiratory cycle and the fluctuating demands of axial postural control (Cresswell and Thorstensson, 1994; Hodges and Richardson, 1997).

To achieve this, the diaphragm, transversus abdominis and the pelvic floor muscles need to be able to both ***co-activate*** in patterns of low grade, *sustained yet varying*

*levels of **tonic** activity* for postural uprightness *and **at the same time*** be able to generate superimposed ***phasic*** activity to meet the prevailing demands of respiration and postural reflex adjustments and movements of the trunk and limbs (Hodges and Gandevia, 2000a,b; Kolar et al., 2010; Beales et al., 2010b).

This is most important to appreciate.

Like the fairy story character Goldilocks' porridge, the amount of IAP needs to be not too high; not too low — but 'just right'. This is not only dependent upon balanced activity *within* the deep 'intrinsic' system but is also reliant upon balanced activity levels *between* the 'deep' and superficial 'extrinsic' myofascial systems.

It is clinically apparent that in general, patient populations have difficulty achieving and modulating this balance where *the amount of IAP is either deficient or excessive*. Either way the quality of breathing and postural control suffers.

The principal elements contributing to 'core control'

The diaphragm: the forgotten element in 'core control'?

Long acknowledged as 'the' principal muscle of respiration, we now know that the diaphragm is also important in postural control (Allison et al., 1998; Hodges et al., 2001b, 2003; Kolar et al., 2009, 2010) through its contribution to the generation of IAP (Hodges et al., 1997a; Hodges and Gandevia, 2000a,b).

The crural and costal parts of the diaphragm *simultaneously co-activate with transversus and the PFM* to create IAP as part of the feedforward postural responses *prior* to limb movement (Hodges et al., 1997a; Kolar et al., 2010).

The diaphragm is non-uniformly recruited responding differently to postural and respiratory demands. The increased descent in response to limb load postural challenge is greater than during tidal breathing alone and is more marked during lower extremity challenges e.g. supine resisted hip flexion. The contraction occurs mostly at the dome apex and the crural (posterior) sections (Kolar et al., 2010).

While diaphragmatic activity is largely reflexive, its postural function can be activated voluntarily independent of respiration. Subjects were able to increase the degree of diaphragm descent while breath holding beyond that seen in tidal breathing — with varying individual response patterns (Kolar et al., 2009).

As the crura are attached between T12 to L2-3 the diaphragm directly affects *upper* lumbar stiffness (Richardson et al., 2004). Experimental stimulation of the diaphragm *without concurrent activity of the abdominal or back extensor* muscles creates an extensor torque in the spine (Hodges et al., 2001b).

When respiratory demand is substantially increased (during hypercapnoea; taxing exercise; or respiratory disease) respiration wins over postural control. The diaphragm (and transversus and the PFM) show diminished tonic activity and postural IAP may be degraded (Hodges et al., 2001a).

With added significant spinal loading and ventilatory challenge the trunk becomes stabilized by the large axial muscles and the diaphragm goes into respiratory mode Entrainment of the abdominals to the breathing cycle may be apparent (McGill et al., 1995).

The abdominal muscles: more than just flexors

'The abdominals', a group of myofascial layers forming the anterolateral abdominal wall (ALAW) do not work alone but in complex synergies of control which contribute to both breathing and three dimensional posturo-movement control.

It is important that training the ALAW is done in a way that is both safe for the spine and promotes functional capacity.

Postural perturbation (Hodges and Richardson, 1997, 1999a) and respiratory studies (Hodges et al., 1997b) suggest that there is *independent control* between the deeply placed transversus and the more superficial abdominals — the obliques and rectus abdominis. Transversus activates *in advance* of the superficial abdominals (Hodges and Richardson, 1999b) and is more *tonically* yet adaptively involved in the generation and modulation of IAP for the fluctuating demands of respiration and postural control (Eriksson et al., 2011).

More task dependent, the obliques and rectus work more phasically to control the imposed torques and the spatial relationship between the thorax, pelvis and the axial spine in posturo-movement (Bergmark, 1989; Hodges, 2003; Saunders et al., 2004; McCook et al., 2009). Their activity is low grade for most ordinary activities of daily living and it is only during 'high load' activities where they strongly splint the body wall — stiffening the body and limiting breathing.

Importantly, transversus activity *does not* occur in isolation but as part of the coordinated pre-movement' ***'stabilizing synergy'*** *creating IAP*. Some researchers concluded that it is transversus activity which is most consistently related to changes in IAP (Cresswell et al., 1992; Cresswell and Thorstensson, 1994) while others thought it was the diaphragm (Hemborg et al., 1985b).

However, this differential function between the deep and superficial abdominals is generally overlooked by trainers. Instead of *specific activation and building control and endurance in the deep 'stabilizing synergy'* to support 'uprightness', much of the 'core training' offered simply becomes 'strengthening the abs' as a group — principally the superficial abdominals — invariably in supine into repeated cycles of spinal flexion: crunches, curls, sit-ups etc with predictable adverse consequences on the discs and spinal health and wellbeing.

Abdominal activation patterns change depending upon whether the prime purpose is to control pelvis motion or thorax motion: the obliques are most active particularly the internal oblique, and more so when the pelvis initiates the movement (Vera-Garcia et al., 2011). During a supine ASLR, the lower internal obliques are generally more active (particularly ipsilaterally) than the external obliques (Beales et al., 2009a).

Regional variations in the morphology and recruitment of transversus and internal oblique have also been shown. The greatest tonic postural activity occurs in the lower section; the least in the upper sections while the middle

was most associated with respiratory activity. Activation of the lower and middle sections was independent of the upper region (Urquhart et al., 2005).

Clinically, differing activity levels between the 'upper' and 'lower' abdominals have been long reported with 'upper' strong and 'lower' weak the most common, followed by both 'upper' and 'lower' weak (Kendall et al., 1993).

Significantly, the abdominal muscles particularly transversus, are important when antigravity for efficient diaphragm activity: on inspiration they provide both stability of the lower rib cage to support diaphragmatic descent and counter support for the abdominal contents — and so the generation of IAP. Transversus is more eccentrically active on inspiration and concentrically active on exhalation (Hodges and Gandevia, 2000b). As respiratory demand increases the whole abdominal group becomes increasingly involved in active exhalation to assist diaphragm ascent in readiness for the next diaphragm descent and inhalation. However individual strategies vary and some may show greater activity synchronised to inspiration (Beales et al., 2010a). During hypoxic hypercapnic breathing studies, transversus activity occurs well before activity in the other abdominals (De Troyer et al., 1990).

The 'Abdominal Drawing in Maneuver' (ADIM) or 'Abdominal Hollowing' is a suggested strategy to activate the 'deep muscle corset' which aims to preferentially recruit the lower transversus while minimally contracting the obliques. Subjects are asked 'to pull in the lower abdomen' keeping a 'neutral spine' (Richardson et al., 2004). The quality of the response is important and substitution patterns avoided. The lower internal oblique is also considered part of the 'deep corset' by some and the ability to isolate it from the upper rectus and external oblique in the ADIM has been demonstrated (O'Sullivan et al., 1997b). Correct performance of the ADIM also recruits the diaphragm (Allison et al., 1998) and PFM (Sapsford and Hodges, 2001). Positive treatment effects have been demonstrated utilizing the ADIM combined with co-activation of lumbar multifidus in a CLBP subgroup (O'Sullivan et al., 1997a).

However, achieving the correct action can be difficult for many 'healthy' subjects (Beith et al., 2001). Ishida et al. (2012) demonstrated that a maximum voluntary exhalation recruits transversus and internal oblique — followed by external oblique, significantly more than during the ADIM.

'Bracing' the whole ALAW has been shown to be more effective in increasing lumbar stiffness or 'stability' than the ADIM (Grenier and McGill, 2007). However, it's also important to keep in mind that this can create 'too much stability', rigidity and stiffness for healthy spinal control. While the obliques and rectus help to anchor the thorax caudally their excessive activity also constricts the inferior thorax interfering with diaphragm descent. Conversely, transversus activity through IAP increases the transverse diameter of the lower rib cage.

Underactive or overactive abdominals compromise the diaphragm's function

When the ALAW is underactive, the abdomen protrudes, the 'neutral' spino-pelvic posture is lost and so also control of the functional relationship between the thorax and pelvis, affording little stability for the diaphragm and the rest of the 'stabilizing synergy' in the creation of optimal IAP.

Conversely, when the superficial abdominals are 'too strong', the 'neutral' spino-pelvic 'posture is also lost, the inferior thoracic opening is constricted, inhibiting diaphragm descent and so, disturbing the associated reflex function between the diaphragm, transversus and pelvic floor — again IAP generation is compromised.

Balanced activity between all muscles in the abdominal group ensures an 'ideal' thoraco-pelvic alignment and a stable, 'open centre' for the generation of optimum IAP and postural control. To achieve this, transversus (and the diaphragm) via the 'stabilization synergy' ***needs to have the capacity to match*** the activity of the more superficial rectus and the obliques. This is important to appreciate.

Abdominal postscript: an 'hour glass figure' is a beauty myth and non-functional! Just observe the torso of a singer, an elite track and field athlete or a professional dancer — the thorax is balanced over the pelvis, the 'centre is open' with balanced activity in the ALAW (Fig. 2.) and the extensor system (Fig. 3.). The waist is subtle.

The pelvic floor: the seat of breathing and postural control

The PFM must contract during tasks that elevate IAP to both contribute to pressure increase and to maintain continence (Sapsford and Hodges, 2001). Avoiding bladder neck depression requires the PFM activity to be high relative to the IAP increase (Junginger et al., 2010). Increasingly, there is an evident association between CLBP, continence and breathing disorders (Smith et al., 2006; Eliasson et al., 2008; Smith et al., 2009). If you don't breathe well and posture well, you are more likely to get CLBP and develop incontinence.

The PFM are tonically active as part of the 'stabilization synergy' and demonstrate respiratory modulation — showing more activity on exhalation (Hodges et al., 2007).

Upright unsupported sitting postures recruit greater PFM activity than slumped supported postures (Sapsford et al., 2006, 2008). Resting PFM activity is also higher in standing and is affected by the lumbo-pelvic posture being highest in a hypo-lordotic posture (Capson et al., 2011) — not necessarily a good thing as continence disorders have been linked to increased PFM and external oblique activity (Smith et al., 2007a,b). Over-training the PFM and abdominals can be deleterious!

Voluntary activation of the PFM normally creates a co-contraction in the abdominal muscles (Sapsford et al., 2001) — here, transversus activation was greatest with the spine in extension; external oblique when the spine was flexed. Similarly, voluntary lower abdominal activation results in a reflex activation of the PFM which occurred in advance of IAP (Sapsford and Hodges, 2001).

The PFM also contribute to intrapelvic myomechanics (Bendova et al., 2007). Bear in mind that their (over) activity counternutates the sacrum and coccyx which places the sacroiliac joint in its less stable position. The ability to eccentrically lengthen the PFM is important in 'fundamental patterns of pelvic control' (Key, 2010a) which support healthy axial control mechanisms.

Figure 2 Balanced activity in the ALAW is evident in these two professional dancers.

'Core control': It's about coordination rather than strength

As research has demonstrated, the 'core response' is about *muscle co-activation and coordination*. Reliant upon input from the sensory system, it is the accurate interplay of many muscles working in synergies to produce complex *patterns of control* and movement rather than the strength of individual muscles (Hodges, 2003). No muscle works alone. Activating single muscles is impossible — trying to, creates dysfunctional spines (McGill, 2004). Retraining 'core control' involves relearning basic motor skills.

Functional control requires the ability to coordinate the postural and respiratory functions of the trunk muscles. To achieve this, a well-coordinated IAP mechanism contributes much towards our ability to operate well in a gravity-based environment.

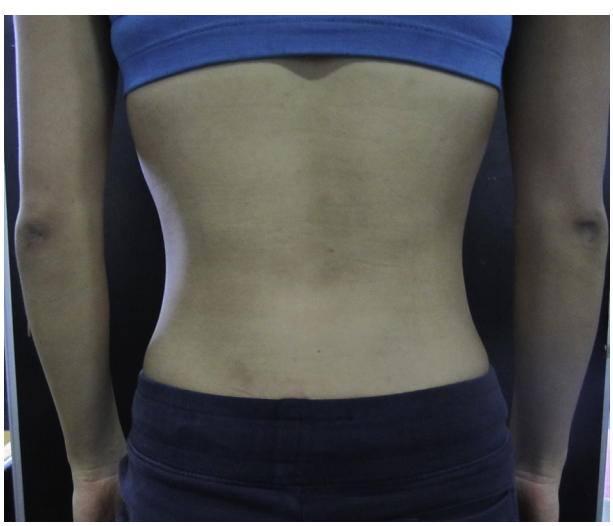

Figure 3 Balanced activity in the extensor system in a professional dancer.

This suggests a definition of 'core control': "The ability to generate optimal IAP to support both breathing and the provision of three dimensional postural and movement control of the torso — particularly control of the pelvis on the legs".

Real 'core control' comes from inside. Most people try to train it from the outside.

What goes wrong with 'the core'?

Dysfunction of 'the core' involves subtle to overt shifts in the pattern of motor activity. There is *both* dyscoordination in the deep system and imbalance between 'inside' and 'outside' control — too little, too late deep system control necessitates substitution strategies by various superficial muscles (Hodges, 2003) which show distinct patterns of *tonic and/or phasic* ***overactivity***. Their overactivity involves both timing (too early) and degree of activity (too much) — further interfering with the mechanisms of deep system control. This augmented muscle activity is being increasingly reported (Hodges et al., 2009; Van der Hulst et al., 2010; Jones et al., 2012). This creates greater trunk stiffness — and so, and contrary to popular belief CLBP subjects actually move their spines less (Mok et al., 2007) and move with excess muscle tension and effort — and breath holding.

Importantly, the deep system 'stabilization synergy' is not coordinated. The principal problem is more one of poor coordination and endurance than reduced strength.

CLBP and related research now provides ample evidence showing delayed and/or reduced activity of the individual deep system elements which contribute to IAP and control — transversus abdominis (Hodges and Richardson, 1997, 1998, 1999a,b; Ferreira et al., 2004; Hides et al., 2010); lumbar multifidus (Hides et al., 1994, 2008; MacDonald et al., 2009) transversus and lumbar multifidus (Hides et al., 2011b); PFM — delayed yet increased activity in incontinent women (Smith et al., 2007a; Madill et al., 2010).

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Similarly, altered postural function of the diaphragm has been shown. In a CPGP cohort, an ASLR on the painful side resulted in increased bilateral oblique muscle 'bracing' of the abdominal and chest wall associated with diaphragm 'splinting' and reduced excursion while PFM descent was increased (O'Sullivan et al., 2002a; Beales et al., 2009b). This was associated with an increased baseline shift in IAP, increased minute ventilation and a high variability of respiratory patterns including accessory breathing patterns and transient breath holding. Significantly, in the O'Sullivan study, over half the sacroiliac pain cohort showed zero diaphragmatic motion! It is important to note that with this 'inversion function' of the diaphragm, the automatic reflex relationship between it, transversus and the PFM is lost, hence the non-optimal IAP generated by superficial abdominal splinting was associated with increased PFM descent.

Another CLBP study found a higher resting position of the diaphragm and in response to postural tasks in supine (resisted bilateral arm or hip flexion) there was significantly less diaphragmatic excursion (Kolar et al., 2012).

How can we see what goes wrong with the 'core'?

Altered neuromotor control results in common observable effects — in essence:

- *Altered sagittal spatial pelvic position* (and intrapelvic control) and related…
- Altered spinal alignment
- *Deficient 'intrinsic' control* — including the 'stabilizing synergy' and
- *A compensatory over-reliance on 'extrinsic' control* in distinct patterns of myofascial 'holding' or 'cinching'— creating regional segmental 'hyper-stability' while in other regions, spinal segmental control is inadequate.

The body shape and its functions change resulting in *disturbed regulation of internal pressure change mechanisms* because of compromised diaphragmatic function. The IAP generated provides suboptimal support for breathing and postural control (Fig. 4).

The necessary compensatory control strategies actually stiffen and bother the spine and pelvis in differing ways.

Two subgroups are apparent — the architecture of 'the core' and its control are differently compromised

Based upon the altered postural alignment and changed regional myofascial activation patterns, two main subgroups are clinically apparent which have been described as the Pelvic Crossed Syndromes (Key et al., 2008; Key, 2010a,b).

Simply looking at the client as he sits or stands in front of you tells you his problems. In particular, observing the architecture of the lower pole of the thorax and the ALAW informs as to the activity level and balance between the diaphragm and transversus abdominis.

Imbalance in the ALAW is common yet differs between groups. In general there is underactivity of the deep transversus associated with either increased or decreased superficial activity in the obliques and rectus. The increased activity is more apparent in the 'upper' ALAW while the 'lower' ALAW is generally deficient.

The posterior pelvic crossed syndrome (PPXS)

This subgroup is more ***axial extensor dominant***. This is non-uniform, principally occurring in the extensor system over the thoracolumbar junction between the dorsal hinge

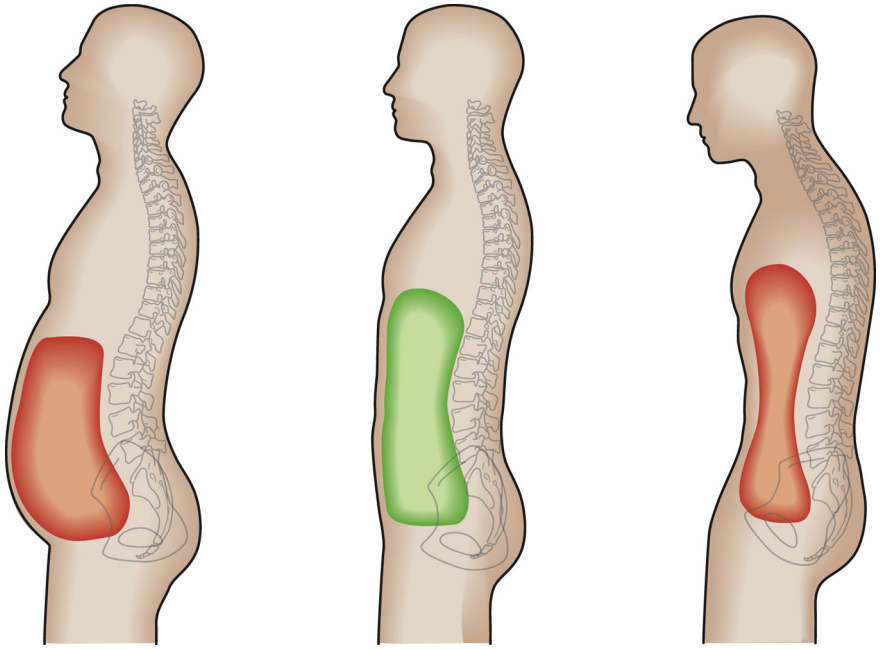

Figure 4 Schematic depiction of 'healthy alignment' (centre) and the apparent altered body shape including that of the thoraco-abdomino-pelvic cavity in the crossed syndromes: Posterior Pelvic Crossed Syndrome (PPXS) (left) and Anterior Pelvic Crossed Syndrome (APXS) (right).

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and the mid lumbar spine. Termed a 'Central Posterior Cinch' (Key, 2010a), this automatic *reflex hyperactivity* is a tonic, bilateral, posterior 'bracing' response (Fig. 5) characteristically co-associated with observable *underactivity of the **entire** anterolateral abdominal wall* (Fig. 6).

The quality of breathing and postural control patterns suffers in a typical manner.

Thoraco-pelvic alignment alters — the pelvis moves back and the thorax moves forward assuming a more oblique relationship to each other. Importantly the whole thorax also moves up because of the poor inferior stabilisation afforded from the abdominals. The infra-sternal angle is increased being generally greater than 90° while the postero-inferior thorax is hyper-stabilized and 'drawn in' limiting postero-lateral costo-vertebral movement. The person principally relies upon habitual 'Central Posterior Cinch' (CPC) behaviour for antigravity postures and movement control (Dankaerts et al., 2006a,b). The resulting more anterior and elevated position of the thorax interferes with the functional relationship between the thoracic and pelvic diaphragms disturbing Lower Pelvic Unit 'stabilization synergies'.

As a result the person lifts the thorax on inspiration through a synergy of pectoral 'lift' and 'CPC' adopting an upper chest breathing pattern. Active exhalation is difficult as abdominal activation is inadequate to bring the thorax down and back into the more 'expiratory' caudal, or 'neutral' position, as well as generate the necessary IAP. The expiratory phase is shortened. Breathing pattern disorders are common. In general, the person cannot achieve *posterior basal expansion and a lateral widening* of the lower rib cage and he cannot generate appropriate IAP when antigravity — let alone during movement where breath holding is common. The important co-activation and coordination, between transversus and the diaphragm is missing — the abdominal underactivity is paramount. He is forced to rely upon 'CPC' behaviour which is co-associated with overactivity in the psoas and probably the crural diaphragm, further disturbing patterns of control.

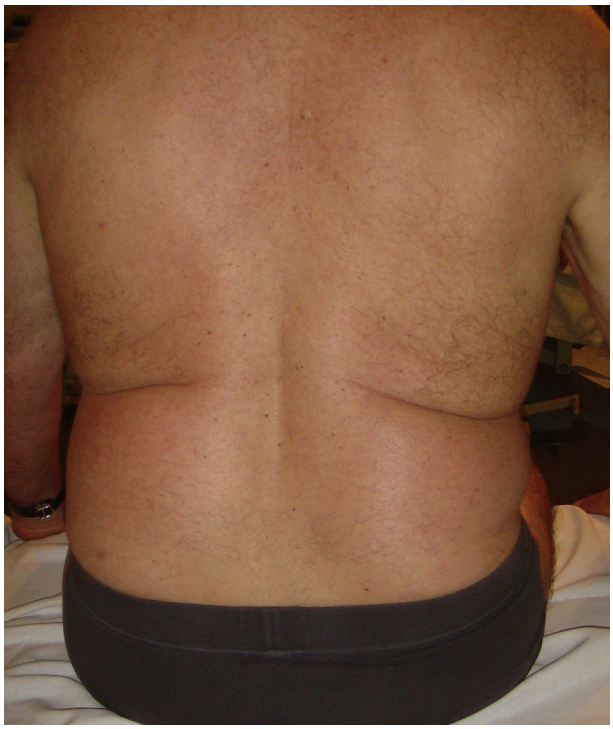

Figure 5 Typical appearance of a 'Central posterior Cinch' activity in a PPXS picture.

Figure 6 Typical appearance of underactivity in the whole ALAW in a PPXS picture.

Retraining the PPXS client

In rehabilitation, this group certainly need to generate more activity in the ALAW! However, 'sit-ups', 'crunches' 'curls' etc are not the answer! These create large flexion loading stresses on the spine (McGill, 2002) and do not restore the function actually needed. Multiple, deleterious segmental effects ensue from over-flexing spinal tissues (Solomonow, 2012).

The best way to initially activate the ALAW in particular transversus is through *improving active exhalation* (Ishida et al., 2012; Ishida and Watanabe, 2013) to bring the *thorax caudally on a stable pelvis*. Initially the client may need assistance with this (Figs, 7 and 8). He then has to learn to *maintain* this more 'neutral' position through ALAW activation while *also breathing down* not up! (Fig. 9) And then further, to be able to maintain the above while generating ***sustained LPU activity and IAP with a regular basal breathing pattern*** — in particular a more extended exhalation (Fig. 10). The IAP is monitored low down at the lateral iliac fossa (Fig. 11) where a *sustained firming* should be felt. This pressure can only be developed if ***all elements of the 'stabilization synergy' are co-activated***.

Applicable to both subgroups *albeit with differing emphasis*, this is 'The Fundamental Pattern of Control' which simultaneously trains both the postural and respiratory aspects of the 'stabilization synergy'. It is easiest to

Figure 7 In supine supported hip flexion, the 'inspiratory' more cephalad position of the thorax is apparent. Note the reduced abdominal tone and wide infra-sternal angle.

first establish with the hips in supported flexion, gravity eliminated. When the correct pattern is mastered it is increasingly sustained to build endurance and capacity in the 'stabilization synergy'. This is further progressed into unsupported hip flexion (Fig. 12), progressing to various limb load challenges and sustained antigravity control in sitting and standing.

Postero-lateral expansion of the lower rib cage can only be achieved by *ALAW activation with an appropriate pattern of IAP* hence we simply work for this. This is progressed from recumbent (to 're-groove' the postural response) to upright. 'Opening the centre' is achieved by '*pushing the ribs* ***wide and back****' without lifting the thorax while continuing a regular basal breathing pattern* (Fig. 13). Developing capacity in the 'stabilizing synergy' helps overcome the tendency to 'Central Cinch Pattern' behaviour when antigravity. Once this is mastered, appropriate limb load challenge can be judiciously applied *provided that control of the 'fundamental pattern' affording thoraco-lumbo-pelvic stabilization, IAP and a regular diaphragmatic breathing pattern are maintained*. If lost, we need to go back and reestablish better 'fundamental control', reduce the challenge such that it can be properly sustained.

Abdominal 'bracing' strategies in a 'neutral' thoraco-pelvic position are more appropriate for this group but need to be carefully applied while ensuring ***correct and adequate pre-activation*** *of the 'stabilizing synergy'*.

Figure 9 The practitioner helps to maintain the caudal thorax while asking the patient to 'breathe down to my lower hand'. Encouraging an active and longer exhalation helps activate the ALAW and facilitate a firming in the 'Lower Pelvic Unit' giving him 'the sense of' the required action which he also monitors with his (R) hand.

Figure 8 The thorax is passively brought into the caudal 'expiratory position' to help give the client the sense of the 'neutral' thoraco-pelvic position. Holding it so helps him inhibit lifting the thorax on inspiration and also facilitates better diaphragmatic and ALAW activity so that he can experience the 'feel of it'.

Figure 10 He is now managing to control the thorax position and generate sustained IAP while continuing to regularly 'breathe down not up'. He needs to keep focusing upon a longer exhalation and holding the lower ribs down and back in contact with the support surface. Sustaining the action for increasing periods of time builds capacity and endurance in the 'stabilizing synergy'.

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Figure 11 Sustained Lower Pelvic Unit 'switch on' is monitored low down in the 'lateral valley' of the iliac fossa — not centrally over rectus abdominis.

Otherwise, overdeveloping abdominal 'bracing' risks compromising diaphragm descent and creates hyper-stability and spinal compression (Reeves et al., 2006) limiting movement through the spine and degrading posturo-movement control and balance (Grüneberg et al., 2004).

'Planks', 'side bridge' 'stir the pot' etc. are way too much for many and encourage superficial 'lock down' — in particular reinforced 'Central Cinch Pattern' behaviour, 'pectoral armouring', and further deep system inhibition.

Attempting 'abdominal hollowing' invariably results in a 'suck in' and lift of the thorax and/or a posterior pelvic tilt with lumbosacral flexion. This just further imprints patterns of non-optimal control.

Figure 12 When the correct pattern is mastered it is further progressed to no support for the legs. Care must be exercised in not over challenging the client beyond his abilities. Note that the subject's lower ribs have lifted slightly of the support surface hence 'going back' and spending longer time developing and sustaining a better pattern of control in the 'legs supported position' is indicated.

Figure 13 The client is being asked to 'push out sideways and back into my hands'. She can only do this by adequate activation of the 'stabilization synergy'. Note the 'Central Posterior Cinch' hyperactivity which will lessen as she improves internal control.

Anterior pelvic crossed syndrome (APXS)

This subgroup is more ***axial flexor dominant*** with overactivity of the ***upper*** *anterolateral abdominal wall* between the umbilicus and the xiphoid. Termed a 'Central Anterior Cinch' (Key, 2010a), this automatic *reflex hyperactivity* is a bilateral, tonic anterolateral 'bracing' response which is co-associated with *underactivity in the* ***lower*** *ALAW and relative underactivity in the axial extensor system*. A crease and/or a hollow are generally apparent above the umbilicus (Fig. 14). However, transient 'Central Posterior Cinch' (CPC) behaviour occurs when the postural system is challenged — and more so in pain states. This combined with the Central Anterior Cinch (CAC) behaviour, hyper-stabilises and 'draws in' the whole lower pole of the thorax (Fig. 15). Regional joint function is suffocated.

The quality of breathing and postural control patterns suffers in a typical manner.

Thoraco-pelvic alignment again shows an oblique relationship — the pelvis moves forward and the thorax back, assuming a more 'expiratory' position further constricting the lower pole of the thorax. The infra-sternal angle is usually less than 90°.

Static antigravity strategies invariably involve axial collapse and 'slumping' relying upon passive end range

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Figure 14 Typical appearance of 'Central Anterior Cinch' activity in an APXS picture.

Figure 15 Combined anterior and posterior Central Cinch Pattern behaviour constricts the lower pole of the thorax. The subject is a 19-year-old 'gym junkie' who presented with a right femoral nerve irritation.

loading of the spinal joints and posterior myofascial tissues into flexion (Dankaerts et al., 2006a,b). This postural malalignment and the associated 'Central Cinch Pattern' behaviour interfere with the diaphragm's ability to descend. Without diaphragmatic descent, the reflex relationship between it and the PFM and transversus is lost (O'Sullivan et al., 2002a). Without this co-activation, the ability to generate IAP is compromised and so suboptimal breathing and postural control ensues. Kolar suggests (2008) that when this 'inversion function' of the diaphragm occurs (it goes up instead of down) and IAP is deficient, the central tendon necessarily becomes the compensatory 'place of stability', further pulling in the lower pole of the thorax.

Posturo-movement challenges result in increased 'CAC' behaviour, transient 'CPC' behaviour and breath holding. Restricted chest wall expansion during exercise has been shown to increase diaphragmatic fatigue, reducing its endurance (Hussain et al., 1985; Hussain and Pardy, 1985).

The person further compensates with an upper chest breathing pattern as they find it difficult to relax the upper ALAW and 'push' the diaphragm down and so, lateral expansion of the lower rib cage and 'opening the centre' again suffers.

Breathing pattern disorders and poor energy levels are common.

While the thoracic diaphragm is relatively underactive, the pelvic diaphragm and related myofascial tissues over the posterior inferior pelvis are characteristically tight — yet may show timing delays (Smith et al., 2007a,b) further disturbing control. This is part of an 'inferior tether' pattern of dysfunction in the pelvis (Key, 2010a).

Pelvic girdle pain syndromes are a common feature in this subgroup.

Retraining the APXS client

In rehabilitation, it is important to understand and recognise the real needs of this subgroup. Their real difficulty is the diaphragm — too little too late. Obtaining balanced and coordinated activity between the ALAW and diaphragm can be tricky. The 'CAC' *reflex hyperactivity* means that attempting the ADIM predictably results in early 'upper' ALAW over-activation (Lee et al., 2008) often involving a 'suck in' and thorax lift and breath holding, further augmenting the CAC response (Fig. 16) — and difficulty activating the *'lower' ALAW* (Hides et al., 2011a). Similarly, because the 'upper' ALAW is already overactive, abdominal 'bracing' strategies are inappropriate.

The increased external oblique activity common in this group is often associated with increased PFM activity (Smith et al., 2007b). Like squeezing a tube of toothpaste in the centre, this Central Cinch Pattern behaviour constricts the waist, creating undue pressure on both diaphragms.

Instead, we need to 'down train' the 'Central Cinch pattern' activity — *in particular the CAC behaviour*; and really ***encourage better diaphragm activity*** towards achieving *good co-activation and balanced activity within the whole 'stabilization synergy'*. Establishing this also helps to relax the upper ALAW and gain better lateral expansion of the lower pole of the thorax (Fig. 17). With this, it's helpful to think of IAP as a balloon: — if you squeeze the bottom (co-active PFM and lower transversus

Figure 16 Asking for "draw the lower abdomen up and in" results augmented CAC behaviour and breath holding. Note the asymmetry of the lower pole of the thorax.

in response to diaphragm descent) — the top expands (pushing the ribs out), 'opening the centre'.

Cueing the PFM to help re activate the lower transversus isn't necessarily helpful as this can still result in augmented CAC behaviour. Getting better 'push down' of the diaphragm and re-establishing the 'stabilising synergy' helps normalize PFM function.

Discussion

Improper coordination between the abdominal wall and the diaphragm results in compromised breathing and 'internal support' and spinal stability mechanisms.

Figure 17 'Letting go' the upper ALAW, establishing better diaphragm descent and its co-activation within the 'stabilizing synergy' now enables 'opening the centre'.

Each person has an individual presentation yet there are common subgroup patterns.

In the PPXS group the ALAW deficit is paramount causing them to rely on CPC behaviour and related overactivity of psoas.

In the APXS group, reduced diaphragm activity necessitates reliance upon CAC behaviour and 'locking' the postero-inferior pelvis.

The dysbalance may be subtle or marked where more compromised function occurs.

The crux of the problem

'Core problems' are apparent in our clients as a common difficulty in simply 'sitting up' and breathing properly!: — achieving antigravity 'neutral' thoraco-pelvic postural alignment with a regular diaphragmatic breathing pattern (O'Sullivan et al., 2002a; Beales et al., 2009a; Roussel et al., 2009). This is ***basic to all their other problems*** *in achieving healthy spino-pelvic movement control*. These include diminished triplanar weight shift and rotation through the spine and pelvis and so, reduced variability of postural strategies (Moseley and Hodges, 2006), impaired postural compensations (Grimstone and Hodges, 2003) and reduced postural adjustments through the pelvis/hip affecting balance (Mok et al., 2004, 2011; Smith et al., 2008).

The Pelvic Crossed Syndromes are an expression of deficient deep system control.

In addition, a 'Key Sign' over the lower postero-lateral thorax is further indicative of an *incapacity of the deep 'stabilizing synergy'* to match the degree of superficial (over) activity seen in the 'Central Cinch Patterns' — where internal counter support, 'opening the centre' and it's three dimensional control is wanting (Fig. 18 — and also Figs. 5, 15 and 22). It is usually more marked on the symptomatic side.

Correct breathing patterns are 'the' basic building block of 'core control'. Retraining faulty breathing is multifaceted (Chaitow et al., 2002; McLaughlin, 2009) and may

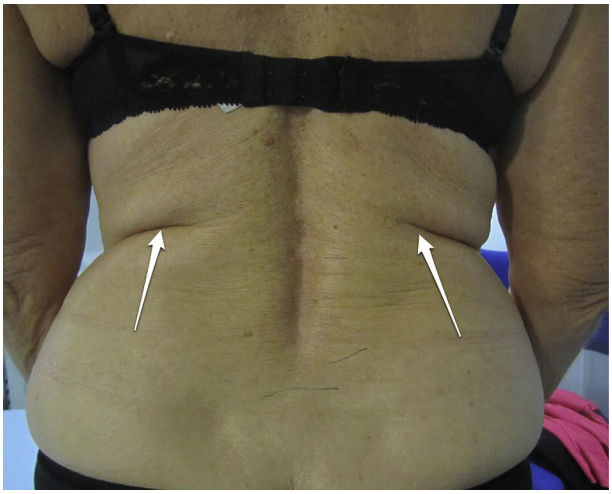

Figure 18 A 'Key Sign' might be construed as a 'roll of fat' but is indicative of inadequate and 'empty' intrinsic control and compensatory extrinsic hyperactivity.

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Figure 19 The ability to 'fill out' *sideways and back* under the subjects hands and sustain 'opening the centre' with a regular basal breathing pattern when antigravity requires capacity and endurance in the 'stabilizing synergy' and helps remedy a 'Key Sign'.

require quite some work in order to reestablish healthy patterns. Once mastered, it is important that they then become incorporated through the '*stabilizing synergy*' into sustained antigravity postures (Fig. 19) and functional patterns of posturo-movement control. In this regard, Kolar (2007) offers an excellent protocol.

Skilled assessment will delineate if any one element — the diaphragm, PFM, multifidus or transversus requires *particular individual attention in order to* ***achieve co-activation of the whole 'stabilization synergy'***. This requires practitioner intuition, skill, patience and a preparedness to 'play around' to achieve the correct response.

Retraining the coordination between the diaphragm, transversus and PFM has demonstrated improvements in

Figure 20 The practitioner is providing tactile feedback to help the client inhibit lifting the chest on inspiration; while at the same time directing his awareness to bringing the lower ribs down and back; and then expanding them sideways and back while also sustaining Lower Pelvic Unit engagement and a regular basal breathing pattern.

Figure 21 Habitual 'slumping' switches off the deep system and feels 'normal' over time.

postural control (O'Sullivan and Beales, 2007) and continence (Hung et al., 2010).

The desirable Fundamental Pattern of Control is always one of correct thoraco-pelvic relationship with regular diaphragmatic breathing, IAP generation and 'opening the centre' and the ***ability to maintain this*** while integrating *appropriate incremental* limb load challenge. In general, the PPXS group need to master 'opening the centre' *sideways and backwards*; the APXS *sideways—- and possibly*

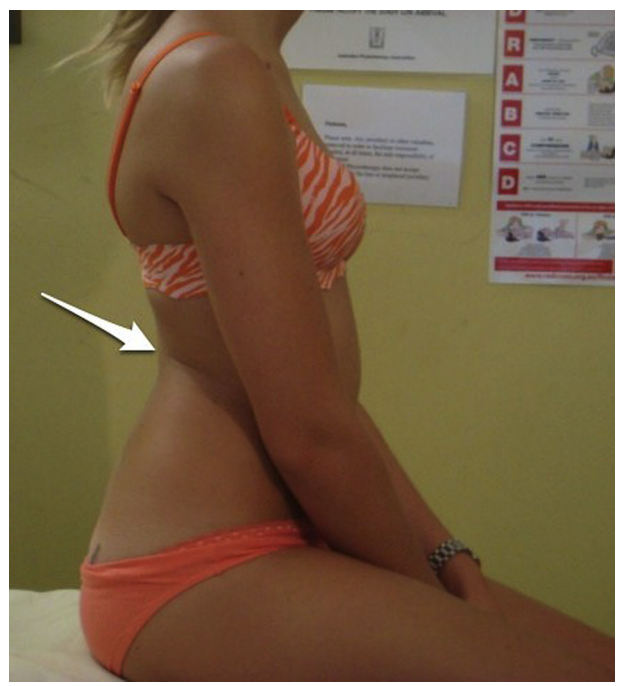

Figure 22 'Sitting up straight' involves Central Posterior Cinching and throwing the lower ribs forward because of reduced intrinsic control. This strategy will be short lived. Note the inability to achieve a *lumbosacral lordosis* and the 'Key Sign'.

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forward. Otherwise, without adequate 'control of the centre', proximal limb girdle activity predictably results in further 'Central Cinch Pattern' behaviour.

Overly focusing upon 'the abdominals' — particularly with cues to 'tummy tuck' or 'tail tuck' degrades control of the lumbosacral 'neutral' and disturbs diaphragmatic and PFM kinematics — particularly so in the APXS group. The diaphragm has to come first (Kolar, 2008) with co-activation of transversus and the PFM.

Commonly, breathing instruction is delivered as an afterthought and so does not involve the correct pattern of *lateral basal expansion*. This is not possible if appropriate IAP is not generated and/or the chest lifts on inspiration.

Focusing on the PFM alone risks compromising spino-pelvic postural control — yet activating the PFM (with the lower transversus) and diaphragm improves postural control (O'Sullivan and Beales, 2007).

The correct pattern of IAP and stable control can only be achieved if ***all elements in the 'stabilizing synergy' are equally co-active***.

Current approaches to 'stability retraining' seem to vie between either 'abdominal hollowing' or 'bracing' strategies. Re-establishing the 'stabilizing synergy' as described incorporates aspects of both approaches towards achieving better functional control. It is important to ensure that the principal activity is in the Lower Pelvic Unit, with *postero-lateral costal expansion* while the pelvis and thorax position are appropriately controlled (Fig. 20). Undesirable compensations such as upper chest breathing; breath holding; pushing with the feet; clenching the buttocks; posterior pelvic tilt, increased 'Central Anterior Cinch' behaviour; 'ballooning the belly'; abdominal 'suck in' and lifting the thorax need to be anticipated. Appreciating the typical features of the Pelvic Crossed Syndromes helps predict the likely strategies to overcome.

Remember that increasing the force or load increases superficial myofascial activity. If the client is 'over-challenged' beyond his 'deep system' ability he *will have compensate* with Central Cinch Patterns — the reverse of what we want! Clients need to 'work smarter', not 'harder'. High load 'bracing' strategies aimed at 'not letting it move' risk developing 'corsets of concrete' which compress the spine and stiffen the body wall, limiting inner movement.

Thus, it is important that the deep 'stabilizing synergy' is first established and has the ***capacity to match the activity level*** of the superficial muscles to allow stable yet adaptable patterns of spino-pelvic control. This is important.

Sitting and 'the core'

Most people these days habitually sit in lumbo-pelvic flexion (O'Sullivan et al., 2010) —switching off their deep system! — particularly the APXS group (Fig. 21). Normally, adopting 'neutral' thoraco-pelvic postures in sitting and standing automatically facilitates better deep system activity without activating the large superficial muscles (O'Sullivan et al., 2002b, 2006; Claus et al., 2009a; Reeve and Dilley, 2009; Pinto et al., 2011). However, there is non-uniform agreement between physiotherapists as to what constitutes a 'neutral spinal posture' (O'Sullivan et al., 2012) Also bear in mind that most people are stiff with poor intrapelvic control and so, have difficulty assuming a lumbosacral 'neutral' lordotic posture (Claus et al., 2009b) — even the young. This, coupled with inadequate IAP generation means that attempts by the subject to improve his posture and 'sit up' will usually result in increased 'CPC' behaviour (marked in the PPXS group) and possibly 'CAC' strategies (in the APXS group) which may well exacerbate symptoms (Fig. 22). Conversely, establishing and improving the capacity of the 'stabilising synergy' helps to regain a neutral thoraco-pelvic position and reduce this superficial global muscle hyperactivity and tension when antigravity (Fig. 23).

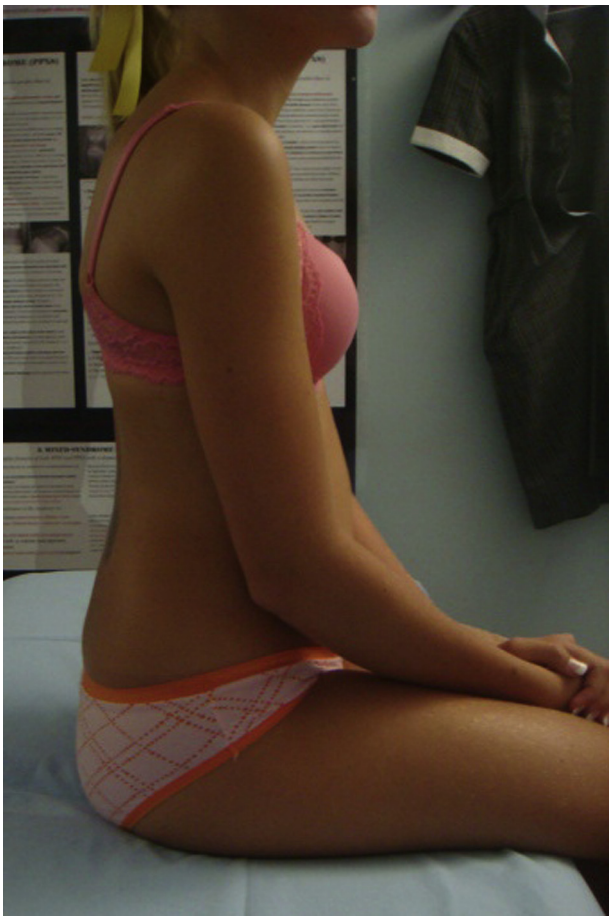

Figure 23 Activating the 'stabilizing synergy' helps achieve a 'neutral' thoraco-pelvic alignment and removes the 'Key Sign'.

Conclusion

'Retraining the core' should redress the client's actual functional deficits and promote functional capacity.

Understanding healthy 'core control' is a prerequisite to seeing it's dysfunction.

'Core dysfunction' is both a reflection of inadequate 'intrinsic' neuro-myofascial system control and the related, necessary compensatory 'extrinsic' motor behaviour.

Two basic subgroups are clinically apparent, each displaying common features and distinct difficulties with 'core control'. Posture and movement control of the spine are

compromised, contributing to both the cause and perpetuation of many spino-pelvic pain syndromes.

It is important that the practitioner can appreciate and recognise these subgroup patterns as each dictates a different emphasis in therapeutic movement retraining.

Re-establishing the 'stabilizing synergy' helps restore fundamental control and has been described for each group.

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