**Retraining the virtual body: Dynamic control vs. stiffness**

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## Abstract

Dynamic motor control of the lumbo/pelvic /hip region involves complex movement patterns and interrelated kinematics of many joints. Not only must key muscles have endurance and contraction specific strength, but the Central Nervous System (CNS) must consider input from the periphery and adjust its “belief system”, so that over time its pre-programmed responses — or ‘virtual body’ — are adjusted accordingly for optimal function.

Research into muscle and proprioceptive requirements in the lumbo/pelvic /hip region, and our experience in practice of the changes that occur with pain, give us insight into the many aspects of rehabilitation that must be considered to optimise dynamic control. Such changes include: local muscle recruitment, function specific recruitment combined with faulty virtual body engrams within the motor cortex itself; and the individual’s perception of ‘threat’ associated with anticipation of pain (Moseley, 2004).

This paper will outline some of the key changes that occur with low back pain (LBP) and detail practical strategies that can be incorporated into rehabilitation and maintenance training programs to optimise dynamic lumbo /pelvic/hip control and proprioception. If motor control retraining is focused on lumbo pelvic stiffness and does not retrain the complex proprioceptive and motor planning components of dynamics movement, than dysfunctional virtual body motor recruitment patterns can continue well after the initial pain has settled. Such continued dysfunction in the virtual body and recruitment patterns in the lumbo /pelvic region may actually increase susceptibility to hip dysfunction and injury further along the kinetic chain.

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## The muscular system — A major dynamic support

A diverse and world wide expansion of research over the past 20 years into the role of muscles in control of low back, pelvic and more recently hip function indicates both deep and superficial muscles work via networks of fascia to become the major supporting framework when sustained postures or dynamic movement is required (Barker et al., 2004; Hides, 1997; Hodges, 2003 2009; O'Sullivan, 1997; 2001; Panjabi, 1992; Panjabi et al., 1994; Richardson et al., 1999; 2002; Holmich, 2007; Vleeming et al., 1995a; 1995b; Vleeming and Lee, 2000; McGill and Cholewicki, 2001; McGill et al., 2003; Mens et al., 2006)

## Motor control of the lumbo/pelvic/hip complex

Motor control of the lumbo pelvic hip complex is a complex synergy of:

- Interrelated kinematics of the spine, pelvis, hips and lower limbs;
- Influences by complex internal and external forces and environmental factors;
- Muscles require stabilising tonic strength, endurance and eccentric control. Dynamic phasic strength, particularly of two joint muscles requiring finely tuned timing of activation and healthy tendons.
- CNS must consider input from the periphery against internal model, then finely adjust muscle recruitment patterns.

## Solving the puzzle of ongoing and /or recurrent lumbo pelvic pain and dysfunction

When acute pain occurs, immediate reflex changes at the motor neuron and within the muscle spindle, due to pain, swelling and inflammatory mediators, result in inhibition of muscle function. A change in muscle fiber type, fatigability and excitability can rapidly occur (Hides et al., 1995). Addressing the multiple and varied component that may be present with ongoing lumbo/pelvic/hip dysfunction and recurring pain involves the following:

- Attempt to understand the underlying causes of initial and possibly ongoing pain/injury/dynamic dysfunction;
- Diagnose body systems involved (likely to be multiple) as sources of dysfunction
  - motor control issues at the lumbar spine (L/S), sacro-iliac joint (SIJ) and hips. Alterations in speed, joint angle and function specific motor recruitment strategies
  - decreased passive stability and/or inflammation L/S, SIJ, hips. Passive structures may need to be addressed as a failure of joint form closure may make optimal dynamic function unachievable without medical intervention (Cusi et al 2010).
  - bone, ligament, tendon compromise
  - neural compromise (peripheral and/or central), tethering or hypersensitivity
  - virtual body changes (i.e. feed forward CNS engrams from the motor cortex), beliefs, coping strategies, proprioception postural sway and balance issues.

## The effect of induced low back pain on postural sway and dynamic control

Postural equilibrium is maintained by subtle but continual body postural sway involving reciprocal activation of the muscles of the spine, pelvis, hips and ankles. This body sway allows fine tuning of postural responses (Mok et al., 2004) to changes occurring internally (e.g. movement of the rib cage with breathing), and externally (e.g. changes in supporting surface) or external forces exerted on the body. When an individual experiences pain, the motor control system will attempt to limit movement with increased muscle co-contraction, limiting movement velocity (McGill, 2004) and will directly impact postural sway.

Experimentally induced low back pain (LBP) results in greater co-contraction of the superficial muscles of the low back region, resulting in increased spinal stiffness and increases spinal compressive forces (Hodges and Moseley, 2003). By increasing co-contraction of the muscles of the low back region, induced LBP has been shown to decrease lumbar spine movement in postural sway with compensated increased pelvic, hip and/or ankle movement (Smith and Hodges, 2005), resulting in greater overall postural sway. Such changes in postural sway make the task of controlling dynamic stability more difficult (Mok et al., 2004), accompanied by a decrease in the variety of motor recruitment strategies utilised (Moseley et al, 2006).

## Changes in the virtual body as a protective adaptation to pain.

As a result of induced pain the virtual body develops compensatory strategies to protect against the perceived threat of pain. These occur at the CNS level and become a preprogrammed feed-forward strategy. With increased co-contraction of the lumbar spine and decreased spinal movement, the virtual body may plan to compensate with increased hip movement contributing to postural sway. This is a complex CNS task and in subjects with induced LBP, standing on a small base of support with eyes closed, resulted in poorer balance (Mok et al. 2004; 2007).

Protective adaptations within the virtual body with induced LBP not only result in changes in muscle recruitment but also change in balance reactions. Mok et al. (2007) noted that subjects with induced low back pain displayed decreased ability to perform repositioning tasks and increased reaction time.

## The effects on the virtual body of beliefs, anticipation of pain and coping strategies

Research indicates that the threat value of pain has the most direct impact on posture and motor control (Moseley et al., 2004).Unfortunately, despite resolution of the original pain, changes to the virtual body can continue, specifically with the anticipation or threat of pain (Moseley et al., 2004), This results in invariable motor recruitment patterns (Moseley and Hodges, 2006); its occurrence may be influenced by ‘resolver’ compared to ‘non resolver’ personalities (Moseley et al., 2004).

In induced LBP subjects, ‘resolvers’ tended to see pain as nuisance and strong motivation to return to normal activity. ‘Non resolvers’ lost normal posture/motor commands and were characterised by increased perception of threat associated with pain. With ongoing pain, the brain’s sensory cortex reorganises itself so a larger part of the brain is devoted to the painful threat. When changes in the virtual body become longstanding, decreased pain or increased functional control in isolation, does not mean decreased disability (Woby et al., 2004).

Positive prospects for reversing some of these longstanding and centrally driven changes to the virtual body lays in research by Moseley (2004), which demonstrated that one three hour “Explain Pain” training session was effective in decreasing the amount of sensory cortex related to the painful area. The addition of psychosocial strategies addressing the perceived threat of pain, combined with the use of graded Motor Imagery Programs, such as “Recognize”, to reverse sensory cortex and homunculus changes possibly holds the key to reversing maladaptive virtual body patterns. Effective rehabilitation programs should provide both distraction and decreased hypervigilance to encourage positive modifications to the CNS (Refshauge, 2004).

Strategies to address virtual body changes, combined with a graded, functional and proprioceptive challenging motor retraining program aim to positively influence the multiple components outlined above that may be present with ongoing lumbo/pelvic/hip dysfunction and recurring pain

Using a biopsychosocial approach, an effective rehabilitation program needs to measure: function (Roland Morris/ Oswestry), pain (VAS), work disability (workplace assessment), fear avoidance (OMPQ) and satisfaction of outcome by the individual. A rehabilitation program should aim to optimise dynamic function and build confidence in normal movement, while decreasing the fear of pain by developing coping and pacing strategies for future episodes of pain or dysfunction.

## Changes in lumbo pelvic posture and motor control linked to groin/hip pain

The link between changes in motor recruitment in LBP and the presence of hip dysfunction has been noted by several researchers. Delayed onset of transverse abdominus has been noted in chronic groin subjects (Cowan et al., 2004), while Mens et al. (2006) noted manual compression of SIJ, increasing adductor force by 39% while decreasing isometric adductor pain in 68% of a symptomatic sporting population. O'Sullivan et al. (2001) noted a similar manual compression of the SIJ during active straight leg testing, which changed minute ventilation patterns towards resting patterns (thus likely altering muscle recruitment patterns) when performed on subjects with SIJ pain and dysfunction. Such SIJ compression can be provided by muscles as demonstrated by Barker et al. (2004), who noted 10N of force through latissimus dorsi and/or gluteus maximus increased stability to lumbar spine and SIJ bilaterally via the influence of the thoraco lumbar fascia. This research reinforces the findings of Snijders and Vleeming, who indicate compression forces required to control shear forces in the SIJ are provided by large global muscles working in discrete synergistic groups (Snijders et al, 1995; Vleeming et al, 1995a; 1995b; Vleeming and Lee, 2000). McGill et al. (2003) suggest co-contraction of muscles in the lumbar spine in the presence of LBP leads to inhibited recruitment of the Gluteals (McGill et al., 2003), resulting in decreased SIJ compression and compensatory increased recruitment of hamstrings, psoas/iliacus to resist resultant reaction forces at the hip (McGill, 2004). Such a pattern of preactivation of the muscles surrounding the hip combined with delayed activation of deep abdominals, pelvic floor and/or gluteals is commonly seen in the presence of LBP (Tsao 2008), SIJ pain (Hungerford et al 2001), longstanding groin pain (Jansen et al 2008; Maffey et al 2007), osteitis pubis (Pizzare et al 2008), hamstring strains (Thelen et al, 2006) and hip dysfunction (Borghuis et al, 2008).

Verrall et al. (2007) was able clinically to link lumbo/pelvic muscle control and hip muscle function. Within an Australian sporting population Verrall et al. (2007) demonstrated 89% of their subject population demonstrating pubic bone oedema returned to sport with a lumbo pelvic program that focused on structured and progressed dynamic function control.

## Changes in motor programming with running speed

Analysis of dynamic function at varying speeds and complexity gives insight into the changes that occur in both joint movement and muscle recruitment patterns with altered demands. Research analysing the changes in muscle recruitment and movement patterns with changes in ambulation speed (from walking to running greater than 3 meters per second), indicate that as speed of walking increases, so does the activity of both deep and superficial abdominals and multifidus muscles (Saunders et al., 2005). As both deep stabilising muscle activity and lumbo/pelvic movement increase concurrently with increased speed, it is logical to suggest that these muscles are not eliminating movement or providing a stiff lumbo/pelvic strategy in these dynamic activities.

Analysis of running kinematics also demonstrates that as ambulation turns to running at speeds of greater than 3 meters per second, the virtual body will change movement strategies by generally increasing the amount of hip flexion and decreasing hip extension (Schache et al. 1999). Muscle recruitment patterns at similar running speeds indicate the virtual body changes muscle recruitment patterns with the changing demands and aims of a dynamic activity. Saunders et al. (2004; 2005) noted in normal subjects, external oblique fired concentrically in walking but eccentrically in running, while transverse abdominus became phasic in activation while the runner is airborne, with concurrent increases in rectus abdominus and external oblique activity.

Such research into dynamic activities demonstrates that optimal dynamic function should be progressed through functional stages that do not aim to encourage lumbo/pelvic stiffness, but are adjusted to retrain appropriate movement and varied as the speed of movement demands.

## Dynamic stability is not stiffness

Many common core stability retraining programs have ignored the importance of movement in optimising dynamic function. Retraining optimal lumbo/pelvic/hip function by advocating co-contraction of lumbar spine muscles during functional dynamic activities only reinforces dysfunctional virtual body strategies that occur with experimentally induced low back pain (Mok et al., 2004). Such spinal co-contraction strategies have been demonstrated in subjects with induced LBP to increase displacement of the whole body during reactive movements from the limbs (Moseley and Hodges, 2006,) while increased reaction times and decreased ability to perform reposition tasks was noted in a similar subject group (Mok et al., 2007).

Advocating increased spinal stiffness as a valid strategy during dynamic functional activity may, in fact, stimulate further trauma along the kinetic chain due to compensatory strategies at the hip and ankles or due to ongoing dysfunctional changes in the virtual body

## A functional and proprioceptive stability program to optimise dynamic function

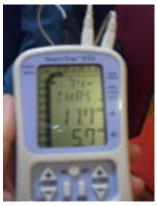
Functional training goals should be not aim to limit movement but to optimise an individual's ability to generate speed-specific strength throughout complex movement patterns, while preserving balance, joint stability and avoid injury risks (McGill 2001; 2004). These goals are:

- Control acute pain, swelling and inflammation if present;
- Retrain tonic (type 1 fiber) muscle endurance of deep stabiliser muscle activity (Tsao et al 2008), progressed with overlaid phasic (type 2 fibers) speed specific and joint angle specific function;
- Build muscle endurance and hypertrophy muscle fibers aiming towards joint angle and contraction specific retraining. Improved motor recruitment does not always equate to improved muscle endurance and/or strength (McGill, 2004);
- Build function and speed specific concentric and eccentric control of key muscle groups (Luoto et al., 1995; McGill, 2003).
- Address changes in proprioception, balance, belief systems and the virtual body.
- Progress proprioceptive training by using small base of support, labile surfaces and labile loads. Utilise Plyometrics to develop speed (Borghuis et al., 2008).

## A graded functional and proprioceptive stability program

***Grade 1** - Tonic and independent contraction of key stabilising muscles*

Exercises performed in static and stable postures using real-time ultrasound (RTUS) and or dual channel muscle EMG biofeedback (EMG).



***Grade 2** - Progress proprioceptive control of core stabilisers*

Endurance of stabilisers while slowly moving arms or legs. Feedback from RTUS and EMG.

***Grade 3** - Dynamic 3D stability of the spine and Hypertrophy muscle fibres*

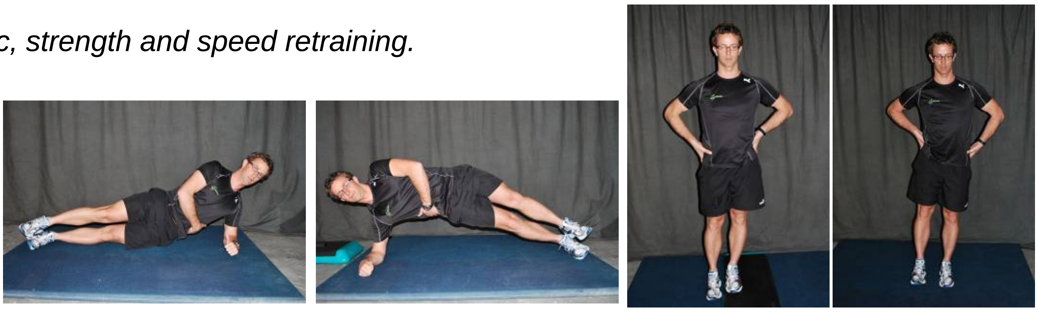
Retrain eccentric contraction of stabilisers working in dynamic slings. Concentrate on effective patterns of movement rather then individual muscles.

***Grade 4** - Dynamic stability of limbs in joint angle and speed-specific patterns*

Increase speed of movement and decrease base of support to challenge balance and postural sway.

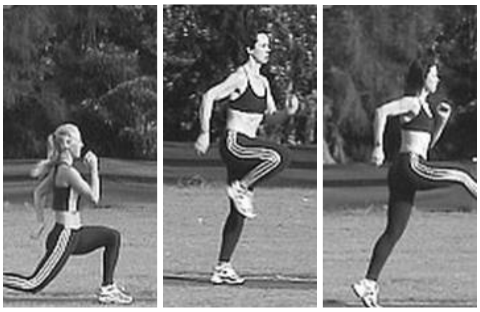
***Grade 5** - Dynamic core stability in speed specific, whole body functional postures*

***Grade 5** - Eccentric, strength and speed retraining.*



***Grade 5** - Activation pattern fine tuning.*

To fine tune preprogrammed movement patterns.



## Intervention to optimise preplanning responses and postural sway

In addition to the above graded and progressed stability program, the following strategies can be utilized and superimposed on the graded exercises. These strategies help to build the individuals ability to pre-plan movement patterns and encourage normalisation of postural sway reactions.

- Retrain internal model or virtual body.
- Retrain feed forward muscle recruitment by balance challenges.
- Utilise small base of support while exercising to encourage normalisation of postural sway, progressing to labile surfaces and labile loads to stimulate variety in preplanned responses (Borghuis et al., 2008).
- Overlay cognitive and distraction tasks while performing challenging tasks e.g. while watching TV or juggling balls, repeating months of year backwards while doing motor control tasks.
- Paired partner tasks with balls, theraband, medicine balls.
- Practice motor control and complex functional/skill bases tasks at the end of training when fatigued.
- Utilise video analysis/ mental practice to excite mirror neurons within the CNS.

## Intervention to optimise virtual body and psychosocial strategies

In conjunction with retraining proprioception and postural sway, the following strategies attempt to address psychosocial and work issues, CNS changes and fear or anticipation of pain effects on motor control patterns.

- Include education on pain and environment with psychological coping mechanisms. Strategies for dealing with the threat of pain and future flair ups. (Kankaanpaa et al., 1999).
- Use of the “Explain Pain” educational material and “Recognise” graded motor imagery web-based program, if central sensitisation and homunculus changes are evident with testing.
- Progress to group setting for functional rehab where appropriate to promote independence with added benefit of social networking within the group.
- Adherence is an important predictor of good outcome, so training and function diaries helpful. The greater the perceived value of the rehabilitation program to the patient the greater the likely effect (Dean et al., 2004).
- Behavioural and psychological support required with a multidisciplinary framework.
- Therapeutic and graded exercises progressing towards joint angle endurance and speed specific function, with an emphasis on building muscle endurance and muscle strength where appropriate.
- Address ergonomic factors and removal of causes.

## Conclusion

When optimising dynamic function of the lumbo/pelvic/hip region, key muscles must not only possess endurance and contraction specific strength, but the CNS must consider input from the periphery and adjust its virtual body accordingly. Addressing proprioceptive changes occurring with LBP involves consideration of balance reactions, speed of movement and the effects of anticipation of pain.

A focus on lumbopelvic stiffness will reinforce dysfunctional movement patterns induced by low back pain, thus training dysfunction and possibly increasing the incidence of hip and lower limb injuries further along the kinetic chain.

# References

Barker PJ, Briggs CA, Bogeski G. (2004) *Tensile transmission across the lumbar fasciae in unembalmed cadavers: effects of tension to various muscular attachments.* Spine 29:129-38.

Butler D, Moseley L. (2003) *Explain Pain.* Adelaide : NOI ISBN: 9780975091005..

Borghuis J, Hof AL, Lemmink K (2008) *The importance of sensory-motor control in providing core stability – implications for measurement & training.* Sports Medicine 38 (11):893-916.

Cowan SM, Schache AG, Brukner P, Bennell KL, Hodges PW, Coburn P, Crossley KM (2004): *Delayed onset of transverse abdominus in long-standing groin pain.* Medicine and science in sports and exercise 36(12):2040-2045.

Cusi M, Saunders J, Hunderford B, Wisbey-Roth T, Lucus P, Wilson S ( 2010):*The use of Prolotherapy in the sacroiliac joint.* British Journal of sports medicine: 44 100-104

Dean S, Weinman J, Payne S (2004) *Exercise therapy for low back pain : a pragmatic controlled trial of a psychological approach to promote adherence and outcome*. 5th Interdisciplinary World Congress on Low Back and Pelvic Pain. Melbourne, Australia, Nov 10-13.

Hides JA, Richardson CA, Jull GA (1995) *Multifidus inhibition in acute low back pain: recovery is not spontaneous.* Proceedings of the 9th Biennial Manipulative Physiotherapy Association Australia Conference. Brisbane MPAA.

Hides JA, Richardson CA, Jull GA, Hodges PW (1997) *Lumbar spine stabilisation: rehabilitation after injury.* Proceedings of the Annual Conference of the Sports Physiotherapy Group (SPG).

Hodges PW, Moseley GL (2003) *Pain and motor control of the lumbopelvic region: effect and possible mechanisms.* Journal of Electromyography and Kinesiology 13:361-370.

Hodges PW, van der Hoom W, Dawson A, Colewicki J( 2009): *Changes in the mechanical properties of the trunk in low back pain may be associated with recurrence.* Journal of Biomechanics, Vol 42, Issue 1:61-66.

Holmich P (2007) *Long standing groin pain in sportspeople falls into three primary patterns, a "clinical entity" approach.* BJSM 41:247-252.

Hungerford B, Gilleard W, Lee D (2001) *Patterns of pelvic motion in subjects with failed load transfer trough the pelvis.* Abstracts of the 4th Interdisciplinary Congress on Low Back & Pelvic Pain. Montreal, pp. 263-268.

Kankaanpaa M, Taimela S, Laaksonen D, Airaksinen O, Hanninen O. (1999) *The efficacy of active rehabilitation in chronic low back pain.* Spine 24(10):1034-1042.

Luoto S Heliovaara M, Hurri H, Alaranta M (1995) *Static back endurance and the risk of low back pain.* Clinical Biomechanics 10:323-324.

McGill SM (2001) *Low back stability: from formal description to issues for performance and rehabilitation.* Exercise & Sports Science Rev 2001; 29(1):26-31.

McGill SM (2004) *Ultimate back fitness and performance*. Wabuno Publishers, Canada.

McGill SM, Cholewicki J. (2001) *Biomechanical basis for stability: an explanation to enhance clinical utility.* Journal of Orthop Sports Physio therapy 31(2):96-100.

McGill SM, Grenier S, Kavecic N, et al (2003) *Coordination of muscle activity to assure stability of the lumbar spine.*. Journal of Electromyography and Kinesiology 13(4):335-9.

Mens J Inklaar H, Koes BW, Stem HJ (2006) *A new view on adductor-related groin pain.* Clin J Sport Med 16:15-9.

Mok NW, Braver SG, Hodges PW (2004) *Hip strategy for balance control in quiet standing is reduced in people with low back pain.* Spine 29(6):E107-E112.

Mok NW, Braver SG, Hodges PW (2007) *Failure to use movement in postural strategies leads to increased spinal displacement in low back pain.* Spine 32(19):E537-E543.

Moseley GL, Nichlos MK, Hodges PW (2004) *Does anticipation of back pain predispose to back trouble?* Brain 127:2339-2347.

Moseley GL, Hodges PW (2006) *Reduced variability of postural strategy prevents normalization of motor changes induced by back pain: a risk factor for chronic trouble?* Behavioral Neuroscience 120 (2):474-476.

Moseley L (2004) *Psychosocial factors and altered motor control.* 5th Interdisciplinary World Congress on Low Back and Pelvic Pain. Melbourne, Australia, Nov 10-13.

O'Sullivan PB, Beales DJ, Avery AF (2001) *Normalisation of aberrant motor patterns in subject with sacroiliac joint pain following a motor learning intervention: a multiple subject case study* Abstracts of the 4th Interdisciplinary Congress on Low Back & Pelvic Pain. Montreal, pp: 178-183 ISBN: 90-802551-1-4 ECO.

O'Sullivan PB, Twomey L. Allison G (1997) *Evaluation of specific stabilising exercise in treatment of chronic low back pain with radiological diagnosis of spondylolysis or spondylolisthesis.* Spine 22: 2959-2967.

Panjabi M (1992) *The stabilizing system of the spine: part 1 function dysfunction adaptation.* Journal of Spinal Disorder 5 (4): 383-389.

Panjabi M, Lydon C, Vasavada A, Grob D, Crisco I, Joseph J, Dvorak J (1994) *On the understanding of clinical instability.* Spine 19 (23): 2642-2650.

Refshauge K (2004) *Interventions aimed at training general fitness and functional restoration programs.* 5th Interdisciplinary World Congress on Low Back and Pelvic Pain. Melbourne, Australia, Nov 10-13.

Richardson C, Jull G, Hodges P, Hides J (1999) *Therapeutic exercises for spinal segmental stabilisation in low back pain.* Churchill Livingstone, Sydney.

Richardson CA, Snijders CJ, Hides JA, Damen L, Pas MS and Storm J (2002) *The relationship between the transversely oriented abdominal muscles, sacroiliac joint mechanics and low back pain.* Spine 27(4):399.

Saunders SW, Rath D, Hodges PW (2004) *Postural and respiratory activation of the trunk muscles changes with mode and speed of locomotion.* Gait and Posture 20:280-290.

Saunders SW , Rath D, Hodges PW (2005) *Changes in three dimensional lumbo-pelvic kinematics and trunk activity with speed and mode of locomotion.* Clinical Biomechanics 20:784-793.

Schache AG, Bennell KL, Blanch PD, Wrigley TV (1999) *The coordinated movement of the lumbo-pelvic-hip complex during running: a literature review.* Gait and Posture 10:30-47.

Smith M Coppieters MW, Hodges PW (2005) *Effect of experimentally induced low back pain on postural sway with breathing.* Exp Brain Res 166:109-117.

Snijders CJ, Vleeming A, Stoeckart R, Kleinrensink GJ (1995) *Biomechanics of sacroiliac joint stability: validations experiments on the concept of self-locking.* Proceedings of the 2nd Interdiciplinary World Congress on Low Back Pain. Rotterdam ECO.

Thelen DG, Chumanov ES, Sherry MV, Heiderscheit (2006): *Neuromusculoskeletal models provide insights into the mechanisms and rehabilitation of hamstring strains.*Exercise and sports science Reviews Vol 34, No 6:.135-141

Tsao H and Hodges PW (2008): *Persistence of improvements in postural strategies following motor control training in people with recurrent low back pain.* Journal of Electromyography and Kinesiology 18:559-567.

Verrall GM et al (2007) *Outcome in conservative management of athletic chronic groin injury diagnosed as pubic bone stress injury.* The American Journal of Sports Medicine 35.3:46-54.

Vleeming A, Pool-Goudzwaard AL, Stoeckart R, van Wingerden JP (1995a) *The posterior layer of the thorico lumbar fascia and its function in load transfer from spine to legs.* Proceedings of the 2nd Interdiciplinary World Congress on Low Back Pain. Rotterdam. pp:141-148 ECO.

Vleeming A, Lee D (2000) *Joint function: development of an integral model for diagnosis and treatment* in KP Singer (ed) Abstracts of the 7th Scientific Conference of the IFOMT. University of Western Australia.

Vleeming A, Snijders C, Stoeckart R, (1995b) *A new light on low back pain.* Proceedings of the 2nd Interdiciplinary World Congress on Low Back Pain. Rotterdam. pp:149-169 ECO.

Woby SR, Watson PJ, Roach NK, Urmston M (2004) *Are changes in fear- avoidance beliefs, catastrophizing and appraisals of control predictive of changes in chronic low back pain and disability*. European Journal of Pain 8:201-210