Functional Core Training

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Part 1
Introduction

The aims of the following articles on functional core training is to allow for the fitness professional to design safe and effective integrated core training programmes that will allow for the client to reach new fitness and sporting levels. In part 1 we will look at the effects of modern living is having upon our posture and how ill advised exercise choice may help to worsen the already present postural distortion patterns. Part 1 also looks at the role the fitness professional should play in postural assessment and upon the importance of correct referral of clients to the appropriate medical professional. Finally in part 1 we look at the aims of functional core training and how it should be applied to achieve an integrated and systematic training programme that are suitable for groups in general training or rehabilitation.

Postural Constraints

The postural constraints of modern life are such that we see prevalence for a shortening and lengthening of many muscle groups that results in the forward postures of the head neck, shoulders, and chronic tightness within the hip flexors. The demands placed upon the pushing muscles has led to a situation where the use of prolonged sitting and being hunched forward over a computer has resulted in a muscular system that is out of balance and the end result may be chronic pain or injuries.

In our role as fitness professionals we should think very hard upon the design of safe and appropriate core training programmes. It is common practice to see athletes or gym members performing numerous sit-up exercises in an order to strengthen their abdominal muscles. Chek (2006) has studied the effects of excessive abdominal training and has noted the following postural changes "Forward head posture, rib cage posture, pelvic tilt and overall postural alignment." What can we learn from the above is that we should be concentrating on exercises that will help to reverse the musculature adaptations to modern life instead of failing our clients by giving them what they think they want. They may say that they want a six pack but I bet they don't want the pain and suffering associated with the likely postural distortion patterns. This is not to say that exercises that work the abdominals are not necessary, but rather that they should be included in safe and effective integrated programmes that has its main aim of improving faulty posture.

Postural Awareness

The first thing that we should become aware of as fitness professionals is in the importance of correct posture. Kendall et al, (1993) cite that stated by Basmajian "among mammals, man has the most economical of antigravity mechanisms once the upright posture is attained. The expenditure of muscular energy for what seems to be a most awkward position is actually extremely efficient." Kendall et al state that "in the standard posture, the spine presents the normal curves, and the bones of the lower extremities are in ideal alignment for weight bearing. The neutral position of the pelvis is conducive to good The neutral position of the pelvis is conducive to good alignment of the abdomen and trunk, and that of the extremities below." Kendall et al, (1993) further state that "the chest and upper back are in a position that favours optimal function of the respiratory organs. The head is erect in a well balanced position that minimises stress on the neck musculature." The above suggests that if correct alignment of the chest, back, neck, head, spine and pelvic areas are not optimal this can result not only in problems for the associated areas (as noted by Chek above) but also for the limbs of the lower body as this has the effect of bringing them out of alignment too. It is outside the scope of practice for fitness professionals to perform postural assessments and to suggest corrective exercise strategies, but rather we should have a proper understanding of posture and postural dynamics that allow for us to design exercise programmes that are both safe and effective. When this is achieved we may truly help our clients to move more functionally. We must remember that a medical referral to the appropriate medical profession is

carried out if we suspect that any clients have abnormal posture.

We must learn to crawl before we can walk never mind attempting to run. Progression of the profession with safe and effective training programmes that are truly functional and integrated with the co-operation and practice of other medical professions is a more prudent method for the development of the fitness Industry. Walden (2006) suggests that blame: In our increasingly litigious environment, we may be in line for blame if we fail to recognise a problem and continue to exercise a client inappropriately for their condition. We must carry out appropriate PARQ medical history, injury history and postural awareness and refer them if we suspect any red flag areas.

Aims of Functional Core Training

The main aim of the fitness professional must be to stay at the forefront of innovation by using the advances in science, and research and being able to apply these into safe and practical exercise programmes. One method that can be used to achieve the above is to design programmes that are functional, systematic and integrated, whether the target group is in general training or rehabilitation. It is therefore important that we as fitness professionals fully understand the functional kinetic chain. Clark (2002) cites Aaron (1996) as stating the importance of the functional kinetic chain as "an integrated training programme is a comprehensive approach that strives to improve all components necessary to achieve optimum performance (strength, balance, flexibility, endurance and power). Since the core is where the human body's centre of gravity is located and is where all movements begin." It is therefore important that we get the training of the core correct and concentrate on methods that are appropriate to the client that result in safe and effective programmes. Proper development of the core musculature will result in more efficient movement patterns and optimal performance.

The aims of functional training therefore are to train the client in an environment that uses multiplanar movements that include acceleration, deceleration and dynamic stabilisation. It is important that we move away from exercises that only work in single planes of motion and only work muscles in isolation. The body functions as a unit, no one muscle acts in isolation, so therefore training should work with exercises that work the full muscle units (agonist, antagonist and synergistic muscles).

Irwin Korr perfectly explains this *"The spinal cord is the keyboard on which the brain plays when it calls for activity. But each "key" in the console sounds not an individual "tone" such as contraction of a particular group of muscle fibres, but a whole "symphony" of motion. In other words, built into the cord is a large repertoire of patterns of activity, each involving complex, harmonious, delicately balanced orchestration of the contractions and relaxations of many muscles. The brain thinks in terms of whole motions, not individual muscles. It calls, selectively, for the programmed patterns in the cord and brain stem, modifying them in countless ways and combining them in an infinite variety in still more complex patterns. Each activity is subject to further modulation, refinement and adjustment by the feedback continually streaming in from participating muscles, tendons and joints."*

Gambetta (1999) states that "The CNS directs preprogrammed patterns of movement (motor programmes) that can be modified in countless ways to react to gravity, ground reaction forces and momentum." The CNS is a key component of functional movement patterns and as such any exercise programmes should be designed that trains the system to perfect movement patterns associated with the sport or activity.

Gambetta (1999) states "All movement involves force reduction, followed by stabilisation, followed by force production. Thus training and rehab should incorporate all planes of motion (sagital, frontal and transverse) while opening and closing the chain." Gambetta (1996) has shown that movements may appear single plane dominant with effect the other planes are working to maintain dynamic stabilisation and maintain optimal neuromuscular efficiency. The aim is therefore to exercise the entire core area with exercises that work all the planes of motion while optimising functional strength and neuromuscular efficiency.

Gambetta (1996) looked at the importance of balance during movement and states that "Because of the traditional definition, we tend to think of balance as static: as in a person standing straight for a period of time. However in functional balance, balance is dynamic. Because an athlete is constantly moving, balance entails the body repeatedly losing and regaining control of its centre of gravity in its attempt to perform efficient movement. Additionally there is a continual reaction to other external forces such as the playing surface, opponents and the ball."

Gambetta (1999) states that "Movement is a constant interplay between force reduction and force production. The key to quality movement is proprioception, which is the position sense provided by the receptors in the joints, ligaments and tendons." Balance training provides the desired proprioceptively rich environment that leads to the core being able to reduce and produce forces safely and effectively that allows for correct and appropriate movement

patterns.

Recent articles by McGill (2006) suggest that "When all muscles at a joint stiffen together a "super stiffness" phenomenon generally occurs. The total stiffness at a joint suddenly becomes more than the sum of individual muscle stiffness. Consider the abdominal wall in creating "core stability". Rectus abdominus, external and internal obliques and transverse abdominus appear to bind together when all are active to create a super stiffness higher than the sum of each individual muscle." The above statement means that particular muscles should never be worked in isolation instead to maximise and recruit the full strength exercises should be performed that works all of the muscles within the core to generate rapid muscle activation and maximal force production, the core must also be equally able to rapidly reduce of muscle forces. McGill (2006) states that "Super stiffness needs only to occur briefly in such cases, but if it needs to brief, the motor control system must be highly tuned to ensure optimal super stiffness." If the aim of the game is to improve sports performance and to maximise power of movement execution it looks as though we need to work in maximising our super stiffness. Muscle stiffness is the key to allowing us to lift heavier weights or to withstand higher pressures whilst minimising the energy losses and most importantly ensuring the core does not buckle.

The aims of functional core training are to improve the dynamic postural control that ensures for the appropriate levels of muscular balance and joint athrokinematics around the lumbo-pelvic-hip area. The training should allow for the development of dynamic functional strength and improved neuromuscular efficiency throughout the full kinetic chain. It is important to remember that the core muscular is the start of all movements and it therefore makes sense that it is developed to its optimal level.

Clark (2000) has stated the benefits of core training as:

- Improve dynamic postural control.
- Ensure appropriate muscular balance and joint athrokinematics.
- Allow for the expression of functional strength
- Provide intrinsic stability to the lumbo-pelvic-hip area, which allows for optimum neuromuscular efficiency of the rest of the kinematic chain.

Gambetta (1999) has stated that "The ultimate goal of core training is to get the athlete standing and then shifting his or her weight from one foot to the other, forcing the core to stabilise the centre of gravity over the changing base of support. This will train the core for what it has to do during the real life functional movements of running, jumping and throwing." If we can remember the above we will be able to design safe and appropriate exercises that will train the core to effectively deal with the movement patterns associated with our sporting activities.

The concepts of core stabilisation

The core can be defined as the lumbo-pelvic-hip complex: there are 29 muscles that have attachments within this area. The importance of the core is to maintain the optimal length tension relationship between the functional agonists and antagonists. The achievement of optimal muscular relationship's result in the optimum force couple relationships in the lumbo-pelvic-hip complex. Clark cites the following studies by Sahrmann (1997), Strohl et al, (1981) and Warmerdam (1996) as they suggest that maintaining optimum length tension relationship and force couple relationships allows for the maintenance of optimum joint athrokinematics in the lumbo-pelvic-hip complex during functional kinetic chain movements. The achievement of this allows for correct neuromuscular control of the entire kinetic chain and allows the muscles to contract with the correct balance of eccentric (braking), concentric (accelerating) and isometric (dynamic stabilisation) contractions during functional movements throughout all planes of motion. Myers in his book Anatomy trains (2001) shows in detail the routes of the pathways of the myofascial meridians and how these are all routed through the core musculature of the body and this shows us how important it is that the musculature of the core is trained correctly to provide optimal movement within the whole body. The above has been concluded by Clark (2002) as *"the core operates as an integrated functional unit, enabling the entire kinetic chain to work synergistically to produce force, reduce force and dynamically stabilise against abnormal force."* It can be concluded that the core or lumbo-pelvic-hip complex must be trained in such a manner that allows the core to efficiently distribute the balance of weight, absorb the forces and transfer the ground reaction forces. The integrated interdependent system of the lumbo-pelvic-hip complex therefore needs to be trained in a fashion that allows for it to function efficiently during dynamic activities.

The problem area that may have to be addressed more than gaining functional strength, power, endurance and neuromuscular control of specific muscles that enable them to carryout functional movements is the ability to develop the muscles to maintain spinal stabilisation. For it is the effective stabilisation of the spine musculature that will allow it to fully develop the strength, power, neuromuscular control and muscular endurance of its prime movers. Research by Hodge's et al, (1996) state "A weak core is a fundamental problem inherent to inefficient movement that lead to predictable patterns of in-

jury." The role of that the core musculature plays is to provide a protective mechanism for the spine and helps to protect it from unwanted forces that are part of functional movements. It is therefore imperative that we as fitness professionals design programmes that help our clients to develop strength, neuromuscular control, and power and muscle endurance of the core/lumbo-pelvic-hip complex. The effective design will allow us to help our clients to develop greater balance and muscular functioning of their entire kinetic chain. The development of the greater levels of neuromuscular control and stabilisation strength helps to provide an improved biomechanical position of the kinetic chain and therefore will allow for the efficient movement throughout the entire kinetic chain.

The development of neuromuscular efficiency is achieved by ensuring good postural control and stability strength are executed, as this will allow the body to decelerate forces of gravity, ground reaction forces and momentum. The importance of the neuromuscular efficiency is such that poor levels of neuromuscular efficiency will limit the ability of the kinetic chain to maintain optimum levels of forces resulting in loss of dynamic stabilisation. This decease in stabilisation may lead to compensation factors such as synergistic dominance, reciprocal inhibition and arthrokinetic inhibition as well as poor posture during movement. This will lead to extra strain and stresses being placed upon contractile and non-contractile tissue. Which in turn will progress to the start of the pain/injury cycle, as the muscles will develop repetitive micro trauma, abnormal biomechanics and injury?

The Lumbo-Pelvic-Hip Complex Musculature

The inner Unit
Transverse Abdominus
Internal Oblique
Multifidus
Lumbar Transversospinalis

The Outer Unit
Rectus Abdominus
External Oblique
Erector Spinae
Quadratus Lumborum
Adductor Complex
Quadriceps
Hamstrings
Gluteus Maximus

The key musculature of the lumbar spine includes the transversospinalis group, erector spinae, quadratus lumborum and latissimus dorsi. The key abdominal musculature includes the rectus abdominus, external oblique, internal oblique and transverse abdominus. The key hip musculature includes the gluteus maximus, gluteus medius and the psoas. Once again it is important to remember that the musculature operates in functional integrated units and the central nervous system is designed to optimise the selection of muscle synergies, not isolated muscles.

The key therefore to proper function of the core is down to the correct levels of synergistic interdependent functioning of the whole lumbo-pelvic-hip complex as this enhances the stability and neuromuscular control throughout the entire kinetic chain.

Postural Factors

The aim of core stabilisation is to maintain good posture (dynamic postural control) throughout functional movements and this helps to prevent the onset of serial distortion patterns. The aim is therefore to provide exercise that will address any postural misalignment in order that correct muscle tension relationships and arthrokinematics are maintained during movement. Gambetta (2006) states "*Posture is clearly an integral part of many aspects of movement. In fact, I believe that dynamic postural alignment and subsequent dynamic muscle balance are fundamental movement skills. So it should be no surprise that a training regime for good posture is very similar to any functional strength conditioning program. We need to train strength, flexibility, balance and movement. We need to incorporate multi-joint and multi-plane work with high proprioceptive demand. We need to target deficiencies with remedial work whenever warranted."*

*G*ambetta (2004) further states the importance of the anti-gravity muscles (gastroc/soleus group, quadriceps group, glutes and erector spinae group) as "*the larger core muscles known as anti-gravity muscles play a major role in maintaining a sound, functional athletic posture."* In other words there should be an understanding on the muscles that defy gravity and keep us in a balanced position. To further our knowledge of the anti-gravity muscles we should also develop a better understanding on the role gravity plays on loading the body. Gambetta (2004) suggests "*Gravity and its effects must be a prime consideration when designing and implementing a functional core training programme or we are not preparing the body for the forces that it must overcome. Therefore we must be aware of our orientation to gravity when we are training the core. When we are standing, we are parallel to gravity and when lying or seated we are perpendicular to gravity. The demands of individual sports will dictate the primary body position we should use to train the core. For most sport, the majority of core training should be performed in upright and moving positions."*

Neuromuscular Considerations

The use of exercises to strengthen and stabilise the core can help to improve the optimum neuromuscular efficiency by improving the dynamic postural control. Research by Beckmann and Buchannan (1995), Bullock-Saxton (1994, 1993) have shown that clients who have low back pain have an abnormal neuromotor response of the trunk stabilisers accompanying limb movement, it has also been noted that there is an increase in the postural sway and an decreased amount of the limits of stability. To further worsen the situation numerous research studies have shown that if clients have had lower body ligamentous injuries they will have decreased dynamic posture stability in the proximal stabilisers of the lumbo-pelvic-hip complex. These ligamentous injuries can lead to further problems with a decrease in the muscle activity. Ligamentous and joint injuries may further lead to muscle inhibition. The muscular inhibition has the effect of altering neuromuscular control of other muscular segments and the kinetic chain then becomes secondary to proprioception and kinaesthesia. In conclusion this means that all of the muscles that cross over the injured or painful swollen area are inhibited in carrying out their full function.

The final neuromuscular consideration that must be addressed is that of athrogenic muscle inhibition. This comes about as a direct result of poor arthrokinetic reflexes that are mediated by joint receptor activity. Therefore clients who show poor arthrokinematics will result in the muscles that move the joint being inhibited. Clark (2002) gives an example of this as *"If an individual has a sacral torsion, the Multifidus and gluteus medius can be inhibited. This leads to abnormal movement in the kinetic chain. The tensor fascia latae become synergistically dominant and become the primary frontal plane stabiliser. This often leads to tightness in the iliotibial band, which decreases frontal and transverse plane control at the knee. Furthermore if the Multifidus is inhibited, the erector spinae and psoas become facilitated. This will further inhibit the inner unit stabilisation mechanism (internal oblique and transverse abdominus) and the gluteus maximus, which also decrease frontal and transverse plane stability at the knee.* " The question is how do we help to prevent the above postural neuromuscular problems? The answer is to include core stabilisation exercises that will improve the strength, dynamic stability, power and muscular endurance of the lumbo-pelvic-hip complex whilst helping to prevent injury and its chain reactions that are started after an injury occurs.

Core Assessment

This is an area that brings up differing opinions within the fitness and physical therapy worlds as some trainers such as Clark believe that the use of -standing postural assessments can allow for the fitness professional to recommend specific exercise strategies to correct any static postural abnormalities. My opinion on the use of static postural assessments for fitness professionals who deal with clients who wish to develop there fitness is limited, as the body is asymmetrical so the successful correction of supposed muscle imbalances may not be achievable or desirable. The common result pattern from static postural assessments are that many clients would not be deemed fit enough for exercise, as nearly all the clients that I have tried this form of assessment on have shown abnormalities and asymmetries, that would require corrective exercise protocols before any major movement or sporting activities would be permitted.

It is clear to see from the above that some form of assessment needs to be carried out that is not static. Physical therapist Gray Cook has developed the movement screens. These include the use of active movement patterns, such as squat, step over etc. These screens may help to improve the assessment of some of the basic movements associated with sports and fitness activities but is it the best method? This method may be amore appropriate within the fitness environment as it will allow the fitness professional to assess some basic movement patterns that we should all be fully familiar with and will allow us to design suitable programmes that will correct the muscular imbalances associated with the movement patterns.

Gambetta on the other hand disagrees with this form of assessment as he sees that the client must be free to move their body performing movements and skill patterns used within their sport. Again if we ask the question is this the best method? We may answer that this is the best method if the coach fully understands the sporting movements and demands placed upon athletes, and has the skill and knowledge to identify the weak areas and how best to develop the weak areas to develop superior conditioned athletes.

Safety Considerations

The training routines of the vast majority of clients who exercise are such that the levels of core stabilisation training are of an inadequate level in comparison to the other major muscle groups. We have established that fact that the aim of the core training programme is to develop the power, strength, muscular endurance and neuromuscular control in the lumbo-pelvic-hip complex. We must however select the appropriate levels of exercise as research by Hodge's (1995, 1996, 7 1997) have shown that there is a decreased firing of the transverse abdominus, internal oblique Multifidus and deep erector spinae in individuals with low back pain.

If exercises are performed with muscular inhibition this will lead to muscular imbalance and inefficient neuromuscular control in the kinetic chain. In the studies by Hodge et al, they concluded that poor pelvic stabilisation during abdominal training led to greater intradiscal pressure and compressive forces upon the lumbar spine. Research by Ashmen et al, (1996), Beim et al, (1997) and Norris (1993) noted that hyperextension training without proper pelvic stabilisation led to increased intradiscal pressure that can cause buckling of the ligamentum flavum that may lead to narrowing of the intervetebral foramen. Beim et al (1997) also noted that there was a reduction in the levels of stabilisation endurance with chronic low back pain. The core stabilisers consist mainly of type 1 slow twitch fibres (red muscle fibres, oxidative). It is important therefore that exercises are included with the correct levels of time under tension (TUT) and this method is best set with a contraction time between 6-20 seconds. Emphasis should be placed upon hyper-contractions at the end ranges of motions. The use of these methods will improve the levels of intramuscular co-ordination, which improves static and dynamic stabilisation. The aim of the core endurance training is to ensure that the client can maintain dynamic postural control for prolonged periods of time.

Beim (1997) further noted that the Multifidus muscle did not have a spontaneous recovery when the symptoms have subsided. Further to this it has been established that traditional curl up increases the intradiscal pressure and compressive forces placed upon l2-l3.

It can be established from the above that whilst exercising the core it is important that pelvic stabilisation is achieved, this leads to another area of debate on how best to achieve pelvis stabilisation. The method favoured by Clark, Chek that was derived from the study by Hodge et al is for the drawing manoeuvre to be performed. The drawing in manoeuvre involves the client actively contracting the transverse abdominus by pulling it in towards the spine. The other side of the fence prefer to use the bracing method that does not isolate any one muscle but tightens the musculature around the core area. This is the method that I have actively used in training clients as I believe that muscle recruitment should be synergistic and this is best left to the wisdom of the body as it fine tunes the muscular activation of the various muscles of the core that allows for the correct amount of pelvic stabilisation to be achieved. McGill (2002) states that the evaluation of various tasks and movements revealed that "The muscular and motor control system must satisfy requirements to sustain postures, create movements, brace against sudden motion or unexpected forces, build pressure, and assist challenged breathing, all the while ensuring sufficient stability. Virtually all muscles play a role in ensuring stability, but their importance at any point in time is Determined by the unique combination of the demands just listed.".

The maintenance of the neutral position of the spine during core work will also lead to improved posture, muscle balance and stabilisation. Finally the position of the head during core work must be such that it is kept in a neutral position as a position of the head during core work must be such that it is kept in a neutral position as a instability and muscle imbalances that are secondary to the pelvo-ocular reflex. It is important therefore that the eyes are kept level during movements. Finally hyperextension of the sternocleidomastoid muscles can have the effect of extending the upper cervical spine, then it is likely that the pelvis will rotate anteriorly to realign the eyes and this may lead to a decrease in pelvic stabilisation and muscular imbalances.

Core stabilisation training guidelines

All programmes should follow the following protocol:

1. Progressive
2. Systematic
3. Activity specific
4. Integrated
5. Proprioceptively challenging
6. Based upon current science

Programme variables

1. Plane of motion
2. Speed of execution
3. Loading parameters (physioball, medicine ball, dumbbell tubing etc.)
4. Body position
5. Amount of control
6. Speed of execution
7. Amount of feedback
8. Duration (sets, reps, tempo, time under tension)
9. Frequency

Integrated Functional training continuum

1. Multi-planar (3 planes of motion)
2. Multi-dimensional
3. Use the full muscle contraction range
4. Manipulate all acute training variables (sets, reps, intensity, recovery, frequency and duration)
5. Use full contraction velocity range

Loading

1. Stability ball
2. Cable
3. Tubing
4. Medicine ball
5. Power balls

6. Body blades
7. Dumbbells
8. Weighted vests

Clark (2002) states that "a comprehensive core stabilisation training programme should adhere to specific guidelines. It should be systematic, progressive and functional. The programme should emphasise the entire muscle contraction spectrum, focusing on force production (concentric contraction), force reduction (eccentric contraction) and dynamic stabilisation (isometric contraction).

The core stabilisation programme should begin in the most challenging environment the individual can control."

Exercise selection criteria

1. Safe
2. Challenging
3. Progressive
4. Systematic (integrated function continuum)
5. Proprioceptively enriched
6. Activity specific

Exercise progression continuum

1. Slow →Fast
2. Known →Unknown
3. Stable → Controlled → Dynamic functional
4. Low force → High force
5. Correct execution → Increased intensity

It is important to remember that the main goal of a core training programme is to improve the levels of neural adaptation. Quality of movements should ultimately be expressed over that of quantity. Finally it is important that instructors who allow clients to train using poor technique and poor neuromuscular control, may result in them developing poor levels of stabilisation and motor patterns.

Before or After

When should the core be trained again this is an area that raises some contention between trainers but I firmly belief that core work should be done before any strength work as if we are to believe what we know on the importance of the core in improving performance levels then it must be trained optimally when we are fresh and fully committed to training and not crammed in at the end of a session as if it is an after thought.

Exercise selection

Below are some suitable exercises that work the core in a truly functional manner from a standing position.

Marching Core

Bent Leg

Outside In

Inside Out

Figure Eight

Straight leg

Outside In

Inside Out

Figure Eight

Hurdle Under

Torso circles

Side bends

Good mornings

Wood chopper

References

Paul Chek; The inner unit, http://www.Ptonthenet.com

Michael Clark; Essentials of Integrated Training Part 5: Core Stabilization Training; http://www.Ptonthenet.com

Gambetta and Gray: Everything in Balance; http://www.momentummedia.com/articles/tc/tc0602/everybal.htm

Gambetta: Hard Core Training; http://www.momentummedia.com/articles/tc/tc0904/hardcore.htm

Gambetta; Force and function; http://www.momentummedia.com/articles/tc/tc0905/forcenfun.htm

Kendall, McCreary and Provance: Muscles Testing and Function, 1993, pp71.

McGill: Super Stiffness: http://www.backfitpro.com/recent%20articles/Enhancing%20back%20performance%20with%20super%20stiffness.pdf

Thomas W Myers, Anatomy Trains; Churchill Livingstone: 2001

Hodges PW, Richardson CA: Inefficient Muscular Stabilization of the Lumbar Spine Associated with Low Back Pain. Spine 21(22):2640-2650, 1996.

Gambetta: Perfect Posture: http://www.momentummedia.com/articles/tc/tc1602/posture.htm

Gambetta: Middle In Motion: http://www.momentummedia.com/articles/tc/tc1407/middlemotion.htm

Beckman SM, Buchanan TS: Ankle Inversion and Hypermobility: Effect on Hip and Ankle Muscle Electromyography Onset Latency. Arch Phys Med Rehabil 76(12):1138-1143, 1995.

Bullock-Saxton JE: Local Sensation Changes and Altered Hip Muscle Function Following Severe Ankle Sprain. Physical Therapy 74(1):17-23, 1994.

Bullock-Saxton JE, Janda V, Bullock M: Reflex Activation of Gluteal Muscles in Walking; an Approach to Restoration of Muscle Function for Patients with Low Back Pain. Spine 18(6):704-708, 1993.

McGill: Low back disorders. Human Kinetics (2002) pp, 144.

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For further articles and information on strength training, functional training, fitness and nutrition please visit the link below.

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