Prevention & Management of Lower Back Pain due to Spondylolysis in Young Aesthetic Athletes

By

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Summary

As a trampoline and tumbling gymnast and diver, many of my teammates and I spent a large portion of our athletic careers fighting lower back pain, with three or more back braces on deck for practices. For the most part, we were underweight, hyperlordotic, flexible, and strong individuals bothered more by the performance and practice reductions brought on by our lower back than the moment-to-moment pain exacerbated by handsprings, loaded take-offs, and other hyperextension skills. Given the statistics presented in the following paper, it appears more than likely that a significant percentage of us were suffering from spondylolysis, a stress fatigue defect of the pars interarticularis correlated with clinical instability, mechanical lower back pain, and sciatica. This condition is present in approximately as many as 1 in 5 aesthetic athletes, who are athletes participating in strongly appearance-contingent sports such as diving, gymnastics, skating, and dancing.

The purpose of this paper is to explore interventions to manage and possibly prevent lower back pain due to spondylolysis in aesthetic athletes. Motor control exercises offer a promising intervention approach that is supported in clinical literature as an appropriate non-operative approach for restoring function in chronic lower back pain, generally, and in theoretical biomechanic literature as a non-operative approach that could be especially effective in cases of clinical instability, such as spondylolysis. Additional recommendations are made in consideration of issues specific to aesthetic athletes, such as psychological and social elements of the aesthetic training athlete and high-risk comorbidities.

In conjunction with this paper, I assembled an evidence-based online resource targeted at current aesthetic athletes and their support network to better understand their risks for spondylolysis and the potential role of a motor control exercise intervention. As I personally experienced and found reiterated in the literature, there is currently minimal consumer-based information online that discusses exercise therapy for spondylolysis. To this end, I prepared illustrations of each of the recommended exercises and the associated anatomy and handouts for an athlete and their coaching team to use. The website and handouts can be found at: http://www.aestheticmce.weebly.com ; I encourage the reader to view it at their leisure. The method of development of my online resource, deliberate artistic decisions, and other choices is explained in Section IV of this paper.

Sports injury prevention is a complicated field with many invested players. I do not believe that my online resource will be revolutionary in reducing the incidence of spinal injuries in aesthetic athletes, but I certainly hope that my website will serve as a useful starting point for an open dialogue between the athlete and his or her support network to take prevention-oriented steps. I also hope that this website can empower the athlete, explain his or her risk of spondylolysis, and clarify the current stance of the literature on suitable prevention strategies. My personal goals for the project are to learn more about relevant musculoskeletal physiology and sports medicine research and to increase my ability preparing effective medical illustrations.

Abstract

This project investigates the prevention and management of lower back pain due to lumbosacral spondylolysis in adolescent female athletes in the aesthetic sports of gymnastics, skating, diving, and dancing. High prevalence of symptomatic spondylolysis, high participation rates and shared biomechanical and social stresses render aesthetic sports a promisingly homogenous subgroup for injury prevention purposes.

Although there is limited research on spondylolysis lower back pain, this paper argues that the most conclusive evidence supports the use of motor control exercises (MCE) as a conservative starting point for managing and possibly preventing lower back pain due to spondylolysis. MCE is first established as a suitable conservative approach for chronic lower back pain, generally, then distinguished from other approaches for treatment of spondylolysis, specifically, based on the theoretical biomechanic literature presented. Additional recommendations are finally made based on aesthetic-athlete specific issues, including comorbidity susceptibility and her unique practice environment.

This paper also discusses the method of development for the corresponding project: an evidence-based, consumer-based online resource for spondylolysis management and prevention, which can be found at http://www.aestheticmce.weebly.com . The website was developed and originally illustrated using HONcode principles and Kinzie's model for instructional design.

Introduction

Lower back pain (LBP) is an important public health issue that accounts for 5-8% of athletic injuries (Harvey & Tanner, 1991). Effective evidence-based consumer resources targeted to an adolescent athlete with limited scientific background and his or her coaching team, however, are scarce and often confusing or irrelevant due to inconclusive evidence, reliance upon popular strategies rather than exclusively evidence-based research, and the necessity of locating a resource specific to the athlete's sport or biomechanical demands.

For the purposes of this project, I have decided to study chronic lower back pain in relation to lumbosacral spondylolysis in adolescent female athletes in the aesthetic sports of gymnastics, skating, diving, and dancing. This group of sports has incidence rates of spondylolysis three to ten times greater than the general population, where roughly two-thirds of these cases will be symptomatic in the form of lower back pain and/or sciatica (Soler & Calderón, 2000). High participation rates and shared biomechanical and social stresses render aesthetic sports a promisingly homogenous subgroup for injury prevention purposes. The population of interest is gender specific (female) because this group faces different social pressures that influence cortical bone density (Rose, 2008), higher reported spondylolysis progression incidence (Soldera & Calderón, 2002), and lower load distribution that alters spine biomechanics (Virmavirta & Isolehto, 2014). Biomechanically, aesthetic sports involve repetitive hyperextension, loading, and rotation of the lumbar spine, which makes it more susceptible to spinal injury (Soler & Caldreón, 2000). Additional issues pertinent to injury prevention in aesthetic sports include the young age of athletes, multiple party coaching teams (multiple invested coaches, parents, health professionals), demanding practice requirements, high pressure to achieve, an environment that may value "working through pain", susceptibility to female athlete triad (Nattliy et al., 2007), and success dependent upon the ability to continually learn novel higher-risk skills.

Recent systematic reviews do not conclusively support any specific treatment approach for LBP due to spondylolysis. There is also only limited research on spondylolysis LBP prevention, but the most conclusive evidence has supports the use of motor control exercises (MCE) to address aberrant trunk movement in chronic lower back pain (Biely et al., 2014; O'Sullivan, 2005). Additionally, there are a number of biomechanics studies that conceptually support MCE for the prevention of spinal injuries (Standaert, Weinstein, & Rumpeltes, 2008). My research will focus on these two directions to analyze the effectiveness of MCE in preventing lower back pain due to spondylolysis. Then, additional recommendations will be made based on considerations specific to aesthetic athletes.

I. Spondylolysis Background

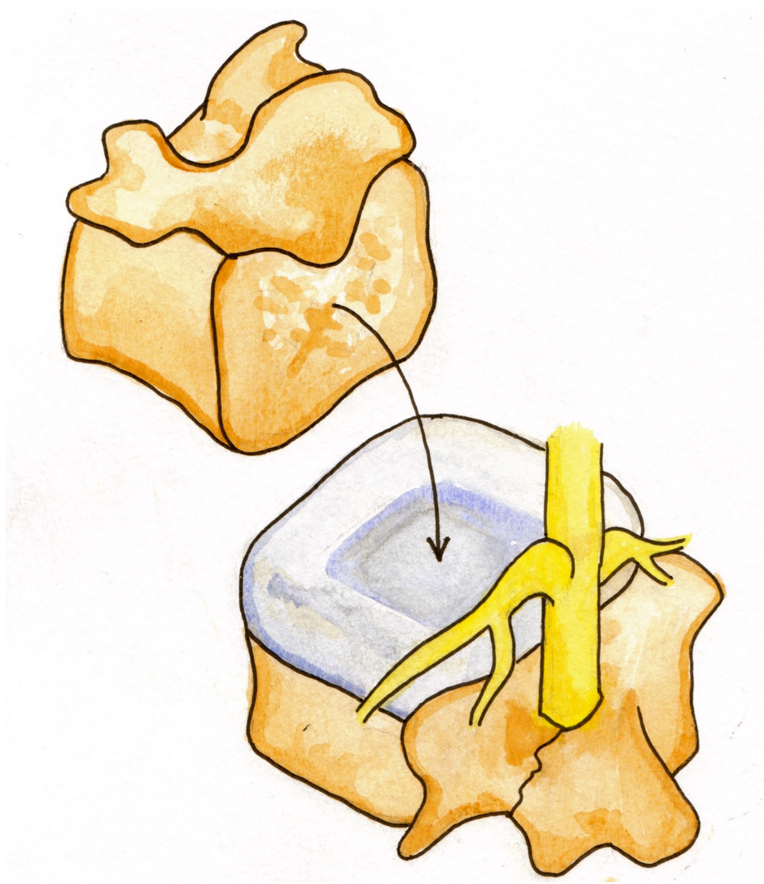
Deriving from the Greek words "spondulos," meaning vertebra, and "lusis," meaning loosening or unbinding; spondylolysis is a condition that describes a bony defect or fracture in the pars interarticularis (literally the part between the [facet] joints) of the vertebral arch of the spine. Spondylolysis has been found in approximately one-half of all young athlete patients complaining of low back pain (Micheli & Wood, 1995; Soler and Calderón, 2000) and it is considered by many clinicians to be the most common cause of low back pain in adolescent patients (Haun & Kettner, 2005; Pediatric Orthopaedic Society of North America [POSNA], 2007).

Functional Anatomy of the Spine

The spine provides the structural framework for humans to achieve upright posture and motion. It is commonly understood subdivided into its four primary curvatures: the cervical (concave), thoracic (convex), lumbar (concave), and sacral/coccyx (convex) curvatures, described in descending location. The lumbar (lower) spine has five vertebrae, each separated by intervertebral discs to cushion the vertebral bodies. Behind each of the vertebral bodies is a bony ring (lamina) with seven main processes: the spinous process, which extends posteriorly, can be seen as superficial "bumps" running down the back, and forms the site for muscle attachments; the left and right transverse processes, which extend laterally and form the site for muscle attachments; and the left and right inferior and superior articular processes, which connect vertebrae to one another by forming synovial facet joints by the articulation (meeting) of the inferior and superior articular processes of an upper and lower vertebra, respectively. The hole (also known as the neural foramen) of the bony ring (also known as the neural arch, vertebral arch, or lamina) contains and protects our spinal cord as well as the adjacent vasculature and exiting and entering nerves.

Fig. 1 Illustration of a Left Unilateral Pars Defect

Exploded view of two lumbar vertebrae, with the inferior vertebrae depicted with a blue intervertebral disc, yellow innervation, and left unilateral pars defect.



Spondylolysis pars defects most commonly occur in the L5 or L4 vertebra (71-95% and 5-23%, respectively; McCleary & Congeni, 2007), which are the lowest two vertebrae of the lumbar spine. When both sides of the pars interarticularis are fractured (a bilateral defect), the inferior articular processes, lamina, and spinous process are physically separated from the superior articular process, pedicles, transverse process, and vertebral body, although there is still a weak soft tissue connection remaining. In some cases, spondylolysis can thus progress into spondylolisthesis, where the impacted vertebra slips forward (anterolisthesis) because it is no longer connected to the adjacent facet joint. Females are two to four times more likely to experience progressive slippage than males, but, after adolescence, only 15% of all spondylolysis cases progress to spondylolisthesis (Watkins & Watkins, 2010; Soler & Calderón, 2000). Spondylolisthesis will be discussed throughout this paper as a condition to better understand spondylolysis, but it is important to note that resolving back pain due to spondylolisthesis will not be the target of any of the proposed interventions because it is an entirely different condition with its own complications.

Epidemiology

Spondylolysis is normally present in 3-6% of the general adult population and 90% of these cases are asymptomatic (Beutler et al., 2003; Roche & Rowe, 1951; Saraste, 1987). Certain adolescent athletic populations, however, have significantly higher incidences of both symptomatic and asymptomatic spondylolysis. The highest reported incidences occur in wrestling (30%), throwing sports (27%), rowing (17%), weightlifting (13-36%), and, the focus of this paper, the aesthetic sports of diving (13-43%), artistic gymnastics (17%), trampoline and tumbling (16%), and dancing (15-20%) (Granhed & Moreli, 1988; Rossi, 1978; Rossi & Dragoni, 1990; Soler & Calderón, 2000; Teitz). Furthermore, 50-67% of aesthetic sport cases were symptomatic in the form of low back pain with or without sciatica (Soler & Calderón, 2000).

Clinical Examination

The most common initial symptom of spondylolysis is localized low back pain exacerbated by activity, especially hyperextension or activity mimicking sport movements (Lonstein, 1999). The pain may extend into the buttocks, posterior thighs, or hamstrings and may be severe enough to require temporary hospitalization (McCleary, 2007). O'Sullivan et al. found that spondylolysis back pain is most commonly described as recurrent (70%), constant (55%), catching (45%), locking (20%), giving way (20%), or accompanied by a feeling of instability (35%) (O'Sullivan, 1997). Another study of gymnasts described spondylolysis pain as chronic, dull, achy, and exacerbated by certain skills (Jackson, Wiltse, & Cirincoine, 1976). These skills include walkovers, handsprings, yurchenko vaulting skills, rebounds, punching skills, dismount landings, and back twists in gymnastics (Kruse & Lemmen, 2009). Similar loadings in other aesthetic sports can be extrapolated to also produce pain, such as all springboard diving (particularly unaligned water entries, forward, inward, and back twisting [using tilt technique] skills), and jumps and hyperlordotic positions in dancing and skating.

In a study of skeletal specimens with spondylolysis, one-third of skeletons were found to have stenosis of the intervertebral foramen that compressed the L5 nerve root, which extends through the leg to the big toe (Edelson & Nathan, 1986). L5 compression is the most common radiculopathy and the second most common symptom in spondylolysis patients, but the majority of patients will not experience radiculopathy (Orney, Micheli, & Gerbino, 2000).

Physical examination frequently reveals lumbosacral tenderness with deep percussion, one- or two-sided muscle spasm, hamstring tightness, flattened lumbar lordosis, and relatively limited range of motion (considering that most aesthetic athletes are extremely flexible) with back extension and single leg hyperextension (McCleary, 2007). "Red flags" indicating a more serious differential diagnosis must be ruled out, especially for the younger population: any history of cancer, night pain, pain at rest, unexplained weight loss, or failure to improve (metastatic cancer flags); immunosuppression, prolonged high fever, or history of IV drug abuse, recent urinal tract infection, cellulitis or pneumonia (diskitis or osteomyelitis flags); recent major trauma or prolonged use of corticosteroids (vertebral fracture flags); and pulsating mass in the abdomen, throbbing resting back pain, or history of artherosclerotic vascular disease (abdominal aortic aneurysm flags) (Beattie, 2011).

Congeni (2000) describes the three classic patient types as such:

"Type I is a hyperlordotic female athlete with increased range of motion and flexibility, such as a dancer or gymnast [This paper's population of interest].
Type II is a muscular male athlete with decreased flexibility who is undergoing a rapid growth spurt and has tight [morphologically shortened] spinal erectors. These include football players and weightlifters.
Type III is the reluctant male or female athlete who is new to his or her sport or activity and now undergoing vigorous routines to prepare for this new sport. They frequently have poor abdominal strength and trunk flexibility."

Imaging

After clinical examination, plain film radiography is traditionally used in the clinical setting to confirm presence of spondylolysis. In the lumbar oblique view, spondylolysis classically presents as a "Scotty Dog" collar, where a pars defect appears as a collar on the neck (pars interarticularis) of a scotty dog formed by the outline of the superior articular process (ear), pedicle (eye/head), transverse process (nose), lamina (body), spinous process (body/tail), and inferior articular processes (legs). While these lumbar oblique views are commonly used, coned lateral spot projections appear to be more diagnostically useful, showing 84% of the defects in one study (Amato et al., 1984), because the majority of pars defects lie 0-30° relative to the coronal plane, rather than perpendicular (Saifuddin et al., 1998). A recent study also found that the diagnostic power of 4-view films (anterior/posterior [AP], lateral, and left and right oblique) was not statistically different from 2-view films (AP and lateral) and exposed adolescent patients to 0.54 mSv more radiation and cost, on average, $145 more (Beck et al., 2013).

Single-photon emission computed tomography (SPECT) scans have recently been explored as an additional prognostic test. SPECT detects the presence of osteoblastic activity and can identify whether the pars defect is undergoing an “active” healing process (producing a positive/hot SPECT scan for osteoblastic activity) or is now “inactive” (a negative/cold SPECT) and has already healed or resulted in nonunion (Miller, Congeni, & Swanson, 2004). These results can also be detected using bone scans, but these scans may expose patients to an excessive amount of radiation (Koerner & Radcliff, 2013). A positive SPECT and negative plain radiographs is considered to represent an early stage of the lytic process (Miller et al., 2004). Conservative (non-operative) management has produced better outcomes in early cases of painful spondylolysis than later stages (positive plain radiographic findings with or without positive SPECT) for up to a decade following intervention (Miller et al., 2004; Sys et al., 2001). Some authors have thus recommended SPECT to be added to the traditional imaging regimen in spondylolysis diagnosis (Miller et al., 2004; Sys et al., 2001).

Computed tomography (CT) is useful for higher resolution visualization of the pars lesion and subsequent healing (Koerner & Radcliff, 2013). Magnetic resonance imaging (MRI) can provide soft-tissue visualization without additional high-energy radiation exposure and may thus be useful in patients with atypical presentations or radiculopathy. In the early stages of spondylolysis (where spondylolysis progresses from early stress to complete spondylolysis), MRI can be used to reliably stage stress fracture progression (Hollenburg et al., 2002).

Plain film radiographs can detect full spondylolysis defect, but MRI scans can detect a Stage I bone marrow edema (Hollenburg et al., 2002).

Finally, one cannot discuss imaging without also recognizing the harms inherent in retrieving this additional diagnostic power. Imaging patients often discloses anatomic abnormalities, such as herniated discs, even in asymptomatic patients (Jensen et al., 1994; van Tulder et al., 1997). The subsequent label that an anatomic abnormality bestows can profoundly influence the psychological component of pain perception, which is not small (Srinivas, Deyo, & Berger, 2012). Randomly disclosing benign abnormalities have resulted in lower sense of well-being, higher likelihood of seeking follow-up care, and increased risk of undergoing surgical intervention in randomized controlled trials studying degenerative disc disease and back pain of at least 6 weeks (Srinivas, Deyo, & Berger, 2012). Furthermore, individually, imaging can expose patients to unnecessary irradiation that poses a risk to reproductive health and increases cancer risk; nationally, it dramatically increases overall health care costs (Srinivas, Deyo, & Berger, 2012). In 2010, the National Physician's Alliance subsequently recommended, "Don't do imaging for low back pain within the first six weeks unless red flags are present" as their #1 recommendation in their "Top 5 List in Internal Medicine of Promoting Good Stewardship in Clinical Practice" (National Physicians Alliance, 2010).

Etiology

Initial development of both spondylolysis and spondylolisthesis appear to have a multifactorial etiology of inherited predispositions exacerbated by mechanical traumas. Genetic predisposition is supported by family studies that have shown higher incidences of spondylolysis and spondylolisthesis (19-69%) in first-degree relatives of children with spondylolysis or spondylolisthesis, perhaps through inherited low cortical bone density or lower sacral table angle, which are risk factors for anterolisthesis (Huan, 2005; Lonstein, 1999). Environmentally, cases of spondylolysis or spondylolisthesis have never been reported in non-ambulatory patients, implicating a mechanical trauma component (Rosenberg, Bargar, & Friedman, 1981) that is supported by biomechanic literature (See: Section II, *Analysis of Theoretical Literature*). Epidemiologically, the high rates of spondylolysis among sports involving repetitive mechanical loading suggest that the majority of spondylolysis cases are stress or fatigue fractures; the prevailing view in research. A minority, though, of approximately 4% of children and 8% of adults with spondylolysis appear to be so genetically predisposed that daily stresses of a normal ambulatory lifestyle are sufficient to produce spondylolysis without additional sports-related stresses (Huan, 2005).

The etiology of pain due to spondylolysis is more controversial and an active area of research investigation. Multiple studies have demonstrated that the fibrocartilage scar tissue associated with the bony pars defect hosts multiple mechanoreceptors, including Pacinian corpuscles, Ruffini receptors, Golgi tendon organ-like receptors, and free nerve endings (Hasegawa et al., 1999;

Schneideman et al., 1995). Hasegawa at al., (1999) suggest that these mechanoreceptors are one of the sources of lower back pain in people with spondylolysis, where the mechanoreceptors protect the spine by using pain to signal instability with increased sensitivity. It has been suggested in the literature that acute onset of back pain is present, in part, when the pars lesion is "active;" a stress fracture is developing or has recently occurred, producing a positive SPECT (Huan, 2005). Chronic lower back pain, alternatively, results when a pars defect was incorrectly repaired in the now "inactive" pars (Huan, 2005). In nonspecific low back pain, Beattie et al. found a relationship between increased diffusion of water in the nuclear region of intervertebral discs and immediate pain reduction following lumbar joint mobilization and prone press-ups (Beattie et al., 2010). Also, in lower back pain, generally, Panjabi proposed that pain results when the spinal state exceeds its neutral zone (Panjabi, 2003). (See: Section II, *Analysis of Theoretical Literature*).

Prognosis

Over 80% of children conservatively (non-surgically) treated for spondylolysis have resolution of symptoms reported at six months after treatment onset (Hu et al., 2008). The effectiveness of various interventions to reduce symptoms and regain function in a timely manner, as the subject of this paper, will be discussed in further detail below. There is limited research that explores the long-term effects of spondylolysis. Osseous healing of the pars appears to be more likely in unilateral pars defects than bilateral and least likely in pseudobilateral (Sys et al., 2001). A fibrous soft tissue connection amidst non-union, however, may be sufficient for good clinical outcomes (Sys et al., 2001). As previously discussed, a minority of spondylolysis cases can progress to spondylolisthesis, especially in adolescent females. In vivo studies have suggested that epiphyseal injury in the juvenile spine may increase the likelihood of abnormal morphology of the L5 vertebral body and sacral base and progression to spondylolisthesis (Sakamuki et al., 2002; Kajiura, 2001; Sairyo, 2001; Sakamaki, 2003). The longest-term study to-date found that, after age 25 years, individuals with spondylolysis also report significantly higher incidences of disc degeneration than those without neural arch defects, but no causal studies have been completed (Szypryt, 1989).

In summary with the above information, female aesthetic athletes are more likely to have a worse prognosis than the general population. As previously stated, rates of symptomatic versus asymptomatic cases are roughly five to six times higher in the aesthetic population (52-67% versus 10%; Beutler et al., 2003; Roche & Rowe, 1951; Saraste, 1987; Soler & Calderón, 2000). Female aesthetic athletes commonly possess multiple risk factors for progression to spondylolisthesis, including female gender (two to four times more likely; Watkins & Watkins, 2010); low cortical bone density due to female athlete triad (discussed later; Huan, 2005; Lonstein, 1999); and hyperlordosis (Lonstein, 1999). Additionally, any symptoms will be exacerbated by participation in aesthetic sport activities (Jackson, Wilkse, & Ciricoine, 1976).

II. Interventions

There is limited research available on the treatment, management, or prevention of lower back pain due to spondylolysis, although there is currently a greater push in the literature to use clinical prediction rules (CPR's) and other techniques to segment the heterogeneous lower back pain population and provide tailored approaches. Consequently, it was not possible to conduct a meaningful review of the literature for evidence of the effectiveness of interventions for spondylolysis, specifically, nor aesthetic athletes.

Instead, appropriate interventions for female aesthetic athletes suffering from spondylolysis have been analyzed and identified using a four-step approach: (1) identification of the most commonly reported approaches for managing spondylolysis; (2) selection of the most theoretically promising approach for managing and possibly preventing spondylolysis, specifically, using theoretical evidence accumulated from the literature's current biomechanic understanding of spondylolysis; (3) analysis of the clinical literature for evidence of the resulting interventions' relative efficacy in addressing pain and disability in spondylolysis or chronic lower back pain, the most common type of spondylolytic pain, where there is a scarcity of spondylolysis specific research; and, finally, (4) suggestion of additional recommendations and considerations to suit the population of interest, young female aesthetic athletes.

Candidate Intervention Approaches

Currently, the main treatment approaches considered by clinicians for chronic lower back pain due to spondylolysis are (1) minimal intervention, (2) spinal manipulative therapy, (3) general aerobic exercise, (4) motor control exercise, and (5) surgical interventions. With the exception of surgical intervention (see below), these are the interventions that will be evaluated for their efficacy in reducing disability from chronic lower back pain due to spondylolysis (See: Section II, *Analysis of Clinical Literature*) and general chronic lower back pain (See: Section II, Tables 1-3).

Minimal intervention is typically one of the control group comparisons for most randomized controlled trials (RCTs) investigating intervention effectiveness. It may represent rest or reduced activity as usual.

Spinal manipulative therapy (SMT), also known as spinal mobilization therapy and spinal manual therapy, is “hands-on” treatment typically performed by chiropractors, manual therapists (physical therapists), orthomanual therapists (physicians), or osteopaths (van de Veen et al., 2005). It consists of low-grade velocity mobilizations within a patient’s range of motion and high-velocity manipulations that are applied to a synovial joint near the end of passive or physiologic range of motion (Rubinstein et al., 2011). The high-velocity manipulations are frequently accompanied by an audible “crack” that is thought to represent gas activity within the synovial cavity (Rubinstein et al., 2011). When performed by a chiropractor, it focuses upon the musculoskeletal and nervous system’s relationship a patient’s holistic health; an orthomanual therapist, upon achieving symmetry; and a manual therapist, resolving functional disorders of the musculoskeletal system (van de Veen et al., 2005). The mechanism of action is debated, but may be due to a mechanical element that reduces internal mechanical stresses at the site of a manipulable lesion (aka functional spinal lesion or subluxation) and a neurological element that affects the primary afferent neurons from paraspinal tissues, the motor control system, and pain processing (Rubinstein et al., 2011). The most common adverse effects after manual therapy is muscle soreness (roughly half of first-time SMT patients), followed by pain (one-fifth), stiffness (less than one-fifth), tiredness, headache, and dizziness, with women reporting more adverse events than men (Paanalahti et al., 2014).

General aerobic exercise interventions generally consist of a multiple week aerobic exercise program with whole body stretching beginning and ending a workout of general strengthening, such as cycling, swimming, walking, sling exercise, and gym work (Brooks, Kennedy, & Marshall, 2012; O'Sullivan et al., 1997; Haladay et al., 2013).

Motor control exercise (MCE), also known as lumbar stabilization exercise, dynamic stabilization, neuromuscular training, neutral spine control, muscular fusion, trunk stabilization, and (segmental) stabilizing exercise, incorporates general trunk focused strengthening exercises, whole-body movements, and trunk and hip stretching in order to achieve cocontraction of spinal stability muscles, especially as in abdominal drawing-in maneuvers (ADIM) and abdominal bracing (Brooks et al., 2012). The only contraindications for MCE are acutely unstable or compromising spinal or medical conditions that prohibit trunk muscle exercise (Standaert, Wendelstein, & Rumpeltes, 2008).

Surgical intervention for lumbar spondylolysis usually involves direct repair of the pars defect or (lumbar spinal) fusion surgery of the affected lumbar segment. Direct repair is more recently popular because it theoretically preserves the motion of the affected segment where fusion surgery reduces mobility in the affected surgery and leads to adjacent disc degeneration (Lee et al., 2015). In direct repair surgery, a cortical screw is inserted into pars defect site, then overlaid with autologous corticocancellous bone to improve union rate (Lee et al., 2015). As a non-invasive treatment, surgical intervention is associated with higher risks. Possible surgery complications include mild to severe pain around the site of bone harvesting (for autograph overlay), post-operative neurologic deterioration, drug-induced problems, and infection or inflammation (Lee et al., 2015). Although surgical intervention may be considered in parallel with non-operative treatments for the treatment of all chronic lower back pain, current treatment algorithms for spondylolysis, specifically, specify that surgery should only be pursued after a "trial of aggressive conservative [non-operative] treatment," and bracing with and without allowing sporting activity (Lee et al., 2015; Omid-Kashani, Ebrahimzadeh, & Dalari, 2014). Furthermore, a recent prospective comparative study found that at 12-month follow-up, traditional conservative treatment for young patients with spondylolysis produced similar clinical outcomes and fewer complications (Lee et al., 2015). With this paper's end-goal in mind, surgical intervention will thus no longer be discussed as a suitable starting point intervention for spondylolysis.

Analysis of Theoretical Literature

Biomechanic literature has produced the strongest theoretical support for MCE in cases of lower back pain due to segmental instability, such as in spondylolysis (Friberg, 1989). Studies conducted on low back pain in spondylolytic patients have found that the pain severity is not significantly related to degree of static anterolisthesis, but is significantly correlated with degree of instability (Friberg, 1987; Friberg, 1989; Friberg, 1991). Studies have posited that this pain due to instability is produced when intervertebral motions exceed the spine's neutral zone (below) and compress or stretch the nociceptor-dense surrounding elements, including the surrounding ligaments, joints, and inflamed neural elements (Panjabi, 1992a; Panjabi, 1992b). If one can reduce spinal instability by proactively completing MCEs that strengthen the spine's stability system, it therefore seems logical that MCE would be a suitable intervention for preventing pain due to spondylolysis and possibly even the original fatigue defect, as it is an example of segmental instability. In such a scenario, MCE theoretically emerges not only as equally suitable to other non-operative interventions in managing lower back pain, but superior to other interventions in the case of spondylolysis in the aesthetic athlete.

The following represents a cursory review of spinal stability to better understand the theoretical targets of MCE in cases of clinical instability:

In 1992, Panjabi (1992b) subdivided the range of physiological intervertebral motion into the *neutral* and *elastic zone*. Intervertebral motion within the neutral zone has minimal internal resistance, whereas intervertebral motion within the elastic zone encounters significant internal resistance (Panjabi, 1992b). In this understanding, Panjabi (1992b) redefined clinical instability as follows:

> "Clinical instability is defined as a significant decrease in the capacity of the stabilizing system of the spine to maintain the intervertebral neutral zones within the physiological limits so that there is no neurological dysfunction, no major deformity, and no incapacitating pain."

Using this definition, spondylolysis patients have been found to have three forms of clinical instability commonly present at the site of lytic defect: (1) unstable slip (anterior instability); (2) increased angular movement (angular instability); and (3) movement in the spondylolytic cleft (posterior instability) (Niggemann et al., 2011).

In 1992, Panjabi also proposed the predominant spinal stability model, where three subsystems prevent clinical instability. These are: (1) the *control (neural)* subsystem consisting of neural and feedback elements of the spine; (2) the *passive (osseoligamentous)* subsystem of the spinal column, i.e. vertebrae, intervertebral discs, facet joints, and spinal ligaments; and (3) the *active (musculotendenous)* subsystem of the spinal muscles and tendons. In 1989, Bergmark further subdivided the active subsystem (the focus of MCEs) into *global muscles*, which are large torque muscles that do not directly attach to the spine; and *local muscles*, which are directly attached and provide segmental stability (Bergmark, 1989). The global muscles are then the rectus abdominus, external and internal (anterior fibers) obliques, and iliocostalis (thoracic). The spine's local muscles are the multifidi, psoas major, transversus abdominus, quadratus lumborum, diaphragm, internal oblique (posterior fibers), iliocostalis (lumbar) and longissimus (lumbar).

In this model, the control subsystem monitors the passive subsystem's force and motion requirements and submits this information for the active subsystem to achieve (Panjabi, 1992a). The passive subsystem does not, itself, provide significant stability, but provides the foundation for the active and control subsystems to act upon (Panjabi, 1992a). Without the active subsystem, the lumbar passive subsystem can only withstand 90 N (9 kg) before buckling, where standing loads on the spine are typically two to three times body weight (roughly 1100-1700 N for a 125 lb person) (Punjabi, 1992a). Typical gymnastics skills have been reported to result in dramatically higher compression loads, from 4 times body weight in skill take-off to 16 times body weight in swings and up to 30 times body weight in landing (roughly 2200-17,000 N for a 125 lb gymnast) (Brüggemann, 2005; Kruse & Lemmen, 2009). Alternately, the elite diver has been reported to experience 2000 – 3300 Nm torque in the lower back upon water entry from 0 to 10° offset entry pitch angle, with torque increasing with pitch angle (Harrison et al., 2012). The active subsystem thus appears to be an attractive target for increasing spinal stability in aesthetic athletes facing high lumbar axial loads and torques, even those without segmental stability. In the presence of segmental stability, like spondylolysis, research has focused on using MCE to strengthen local system in order to provide the segmental stability for the global muscles to further act upon (O'Sullivan, 2000).

In particular, many studies have focused upon the transversus abdominus, diaphragm, and multifidi. The transversus abdominus is a large abdominal muscle that runs horizontally around the abdomen and is obviously contracted in the "hollow position" of gymnastics and diving. Activation of the transversus abdominus is delayed in individuals with lower back pain, although the relevance of this delay is debated (Hodges & Richardson, 1996). The diaphragm and pelvic floor form the roof and floor of the abdominal cavity, respectively. When the diaphragm contracts and the glottis is closed, it acts with the abdominal muscles (especially the transversus abdominus) to increase intra-abdominal pressure, a mechanism that greatly contributes to the stability of the lumbar spine by distributing axial compression and shear loads over a wider area (Norris, 1995). Finally, the multifidi have been shown to produce two-thirds of the stiffness increase at the L4-5 (Kaigle et al 1995; Wilke et al., 1995).

Despite these isolated findings, however, recent research suggests that spinal stability depends upon the relative activation of all trunk muscles, with individual contribution significantly depending upon spinal loading magnitude and direction (Cholewicki, 2002). In light of these new findings, the MCEs recommended in this paper and analyzed against general aerobic exercise, SMT, and minimal intervention will be those that functionally strengthen not only the transversus abdominus, diaphragm, and multifidus, but also all lumbar stabilizing musculature.

Clinical Literature Analysis

As stated previously, there is little research reported on the use of MCE for spondylolysis or aesthetic athletes, specifically. Despite the strong theoretical support garnered for using MCE as a method to both manage and prevent spondylolysis clinical instability, the main clinical evidence resides in a single high-quality study conducted in 1997 by O'Sullivan et al.: a randomized controlled trial, test-retest design with a 3-, 6-, and 30-month follow-up questionnaire that found that MCE significantly reduced pain intensity and functional disability levels over other conservative treatment approaches. The control group, however, was heterogeneous, variously participating in general aerobic exercise, supervised exercise, and local pain-relieving methods such as heat, massage, and ultrasound (O'Sullivan et al., 1997).

Two studies were identified that indicated that MCE or MCE-like methods had lower back pain preventative potential in aesthetic populations. One, (Harringe et al., 2007) found that MCE significantly decreased lower back pain incidence among the team and eliminated pain in half of the teamgym gymnasts (similar to trampoline and tumbling) participating in the intervention. Another small study, (Durall et al., 2009) found that MCE-like training twice per week for ten weeks in gymnastics preseason was associated with reduced lower back pain episodes during the subsequent competitive season.

Additionally, there is a growing body of literature that indicates MCE in the presence of aberrant trunk movements. Hicks et al. (2005) published a prospective cohort study suggesting that clinical examination variables, particularly those related to aberrant trunk movements, can predict success of an MCE intervention. Since 2005, multiple published CPR's have proposed that MCE was favored when a patient had positive aberrant trunk movements, positive prone instability test, young age, and straight-leg raise range of motion greater than 91 degrees (Fritz, Cleland, & Childs, 2007; Rabin et al., 2014).

Although the above results are promising indications that MCE could play a preventative role against lower back pain due to spondylolysis, the evidence is not rigorous enough to confirm such a claim. Consequently, as previously stated, a separate literature search of PubMed (MEDLINE) database was conducted in order to obtain greater evidence of the clinical efficacy of MCE. The following search path was used: (lumbar stabili* OR motor control exercise OR motor control OR exercise) AND (back pain), restricting to human trials written in English, to analyze the effectiveness of MCE against the other candidate interventions, minimal intervention, SMT, and general aerobic exercise, in reducing pain and disability in the presence of chronic lower back pain. Chronic lower back pain was selected because it is the most common type of back pain reported by people with spondylolysis. There is more high-quality literature available on the use of MCE in non-specific chronic lower back pain than in chronic lower back pain due to spondylolysis in aesthetic athletes, which can serve to inform efficacy of MCE for this paper's target population. The original MEDLINE search was also supplemented by hand-searching references from articles from the electronic search for any human randomized controlled trials published in English after December 2011.

The literature review revealed that there is high-quality evidence (≥ 6 points on the 10 point Physiotherapy Evidence Database [PEDro] scale, which independently assesses the quality of trials, reviews, and guidelines) that MCE is superior to minimal intervention (Brooks et al., 2012 [high quality]; Costa et al., 2009 [high quality]; Goldby et al., 2006 [low quality]; Shaughnessy & Caulfield, 2004 [low quality]) and to general exercise in pain (short-, intermediate-, and long-term) and disability (short-, intermediate-, and long-term) for chronic lower back pain (Akbari, Khorashadizadeh, & Abdi, 2008 [low quality]; Critchley et al., 2007 [high quality]; Ferreira et al., 2007 [high quality]; Franca, Burke, & Hanada, 2010 [high quality]; Miller et al., 2005 [low quality]; Unsgaard-Tondel, Fladmark, & Salveson, 2010 [high quality]).

High-quality evidence found that MCE was found significantly superior to SMT with regard to disability (short-, intermediate-, and long-term), but was not statistically superior with regard to pain (intermediate-, and long-term) (Akbari et al., 2008 [low quality]; Ferreira et al., 2007 [high quality]; Goldby et al., 2006 [low quality]; Rasmussen-Barr, Nilsson-Wikmar, & Arvidsson, 2003 [low quality]) and marginally inferior to SMT for pain (short-term) (Balthazard et al., 2012 [high quality]). A recent economic evaluation found that these short-term reductions in pain, in conjunction with the relatively low cost of SMT compared to supervised physiotherapies, rendered SMT most cost effective of the candidate interventions for non-specific acute and chronic low back pain (Michaleff et al., 2012).

Although MCE thus appears to be superior to minimal intervention and general exercise and possibly to SMT in spondylolysis, an MCE intervention does not need to be exclusive. Moderate to low quality evidence supports MCE as part of a multimodal intervention, such as with general exercise (Cairns, Foster, & Wright, 2006 [high quality]; Koumantakis et al., 2005 [high quality]) and SMT (Balthazard et al., 2012 [high quality]; Michaleff et al., 2012). Theoretically, it is important that aesthetic athletes maintain high aerobic fitness during their activities because the nervous system preferentially selects maintenance of breathing over spinal stability producing additional low-back compressive loading (McGill et al., 1995) even when the motor control system is well trained (O'Sullivan et al., 2002). Other recommendations for MCE intervention implementation are reviewed below (See: Section III, *Practical Considerations*).

To summarize the above analysis of interventions for spondylolysis in aesthetic athletes, it seems that MCE is the most attractive choice. Theoretically, it provides targeted strengthening of the segmental stabilizing (local) muscles and torque (global) muscles and emphasizes successful cocontraction of these muscles to achieve spinal stability at critical moments (See: Section II: *Analysis of Theoretical Literature)*. Clinically, it has little contraindications; has proven effective in one high-quality study for managing pain and disability due to spondylolysis and two low to moderate-quality studies that it may prevent incidence and pain severity of lower back pain in aesthetic sport populations; is superior to minimal intervention and general exercise and only marginally inferior to spinal manipulative therapy for reducing chronic lower back pain; is superior to these other interventions for reducing functional disability; and may be combined with others to enhance treatment effects (See above).

Table 1. MCE Compared with Minimal Intervention

PEDro	Authors, Year	Sample	Intervention	Key Findings
9	Costa et al., 2009	N=154. Chronic LBP ≥ 12 wk.	12 sessions over 8 wks of (1) MCE; (2) Placebo detuned ultrasound and short-wave therapy.	MCE produced improvements over minimal intervention in global impression of recovery and ability to perform activities at 2, 6, and 12 mo.
7	O' Sullivan, Twomey, & Allison, 1997	N=44. Chronic LBP with spondylo-lysis or spondylo-listhesis	10 wks of (1) MCE; (2) Treatment as directed by treating practitioner.	MCE reduced pain intensity and functional disability at 3, 6, and 30 mo.
5	Shaugh-nessy & Caulfield, 2004	N=41. LBP ≥ 12 wk.	10 sessions over 10 wks of (1) MCE; (2) No intervention.	MCE reduced short-term functional disability compared to minimal intervention.
4	Goldby et al., 2006	N=346. LBP ≥ 12 wks.	(1) 10 sessions MCE; (2) 1 session education	MCE reduced pain and dysfunction at 6 mo. and medication, dysfunction, and disability at 12 mo. compared to education.
MCE = motor control exercise. LBP = lower back pain. Wk. = week. Mo. = month. N = sample size number. PEDro = rating on the 10-point Physiotherapy Evidence Database scale, where ≥ 6 represents high-quality evidence.				

Table 2. MCE Compared with General Exercise (GE)

PEDro	Authors, Year	Sample	Intervention	Key Findings
8	Brooks et al., 2012	N=64. Chronic LBP	8 wks of (1) MCE; (2) GE cycling.	GE and MCE reduced pain at 8 wks, but MCE reduced pain and disability more at 8 wks. Similar changes in trunk muscle onsets observed between MCE & GE.
8	Ferreira et al., 2007	N=240. LBP ≥ 3 mo.	12 sessions over 8 wks of (1) MCE; (2) Strength and aerobic GE and stretching.	MCE produced higher short-term patient function and recovery perception at 8 wks than GE, but similar outcomes at 6 and 12 mo.
7	Critchley et al., 2007	N=212. LBP > 12 wk.	8 90min sessions over 8 wks of (1) MCE, individual; (2) MCE, group sessions; (3) outpatient PT	Individual and group MCE and outpatient PT similarly reduced pain, time off work, and disability.
7	Franca et al., 2010	N=30. LBP > 3 mo.	12 30min sessions over 6 wks of (1) MCE; (2) GE with trunk strengthening.	MCE increased TrA activation and decreased pain and functional disability compared to GE.
7	Rasmussen-Barr et al., 2009	N=71. Recurrent LBP > 8 wk.	8 wks of (1) Weekly PT-guided MCE; (2) 30 min walks and general home exercise and 2 PT sessions	MCE reduced perceived disability at 12 mo. and pain at 8 wks and increased self-efficacy at 12 mo.
7	Unsgaard-Tondel et al., 2010	N=109. LBP ≥ 3 mo.	8 sessions over 8 wks of (1) MCE; (2) GE sling exercise.	No statistically significant difference between pain or functional disability reductions in MCE vs sling exercise.
7	Unsgaard-Tondel	N=109. LBP ≥ 3	8 sessions over 8 wks of (1) MCE;	No statistically significant difference between pain or

	et al., 2010	mo.	(2) GE trunk strengthening and stretching.	functional disability reductions in MCE vs GE trunk strengthening and stretching.
5	Akbari et al., 2008	N=49. Chronic LBP	16 30min sessions over 8 wks of (1) MCE; (2) GE.	MCE decreased pain more than GE at 8 wks. Both MCE and GE increased TrA and LM muscle thickness.
5	Miller et al., 2005	N=36. LBP ≥ 7 wk	6 wks of (1) MCE; (2) McKenzie occasionally with SMT	MCE not statistically significantly different from McKenzie exercises in reducing pain, but did increase Straight Leg Raise range of lower extremity.
MCE = motor control exercise. GE = general exercise. TrA = transverse abdominus. LM = lumbar multifidus. LBP = lower back pain. Wk. = week. Mo. = month. N = sample size number. PEDro = rating on the 10-point Physiotherapy Evidence Database scale, where ≥ 6 represents high-quality evidence.				

Table 3. MCE Compared with Spinal Manipulative Therapy (SMT)

PEDro	Authors, Year	Sample	Intervention	Key Findings
8	Ferreira et al., 2007	N=240. LBP ≥ 3 mo.	Up to 12 sessions over 8 wks of (1) MCE; (2) SMT.	MCE produced higher short-term patient function and recovery perception at 8 wks than SMT, but similar outcomes at 6 and 12 mo.
5	Rasmussen-Barr et al., 2003	N=47. Chronic LBP ≥ 12 wk.	6 sessions over 6 wks of (1) MCE and daily home training. (2) SMT.	MCE reduced pain, functional disability, and need for recurrent treatment at 3 and 12 mo. vs SMT.
4	Goldby et al., 2006	N=346. LBP ≥ 12 wk.	(1) MCE. (2) SMT. 10 sessions	MCE reduced pain and dysfunction at 6 mo. and medication, dysfunction, and disability at 12 mo. compared to SMT. SMT reduced pain better in patients who have the highest amount of pain at 3 mo.

MCE = motor control exercise. SMT = spinal manipulative therapy. LBP = lower back pain. Wk. = week. Mo. = month. N = sample size number. PEDro = rating on the 10-point Physiotherapy Evidence Database scale, where ≥ 6 represents high-quality evidence.

III. Practical Considerations

As previously stated, additional research was conducted to make additional recommendations to tailor MCE to the target population, female aesthetic athletes. These recommendations (below) are included to address minor equipment changes, methods to increase intervention intensity, comorbidities of interest, and psychosocial factors that may be intimately tied with the success of MCE within this population.

General MCE Implementation Notes

In the gym, certain modifications can be made to optimize athletes' chances of successful rehabilitation. “Sting Mats,” for example, have been shown to reduce spinal loading as much as 20% (Bruggeman, 1999). Foam pits can also be used until gymnasts can prepare for appropriate landing position. Practice and MCE should not be scheduled to begin within an hour of waking because of increased hydrostatic pressures in the disk following waking, where over 50% of the loss of disc water content occurs in the first hour of rising, disc-bending stresses are 300% higher, and ligaments stresses 80% higher (Adams et al., 1987; Reilly et al., 1984).

All MCE and practices should also be accompanied by full stretching. Aesthetic athletes report high incidences of pelvic crossed syndrome, which describes an unequal balance between the gluteal and abdominal muscles versus erector spinae and ilopsoas muscles that creates imbalance in surrounding muscles and functional impairment (Kruse, 2009). Therefore, all

MCE interventions should be accompanied by full stretching, otherwise the upper core strengthening may create greater instability in the context of relatively inactivated antagonistic muscles of the pelvic floor (Kruse, 2009).

To enhance intervention efficacy, researchers have found that increasing intensity of MCE can increase trunk-strengthening treatment effects and should thus be increased where appropriate (Slade & Keating, 2006). Adding motivation strategies into trunk-strengthening programs can also improve long-term pain and function following intervention (Friedrich, 1998). Neural control of the muscles targeted in MCE can be increased by incorporating joint stability (cocontraction) exercises, balance training, proprioceptive training, plyometric (jump) exercising, and aesthetic sport-specific skill training (Caraffa et al., 1996). The latter can be accomplished with the help of a coach well-informed of proper skill form, who can provide feedback of inappropriate postures/form during practices.

In the presence of fear avoidance behaviors, Graded Activity (GA) may be employed to increase exercise program outcomes for low back pain but has not been indicated in the absence of psychological distress (Lindstrom et al., 1992; Van der Giessen, Speksnijder, & Helders, 2012). In GA, the patients gradually exposed to a mutually set quota of specific feared stimuli so that they can be shown that they can safely accomplish activities (Liebenson, 2012). The exposure quota is gradually increased in a time-contingent rather than pain-contingent fashion to enhance motivation (Fordyce et al., 1986).

Finally, conservative chronic lower back pain treatment, like most interventions, can be significantly improved by the presence of a “therapeutic alliance” between patients and clinicians (Ferreira et al., 2013). In the assumption that coaches and an aesthetic athlete’s support network also function, to some degree, as a physical therapist for the athlete, it is recommended that a therapeutic alliance be formed between all members of an athlete’s support network, including clinicians, coaches, and family. This assumption forms the basis for including the whole support network in the target audience of the accompanying website (See: Section IV, *Online Resource*).

Aesthetic Training Environment and Listening to the Body

To achieve high levels in any sport, an athlete must push their body to “play through pain” or ignore body cues to achieve new levels. Many aesthetic sports, particularly, place an emphasis upon not only perfecting rudimentary skills such as sprinting or jumping, but acquiring the ability to perform novel skills that challenge the body both physically and psychologically. In order to learn a new skill, the athlete must ignore or “deal with” body cues like muscle burn from practices and the fear of trying something new that poses new risks to oneself. In flips in gymnastics and diving, for example, there are “blind landing’s,” where the athlete cannot see her landing target until the last second and must rely upon limited body cues, such as a ceiling rafter, and mentally push herself beyond her fears to trust that her kick-out will be timed safely enough that she will not injure herself.

In “bad pain,” such as pain due to stress fractures, however, employing a similar mindset of pushing past body limits and cues can pose harm to the athlete. Athletes must be trained to differentiate between “good” and “bad” pain to buttress their safety in practices and rehabilitation. The Johns Hopkins Department of Orthopaedic Surgery distinguishes the pains as such: “good” pain is short-lived, goes away with rest, and does not interfere with activities of daily life, such as the mild burn associated with muscle strengthening; “bad” pain is associated with the failure of tendons, ligaments, cartilage, bones, and excessive muscle damage (McFarland & Cosgarea, n.d.). Conversely, “bad” pain is generally pain that is constant or increasing over time, does not improve with treatment, wakes the athlete during rest, or is associated with nerve damage (McFarland & Cosfarea, n.d.). Athletes with bad pain should proceed with caution, careful not to exacerbate damages.

Use of Alternative Core Stability Exercises

In considering advanced fitness core-stability programs, it is important that the athlete resists the urge to proceed to any advanced variations until she can master the basic ADIM. She must master, for example, the 2000 N modified curl-up, 2100 N quadruped leg raise, and 3000 N bird-dog of a typical MCE regimen before proceeding to even the 3350 N traditional sit-up and 4300 N prone superman, which represent the upper range of daily loads (2000 – 4000 N) and pose a danger to the unstable back (Panjabi, 1992).

Given such a mastery, there are many popular fitness programs that proclaim to follow core-strengthening principles and could potentially complement MCE, including pilates, some forms of yoga, tai chi, Feldenkrais (focused upon increasing self-awareness during functional activities), somatics (exercises that emphasize internal perception of body position and movement), and matrix dumb-bell programs (where pilates and yoga are the most studied) (Akuthota & Nadler, 2004). Equipment-based Pilates has shown to be more effective than mat Pilates in patients with chronic low back pain (da Luz et al., 2014) and a preliminary CPR (based on promising systematic review results from Lim et al., 2012) suggests that individuals with lower back pain most likely to respond to treatment are those who have total trunk flexion range of motion of ≤ 70°, current symptoms lasting less than six-months, ≥ 25 kg/m2 body mass index, and left or right hip average rotation of 25° or higher (Stolz et al., 2012). Another systematic review, however, found that there is no evidence that Pilates improves pain or functionality in lower back pain patients (Pereira et al., 2012). In yoga, moves such as the *Uddhyana Bhanda and Nouli* (abdominal drawing-in, then contraction of the abdomen from the sides and outward rectus abdominus projection) target the transversus abdominus of the active global spinal stability subsystem, core stabilization, rectus abdominus contraction, and neuromuscular control techniques (Omkar & Vishwas, 2009) and thus seem attractive additions to MCE. Yoga as a whole, however, is a large, heterogeneous body of exercises and lifestyle choices and cannot be categorically recommended as core stability exercises.

Female Athlete Triad

Finally, it is important to address female athlete triad as a common comorbidity tied to stress fracture risk (among other conditions) in the female aesthetic population. Female athletes who participate in aesthetic sports face a higher likelihood of acquiring this serious condition consisting of disorder in one or more of the interconnected three spectrums of: energy availability (optimal to low energy availability with or without an eating disorder); menstrual function (eumenorrhea to functional hypothalamic amenorrhea); and bone mineral density (optimal bone health to osteoporosis) (Nattiv et al., 2007). It is difficult to gain epidemiological data on female athlete triad due to symptom hiding, but estimates have suggested 31-62% of aesthetic athletes exhibit disordered eating behaviors; 69% of dancers have secondary amenorrhea; and 22% of aesthetic athletes, primary amenorrhea (Nattiv et al., 2007). As stress fracture risk is two to four times higher for amenorrheic athletes than eumenorrheic athletes (Bennel et al., 1996) and as reduced cortical bone density is a risk factor for anterolisthesis, amenorrheic aesthetic athletes have dramatically increased risk for spondylolysis and progression to spondylolisthesis.

Many studies have focused on understanding and preventing eating disorders and energy availability, the cornerstone of the triad, in aesthetic sports. Aesthetic athletes report the highest levels of body shame and self-objectification scores of female sport, which could increase their susceptibility to social pressures to achieve “thinness” (Rose, 2008). Self-objectification measures the importance a person places upon appearance; body shame measures the difference between internalized cultural body standards and the perceived ability to achieve those standards (Rose, 2008). High body shame, then, reveals that one feels drastic measures would need to be pursued to achieve cultural body standards. High self-objectification score, alternately, increases the importance of pursuing such measures. Generally, though, aesthetic athletes' eating attitudes and dieting behaviors appear to be significantly more connected to their desire to achieve their performance goals than other athletes (Karin de Bruin, Bakker, & Oudejans, 2009).

The American College of Sports Medicine recommends the following treatment progression: patient education relating restrictive eating to bone mineral density; nutritional counseling and individual psychotherapy with or without cognitive behavioral, group therapy, and/or family therapy; and, finally, training and competition restriction (Nattiv et al., 2007).

Sports psychology researchers have also investigated manipulating performance environment in order to decrease disordered eating and discovered that ego-orientation and performance climate are more highly correlated with disordered eating than task orientation and mastery climate (Karin de Bruin, Bakker, & Oudejans, 2009). Furthermore, ego-orientation was linked to lower self-confidence, lower levels of moral functioning (Kavussanu & Ntoumanis, 2003) and "winning at all costs" justification (Roberts, 2001). Ego and task orientations are the two main goal orientations distinguished in achievement goal theory; ego orientation describes being driven to demonstrate abilities superior to others; task orientation, on the other hand, sets "self-referenced goals" that emphasize personal achievement without depending upon outperforming peers. Conversely, if the motivational climate (of the overall environment) is more ego-oriented (higher emphasis upon social comparison), the motivational climate is described as a “performance climate;” if task-oriented, a “mastery climate” (Karin de Bruin, Bakker, & Oudejans, 2009). Therefore, in addition to the recommendations of the American College of Sports Medicine (Nattiv, 2012), it may be generally beneficial for gym coaching staff to make a cognizant effort to instill a mastery climate.

IV. Online Resource

In order to effectively communicate the results of my research in a meaningful way, I decided to create an evidence-based, consumer-based online resource for aesthetic athletes and their support network (coaches and family members) suffering from spondylolysis. The website (http://www. aestheticmce.weebly.com) aims to fulfill the following functions: (1) introduce the consumer to the purpose and limitations of the site; (2) explain and illustrate the physiology of spondylolysis in relation to sport-specific biomechanics; (3) explain and illustrate the possible role of MCE in managing and preventing spondylolysis given my literature review findings; and (4) encourage a dialogue between the athlete and his or her support network concerning appropriate prevention approaches that is sensitive to aesthetic sport-specific issues. Additionally, this website aims to be written in consumer-friendly terms, easily navigable, and aesthetically pleasing; multiple illustrations were prepared to enhance understanding and as an ode to the aesthetic nature of the target audience's sporting environment.

Need

As an adolescent aesthetic athlete suffering from lower back pain, I personally found targeted evidence-based online resources exceptionally difficult to locate. In my experience, most websites I found on lower back pain were targeted towards spinal disc disorders, lower back pain related to sedentary or other occupational risk factors, targeted towards adults, or inaccurate with minimal peer-reviewed references. My experiences appear to underscore a common theme in effective online resources for lower back pain subpopulations, with one study finding that, in March 2011, the majority of websites concerning acute lower back pain lacked accurate information; of the websites searched, 98% accurately reported "education and reassurance," but only 50% "manipulation," 9% "massage," and 0% "exercise" (Hendrick et al., 2012).

Curriculum Method of Development

Curriculum for the site was developed using the instructional design work of Kinzie (Kinzie et al., 2002; Kinzie, 2005; Hilgart et al., 2012). This work includes internet curricular design based upon health behavior theory recommendations from Rosenstock (Health Belief Model), Bandura (Social Cognitive Theory), and Dearing (Diffusion Theory) and health education theory developed by Gagne (Kinzie, 2005). The primary constructs of this approach (Kinzie, 2005) are to:

> "(1) Gain attention, i.e. convey health threats and benefits; (2) present stimulus material, i.e. tailor message to audience knowledge and values, demonstrate observable effectiveness, make behaviors easy-to-understand and do; (3) provide guidance, i.e. use trustworthy models to demonstrate; (4) elicit performance and provide feedback, i.e. to enhance trialability, develop proficiency, and self-efficacy; and (5) enhance retention and transfer, i.e. provide social supports and deliver behavioral cues."

Construct 1 was completed by including a subheading with health threats and benefits in the cover page reading, “Spondylolysis can lead to low back pain and nerve irritation. Motor control exercise can be added to practices to reduce complications so YOU can get back to practicing, competing and living.”

Construct 2 was completed by creating a logical flow of information for understanding spondylolysis and MCE. First, the purpose of the website was introduced in the “About” page. Second, spondylolysis, aesthetic athletes, and general spine anatomy was clearly defined in “Spondylolysis: Background.” Third, the effect of spondylolysis upon anatomy, spondylolysis presentation, red flags, diagnosis, and prognosis were explained in “Spondylolysis: The Condition.” Fourth, MCE and other treatment approaches were defined and compared in “Exercise Therapy: What is MCE?” before, fifth, explaining the theoretical MCE mechanism of action in “Exercise Therapy: How does MCE work?” Sixth, exercises were presented and illustrated progressing from basic to most difficult skills per peer-reviewed sequence recommendation in “Exercise Therapy: The Exercises” (Rabin et al., 2014). Finally, additional recommendations were presented in concise action items on “Exercise Therapy: Extra Tips & Tricks.”

Construct 3 was primarily achieved through the development and integration of illustrations demonstrating the recommended MCE exercises based on peer-reviewed literature (Rabin et al., 2014). The illustrations were tailored to the target audience and designed to accurately depict exercises using a whimsically styled cartoon of a healthy-weight, muscular adolescent female.

For this site, Constructs 4 and 5 depend upon the level of engagement initiated by the reader. Opportunities for self-directed feedback were provided in the form of progress questions posed through the exercises. Social support was encouraged in “Exercise Therapy: Extra Tips & Tricks” and behavioral cues in the form of handouts were provided on multiple pages.

Presentation Considerations

Utmost efforts were made to develop the online resource in an evidence-based, consumer-friendly manner, which involved adherence to the HONcode principles, effort to present information at lower reading levels, and a thorough basis in the research conducted and presented in this paper. The HONcode is the oldest and most commonly used code for evaluating Internet medical and health-related information quality (Morr et al., 2010). It is composed of eight principles (HONcode, 2014 August):

> “(1) *Authority*: give qualifications of authors; (2) *complementarity*: information to support, not replace; (3) *confidentiality*: respect the privacy of site users; (4) *attribution*: cite the sources and dates of medical information; (5) *justifiability*: justification of claims / balanced and objective; (6) *transparency*: accessibility, provide valid contact details; (7) *financial disclosure*: provide details of funding; and (8) *advertising*: clearly distinguish advertising from editorial content.”

The online resource was personally evaluated and subsequently adjusted using the HONcode evaluation form (HONcode, 2014 May) completed multiple times throughout the development process to achieve adherence (See: Appendix C). Particular emphasis was placed upon justifiability, where references were provided throughout the text in short-hand form and could be clicked to redirect to the full reference in the "References" page.

Reading level was assessed using the Flesch-Kincaid Grade Level formula using Microsoft Word. Studies suggest that it is important for most health information pages to be kept at a sixth to eighth grade reading level, where the average American reading level identified by the United States Department of Health and Human Services is seventh grade (Walsh & Volsko, 2008). The high syllabic nature of the content (i.e. spondylolysis, 5 syllables, and spondylolisthesis, 6 syllables), however, placed the website content at an inherent disadvantage against achieving reading grade level 8. The median reading level of my online resource is: 12, ranging from a high of 12 to low of 10.2.

MCEs were illustrated and described based on instructions in peer-reviewed work (Rabin et al., 2014). The illustrations were first rendered in watercolor and ink, then digitally scanned and uploaded onto the website in two forms: directly embedded onto the "Exercises" page and attached as a downloadable handout form onto the "Print here" page. Original rendering provided greater flexibility to manipulate elements to suit population needs. The cartoon physique, for example, was drawn robustly to better portray the higher healthy weight of a muscular female gymnast. Examples of these illustrations as depicted performing the recommended motor control exercise regimen can be found in Appendix B.

Conclusion

The epidemiology, diagnosis, and prognosis of spondylolysis; functional anatomy of the spine; and sport-specific biomechanics were briefly described. The method of development of the accompanying online resource (http://www.aestheticmce.weebly.com), was also described using HONcode principles and Kinzie's model of instructional design. Aesthetic athletes were defined and identified as a high-risk group for spondylolysis that shared biomechanic and social stresses, rendering it an attractively homogenous group for injury prevention purposes.

While there is limited research available on treatment of lower back pain due to spondylolysis, MCE appears to be the most clinically and theoretically promising approach (of the generally considered approaches, minimal intervention, general aerobic exercise, spinal manipulative therapy [SMT], motor control exercise [MCE], and surgery) for improving pain and functionality, especially in spondylolysis associated with aberrant trunk movement. MCE may be used in conjunction with other therapies, especially aerobic exercise, SMT, and graded activity (GA) where appropriate. There is no high-quality evidence that alternative core stability exercises should replace MCE, but may be used with caution as adjuvant exercises. In the gym, proper injury-prevention apparatus, a mastery climate, rigorous form supervision, and vigilance of female athlete triad risk is recommended.

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Appendices

APPENDIX A. WEBSITE CONTENT (RAW TEXT)

Note: References (Numbers) refer to are no different than those cited in this paper, but can be found at the website, http://www.aestheticmce.weebly.com.

Spondylolysis and the Aesthetic Athlete
WEBSITE CONTENT
Author: Siobhán Kibbey
Last Updated: April 2015

Subheading

Spondylolysis can lead to low back pain and nerve irritation. **Motor control exercise** can be added to practices to reduce complications so **YOU** can get back to practicing, competing and living.

About

Mission

To educate **female aesthetic athletes** of their risk of **spondylolysis.**
Empower them to take preventative action in a partnership with their support networks.
And understand the possible role of **motor control exercise** in managing or preventing lower back pain due to spondylolysis.

Authors

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History

As a trampoline and tumbling gymnast and diver, many of my teammates and I spent a large portion of our athletic careers fighting lower back pain. For the most part, we were underweight, hyperlordotic, flexible, and strong individuals bothered more by the performance and practice reductions brought on by our lower back than the moment-to-moment pain exacerbated by handsprings, loaded take-offs, and other hyperextension skills.

Given the statistics I encountered in my research, it appears more than likely that a significant percentage of us were suffering from spondylolysis. Spondylolysis is a stress fatigue defect of the pars interarticularis correlated with clinical instability, mechanical lower back pain, and sciatica. This condition is present in **~ 1 in 5 aesthetic athletes** -- athletes participating in strongly appearance-contingent sports such as diving, gymnastics, skating, and dancing.

I was deeply concerned by how many people are affected by this condition, which I had never heard of and could hardly pronounce (it's spon-dee-LO-ly-sis). Furthermore, it was very hard to decipher which interventions were relevant and evidence-based. Consequently, I dedicated my senior thesis to understanding this condition and to form an accessible resource (this website) for others to understand what it was, what they could do, and the stance of the current literature.

I hope that my website can serve as a useful starting point for an open dialogue between the athlete and his or her support network to take prevention-oriented steps. I also hope that this website can provide a source of empowerment by clearly explaining this condition and what peer-reviewed scientific research says about exercise therapy.

Acknowledgements
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Disclaimers
This site is intended to complement and not replace any advice or information from a medical or health professional.
The opinions expressed in this site are solely of the author, Siobhán Kibbey. They do not reflect the opinions or stands of any of the mentioned institutions or persons, including those at the University of South Carolina.

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Spondylolysis: Introduction

What is spondylolysis?

Spondylolysis (spon'di-lol'i-sis) derives from the Greek words "spondulos," meaning vertebra, and "lusis," meaning loosening or unbinding. It describes a condition where there is a bony defect or **fracture** in the **pars interarticularis** (literally the part between the [facet] joints) of the vertebral arch **of the spine** (see below). Spondylolysis has been found in approximately one-half of all young athlete patients complaining of low back pain (98) and it is considered by many clinicians to be the **most common cause of low back pain in adolescent patients** (43).

What is NOT spondylolysis?

Spondylolysis is NOT spondylosis or spondylolisthesis. **Spondylosis** is an age-related condition of bony overgrowths on vertebrae; it is usually asymptomatic. **Spondylolisthesis** can result when bilateral spondylolysis allows the vertebra to slip forward from one another. After adolescence, only a small portion of spondylolysis cases (15%) progress to spondylolisthesis (109). Although there are similarities between the two conditions, **all of the research** presented in this website is intended to address cases of **spondylolysis and NOT spondylolisthesis.**

Who are aesthetic athletes?

Aesthetic athletes are athletes who participate in sports where their performance is explicitly contingent upon appearance. Most notably, these are: **gymnastics, diving, skating,** and **dancing**. Spondylolysis is **three to ten times more common** in aesthetic athletes than the general population (98). Roughly **two-thirds of these cases** will present with **lower back pain** and/or **sciatica** (see Signs and Symptoms, below, 98). Aesthetic sports involve **repetitive hyperextension** and **rotation** of the lower (lumbar) spine, which makes it more susceptible to spinal injury (98).

Tell me about the spine!

The spine provides the structural framework for humans to achieve upright posture and motion. It is usually divided into its four primary curves: the cervical (concave), thoracic (convex), lumbar (concave), and sacral/coccyx (convex) curvatures, described in descending location.

The lumbar (lower) spine has five vertebrae. Each of these vertebrae is separated by intervertebral discs that cushion the bodies. Behind each of the vertebral bodies is a bony ring (lamina) that forms a hole (neural foramen) to protect our spinal cord, adjacent blood supply, and exiting and entering nerves. The bony ring also has seven main processes. These are:
(1) The spinous process, which extends backwards, can be seen as superficial "bumps" running down the back, and forms the site for muscle attachments.
(2-3) The left and right transverse processes, which extend sideways and form the site for muscle attachments.
(4-7) The left and right inferior and superior articular processes, which connect vertebrae to one another by forming synovial facet joints by the articulation (meeting) of the inferior and superior articular processes of an upper and lower vertebra, respectively.

Spine defects usually occur in the **L5 or L4 vertebra** (60), which are the lowest two vertebrae of the lumbar spine. When both sides of the pars interarticularis are fractured (a bilateral defect), the inferior articular processes, lamina, and spinous process are physically separated from the superior articular process, pedicles, transverse process, and vertebral body. A weak fibrous connection forms at the site of defect. This weak soft tissue connection may be sufficient for healing (102). It also, however, brings additional nerve elements that increase pain as a method of monitoring stability to protect the spine (36).

Fun Fact: In a lumbar oblique x-ray, spondylolysis classically presents as a "Scotty Dog" collar. The pars defect appears as a collar on the neck (pars interarticularis) of a scotty dog. The scotty dog is formed by the outline of the superior articular process (ear), pedicle (eye/head), transverse process (nose), lamina (body), spinous process (body/tail), and inferior articular processes (legs).

Spondylolysis: Symptoms & More

Signs & Symptoms

The most common symptom of spondylolysis is **localized low back pain** (58). Athletes describe the pain using words like "**chronic**," "**dull**," "**achy**," "**recurrent**," "**constant**," or "**catching**" (44, 69). Usually, the pain worsens with activity, especially during hyperextension or activity mimicking sport movements (58). In gymnastics, walkovers, handsprings, rebounds, punching skills, dismount landings, and back twists have been reported to worsen pain (53). Although not yet reported in peer-reviewed research, similar loadings in other sports may also produce pain. Divers, for example may feel more pain during unaligned water entries and forward, inward, and back twisting skills.

The second most common symptom of spondylolysis is **sciatica** of the L5 or L4 nerve root (22). The majority will not experience nerve irritation, but those who do may feel **pain**, **numbness**, or “**pins and needles**” sensation in the areas (dermatome) with which the nerve connects. For example, if the L5 nerve root is affected, one may feel tingling along the leg from the outside of the knee down the shin and across to the big toe. If the L4 nerve root is affected, there may be symptoms radiating across the front upper leg (outside to inside), and down the inside of the shin or calf.

Red Flags

In a clinical examination, “**Red flags**” indicating a more serious diagnosis must be ruled out. In the younger population, especially:

Any history of cancer, night pain, pain at rest, unexplained weight loss, or failure to improve (metastatic cancer flags);

Immunosuppression, prolonged high fever, or history of IV drug abuse, recent urinal tract infection, cellulitis or pneumonia (diskitis or osteomyelitis flags);

Recent major trauma or prolonged use of corticosteroids (vertebral fracture flags);

And pulsating mass in the abdomen, throbbing resting back pain, or history of artherosclerotic vascular disease (abdominal aortic aneurysm flags) (7).

Diagnosis

After taking a history, a doctor will usually perform a physical examination. People with spondylolysis often have tenderness above the defect, muscle spasm, hamstring tightness, and relatively limited range of motion with back extension and single leg hyperextension.

Spondylolysis symptoms may appear similar to other low back causes, so X-rays can be taken to confirm presence of the lower vertebrae pars defect of spondylolysis. Single-photon emissions computed tomography (SPECT), computed tomography (CT), and magnetic resonance imaging (MRI) may also be used to detect smaller defects, visualize surrounding soft tissue, or provide a more accurate staging of the spondylolysis (51). Spinal abnormalities are relatively common, however, and the presence of an abnormality does not necessarily mean that the defect is causing the low back pain.

Prognosis
Over 80% of children non-surgically treated will recover within six months of treatment onset (42). Bony healing estimates propose that 75-100% of acute lesions heal, 50% of bilateral acute lesions (fracture on both pars interarticularis sides) heal, and no chronic defects heal, though fibrous union may be acceptable for recovery (42).

Exercise Therapy: What is MCE?

What is MCE?
Motor control exercise (MCE) incorporates **general trunk-focused strengthening exercises**, **whole-body movements**, and **trunk and hip stretching** in order to increase spinal stability. It is also known as lumbar stabilization exercise dynamic stabilization, neuromuscular training, neutral spine control, muscular fusion, trunk stabilization, and (segmental) stabilizing exercise.

What are the other treatments?
Currently, the main treatment approaches considered by clinicians for chronic lower back pain due to spondylolysis are (1) minimal intervention, (2) spinal manipulative therapy, (3) general aerobic exercise, (4) motor control exercise, and (5) surgical interventions.

Spinal manipulative therapy (SMT) and **general aerobic exercise** can be combined with MCE to increase treatment effects (5, 15, 52, 63). SMT is "hands-on" mobilization and manipulations of spinal muscles by a chiropractor, physical therapist, or orthomanual therapist. **Surgery** is not recommended until after trying aggressive non-surgical treatments and bracing with and without sport participation (54, 73).

What does the evidence say?
High quality evidence comparing MCE to other interventions in chronic lower back pain cases indicates that:

- MCE reduces **pain and disability** more than **minimal intervention** in chronic lower back pain cases (13, 19, 31, 96).
- MCE reduces **pain and disability** more than **general exercise** in chronic lower back pain cases (2, 20, 23, 25, 64, 104).
- MCE reduces **disability** more than **SMT**.
- MCE and **SMT** reduce intermediate and long-term **pain equally** (2, 23, 31, 82).
- **SMT** reduces **short-term pain** slightly more than MCE (5).

MCE interventions do not need to be exclusive. Moderate quality evidence **supports MCE** with **general exercise** (15, 52) and **SMT** (5, 63).
One high quality trial (69) found that MCE is particularly effective for spondylolysis cases over non-specific chronic low back pain cases.
Low quality evidence indicates that preseason MCE training sessions decrease lower back pain incidence and pain severity later in the season (21, 34). This evidence is promising support that MCE could serve as an effective prevention strategy.
Find the exercises **HERE**.
See more treatment recommendations in **Extra Tips & Tricks**.

Exercise Therapy: How Does MCE Work?

How does MCE work?

People with spondylolysis have **clinical instability** at their defect site. **Clinical instability is correlated with symptom severity** (26, 27, 28). MCE works by **strengthening the spine's stability system** so that it can reduce clinical instability and thus symptoms. Hypothetically, then, MCE could be used preventatively to increase spinal stability before high-risk activities. Currently, though, there are not any published studies confirming this.

How does the spine normally stabilize itself?

In 1992, Panjabi (78, 79) created a model where three subsystems prevent clinical instability.
(1) The **control (neural)** subsystem of the spine feedback systems. Monitors forces on the spine and submits information to the active subsystem.
(2) The **passive (osseoligamentous)** subsystem of the spinal column. Provides structural foundation for neural and active subsystem to act upon.
(3) The **active (musculotendenous)** subsystem of the spinal muscles and tendons, which are grouped into **global** and **local muscles**. Global muscles are large torque muscles that do not directly attach to the spine. Local muscles are directly attached and provide segmental stability (10). Without the active subsystem, the lumbar passive subsystem can only withstand 90 N (9 kg) before buckling.

What about during practice?

Typical gymnastics skills create dramatically higher compression loads, from 4 times body weight in skill take-off **to 30 times body weight in landing** (roughly 2200-17,000 N for a 125 lb gymnast) (14, 53). Alternately, the elite diver has been reported to experience 2000 – 3300 Nm torque in the lower back upon water entry from 0 to 10° offset entry pitch angle, with torque increasing with pitch angle (35).

Consequently, it is very important for aesthetic athletes, especially those with clinical instability, to have **strong active subsystems.** MCE can strengthen the local system and provide the segmental stability for the global muscles to further act upon.

Where can I learn more?
If you would like to learn more about the rationale of MCE, you can read this paper (below), along with a full explanation of this project.

Exercise Therapy: The Exercises!

BASIC ADIM
First, you must learn to perform the basic **abdominal drawing-in maneuver (ADIM)** in **quadruped**, **standing**, and **supine** positions. Following exhalation, tighten your abdominal muscle and draw the belly button up towards the spine or rib cage, without flexing or extending your spine (maintain a neutral lumbar spine).
Practice holding the contraction for **8 seconds** in each position, **30 repetitions** each.

THE EXERCISES
(1) 20x SUPINE ADIM + HEEL SLIDE (each leg) • Starting in a hook-lying position, feet flat on the supporting surface, perform the supine ADIM and slide 1 heel on the supporting surface until the knee is straight. HOLD this for 4 seconds, then return to start. Alternate legs and repeat.

(2) 20x SUPINE ADIM + LEG LIFT (each leg) • Perform a supine ADIM and raise one foot 10 cm above the ground. HOLD this for 4 seconds, then return to start. Alternate legs and repeat.

(3) 30x SUPINE ADIM + 2-LEG BRIDGE • Perform a supine ADIM and raise butt above ground. HOLD this for 8 seconds, then return to start. Repeat.

(4) 30x SUPINE ADIM + 1-LEG BRIDGE (each leg) • Starting in a hook-lying position, feet flat on the support surface, perform the supine ADIM, straighten 1 knee, and raise the butt above ground. HOLD this for 8 seconds, then lower butt to ground, and return to start. Alternate legs and repeat.

(5) 30x SUPINE ADIM + CURL-UP, ELBOWS RESTING ON SURFACE • Starting in a supine position with one leg straight, one leg bent, and elbows resting on surface; place both hands under the lumbar spine in a neutral pelvic and lumbar position. Perform a supine ADIM and raise head and shoulders off the table. HOLD this for 8 seconds, then return to start. Repeat.

(6) 30x SUPINE ADIM + CURL-UP, ELBOWS HELD ABOVE SURFACE • Starting in a supine position with one leg straight, one leg bent, and elbows above surface; place both hands under the lumbar spine in a neutral pelvic and lumbar position. Perform a supine ADIM and raise head and shoulders off the table. HOLD this for 8 seconds, then return to start. Repeat.

(7) 30x SUPINE ADIM + CURL-UP, ELBOWS UP, HANDS ON FOREHEAD • Starting in a supine position with one leg straight and one leg bent, place both hands on your forehead. Perform a supine ADIM and raise head and shoulders off the table. HOLD this for 8 seconds, then return to start. Repeat.

(8) 30x HORIZONTAL SIDE SUPPORT + KNEES BENT (each side) • Starting on side (one forearm extended flat on surface, knees together and bent, resting knee on surface), perform an ADIM and raise your hips and trunk off the surface. HOLD this for 8 seconds, then return to start. Repeat.

(9) 30x HORIZONTAL SIDE SUPPORT + KNEES STRAIGHT (each side) • Starting on side (one forearm extended flat on surface, knees together and straight, resting calf on surface), perform an ADIM and raise your hips and trunk off the surface. HOLD this for 8 seconds, then return to start. Repeat.

(10) 30x HORIZONTAL SIDE SUPPORT + KNEES STRAIGHT + TRUNK ROTATION (each side) • Starting on side (one forearm extended flat on surface, knees together and straight, resting calf on surface), perform an ADIM and raise your hips and trunk off the surface. HOLD this, then ROTATE the trunk backward and forward 4 times in each direction, then return to start. Repeat.

(11) 30x HORIZONTAL SIDE SUPPORT + KNEES STRAIGHT + ROTATE SIDES • Starting on side (one forearm extended flat on surface, knees together and straight, resting calf on surface), perform an ADIM and raise your hips and trunk off the surface. HOLD this, then SWITCH SIDES by rolling over onto the opposite elbow while maintaining a neutral spine. Roll back to start. Repeat.

(12) 30x QUADRUPED ADIM + LEG RAISE (each leg) • Perform a quadruped ADIM, and straighten 1 leg backward while maintaining a neutral lumbar spine position. HOLD this for 8 seconds, then return to start. Alternate legs and repeat.

(13) 30x QUADRUPED ADIM + LEG & ARM RAISE (each leg and opposite arm pair) • Perform a quadruped ADIM, then straighten 1 leg backward AND raise the opposite arm forward while maintaining a neutral lumbar spine position. HOLD this for 8 seconds, then return to start. Alternate legs/arms and repeat.

(14) 30x QUADRUPED ADIM + LEG & ARM RAISE AND CONTRACTION (each leg and opposite arm pair) • Perform a quadruped ADIM, then straighten 1 leg backward AND raise the opposite arm forward while maintaining a neutral lumbar spine position. HOLD this for 8 seconds, then lower WITHOUT returning to start (placing on supporting surface). Repeat. Alternate legs/arms and repeat.

(15) 30x ROWING (standing and quadruped, each arm) • Perform a standing ADIM, then pull a 1 to 1.5 kg weight in a rowing motion until the weight is at chest level. HOLD for 6 seconds, return weight to starting position. Repeat. Then repeat while performing a quadruped ADIM.

* All exercises illustrated and adapted from: (81) Rabin, A., Shashua, A., Pizem, K., Dickstein, R., & Dar, G. (2014, January). A clinical prediction rule to identify patients with low back pain who are likely to experience short-term success following stabilization exercises: A randomized controlled validation study. *Journal of Orthopaedic & Sports Physical Therapy, 44*(1) , 6-18, B1-B13.

How are you doing?
When performing these exercises, make sure to stop and ask yourself:

- Is my spine always in neutral position?
- Am I aware of my body in space?
- How is my body feeling?
- Am I fully completing every repetition and hold?
- Can I increase the intensity of what I am doing?
- Am I applying the ADIM to my sport? For example, do I keep my spine protected in ADIM during flips and landings?

Exercise Therapy: Extra tips & tricks

Talk to your coach, family, and physician

Having your **support network** on your side is important to achieving success with any intervention (24). **Talk** to your coach, family, friends, and medical professional about what you are going through. Ensure their support of your chosen intervention and their help in maintaining a **positive attitude**.

Practice Good Form

Good form is crucial to protecting your back. Make sure that you can perform skills safely before progressing. In the gym, use safety equipment like **Sting Mats** and **foam pits** to decrease impact loads during practice (14).

Stretch

For aesthetic athletes completing MCE, it is especially important to thoroughly **stretch** before exercising to increase the balance between the muscles of the upper core and pelvic floor (53). Also, **be wary of exercising within an hour of waking**, when the ligaments and intervertebral discs experience 80 and 300% higher stresses (1, 84).

Cross-train

Consider combining MCE with spinal manipulative therapy and general exercise. The body will sacrifice spinal stability for breathing, so it is important that aesthetic athletes **maintain high aerobic fitness** during their activities (62, 71). **Spinal manipulative therapy** can complement MCE and decrease short-term pain (5, 63) and **general exercise** can enhance the effects of motor control exercise (15, 52).

Listen to your Body

Playing through pain is not always good; learn to differentiate between “good” and “bad” pain. **Good pain** results from constructively pushing your body, is short-lived, goes away with rest, and does not interfere with daily activities, like walking or sleeping (61). **Bad pain** is generally any pain that is constant or increasing over time, does not improve with treatment, wakes you up during rest, or is associated with nerve damage numbness or tingling (61). Bad pain is associated with the failure or tendons, ligaments, cartilage, bones, or excessive muscle damage (61).

Beware of Female Athlete Triad

Female Athlete Triad is a serious condition where there is a problem with at least one of interrelated spectrums of**:**

(1) **energy availability** optimal to low energy availability with or without an eating disorder;

(2) **menstrual function** eumenorrhea to functional hypothalamic amenorrhea; and/or
(3) **bone mineral density** optimal bone health to osteoporosis (66).

Female Athlete Triad is present in varying degrees in **half of aesthetic athletes** (66). Athletes with menstrual dysfunction have increased risk for progression from spondylolysis to **spondylolisthesis.** They are also **2-4 times more likely to experience stress fractures** (9). Understand that a gymnast could have a normal-weight body mass index (BMI) and still be underweight due to relatively high muscle mass. Also understand that losing one's period is typically a sign of an underlying problem and not a healthy accomplishment.

For more information, see the **Nemour Foundation** and **Female Athlete Triad Coalition's** websites.

Print
You can print out most of the information available on this website HERE. Share evidence with your loved ones and keep the MCE handout handy!

APPENDIX B. MCE HANDOUT SUMMARY – IMAGES ONLY

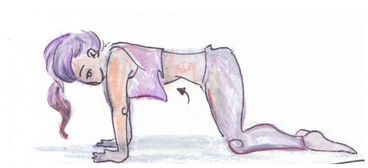
4/21/15

Spondylolysis
& Aesthetic Athletes
http://www.aestheticmce.weebly.com
MCE Handout
Siobhán Kibbey
April 2015

Standing ADIM

30x
http://www.aestheticmce.weebly.com

Quadruped ADIM

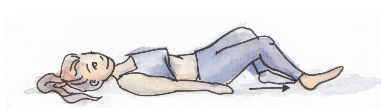


30x
http://www.aestheticmce.weebly.com

Supine ADIM

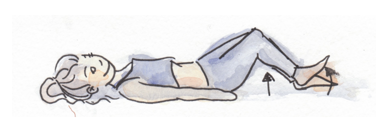
30x
http://www.aestheticmce.weebly.com

1. Supine ADIM + Heel Slide



20x Each Leg
http://www.aestheticmce.weebly.com

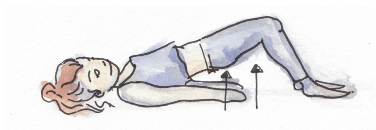
2. Supine ADIM + LEG LIFT



20x Each Leg
http://www.aestheticmce.weebly.com

http://www.aestheticmce.weebly.com 1

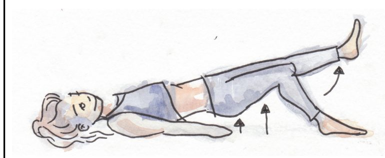
3. Supine ADIM + 2-Leg Bridge



30x

http://www.aestheticmce.weebly.com

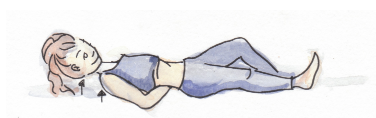
4. Supine ADIM + 1-Leg Bridge



30x Each Leg

http://www.aestheticmce.weebly.com

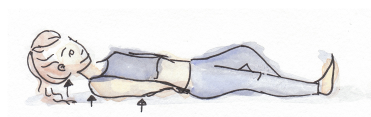
5. Supine ADIM + Curl-up + Elbows Down



30x

http://www.aestheticmce.weebly.com

6. Supine ADIM + Curl-up + Elbows Up



30x

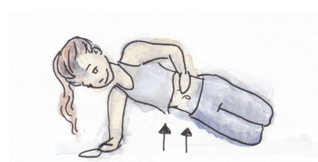
http://www.aestheticmce.weebly.com

7. Supine ADIM + Curl-up + Elbows Up + Hands on Forehead

30x

http://www.aestheticmce.weebly.com

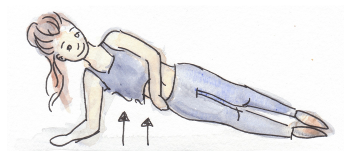
8. Horizontal Side Support + Knees Bent



30x each side

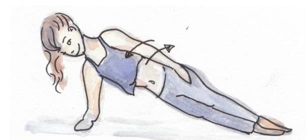
http://www.aestheticmce.weebly.com

9. Horizontal Side Support
+ Knees Straight



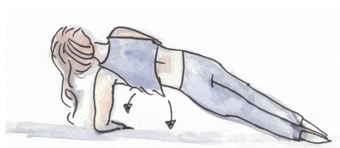
30x each side

10. Horizontal Side Support
+ Knees Straight
+ Trunk Rotation



30x each side

10. Horizontal Side Support
+ Knees Straight
+ Rotate Sides

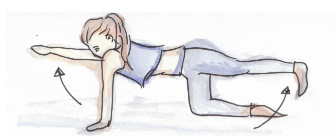


30x

12. Quadruped ADIM + Leg Raise

30x each leg

13. Quadruped ADIM + Leg Raise
AND Opposite-Arm Raise

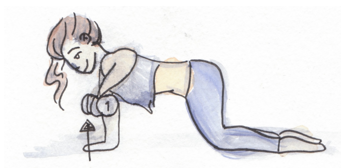


30x each leg/arm pair

14. Quadruped ADIM + Leg Raise
AND Opposite-Arm Raise,
No Rest

30x each leg/arm pair

15. Quadruped ADIM + Rowing



30x each arm

http://www.aestheticmce.weebly.com

How are you doing?

Ask yourself…

- Is my spine always in neutral position?
- Am I aware of my body in space?
- How is my body feeling?
- Am I fully completing every repetition and hold?
- Can I increase the intensity of what I am doing?
- Am I applying the ADIM to my sport? For example, do I keep my spine protected in ADIM during flips and landings?

http://www.aestheticmce.weebly.com

APPENDIX C. HONCODE EVALUATION FORM

Health On the Net Foundation
Non Governmental Organization
Medical information you can trust!

HONcode

PATIENT / INDIVIDUAL | MEDICAL PROFESSIONAL | WEB PUBLISHER

HONcode | HONsearch | HONtools | HONtopics

Trustworthy health sites | Search

- What is it?
- HONcode certification
- Certification Process
  - Step by step
  - Guidelines
  - Guidelines - Web2.0
  - Policing & Supervision
    - Policing
    - Complaints
    - Certificate & Seal
    - Updates
  - Conditions
  - Annual re-certification
  - Apply for certification
  - Site Evaluation Form
- Last Certification Activity
- Satisfaction survey
- HONcode principles
- EU Quality recommendation

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Survey for webmasters:
How can you help to preserve diversity of health information sources?

Follow us on

HONcode Site Evaluation Form

English - French - German - Spanish - Russian - Romanian - Polish - Chinese

This tool allows you to test your site, to really register you, please **click here**

Step 1: Does my site follow the HONcode principles?

Principle 1. Information must be authoritative

1. My site provides general information about the organization or individual responsible for its operation and content, and a person is named as editor or principal author

- ◯ Yes, an author's or editor's name is given
- ◯ No

2. My site provides medical/health information or advice

- ☐ Given by medical/health professionals whose training/credentials are listed
- ☐ A clear statement (e.g. a disclaimer) is made whenever medical/health that the information or advice is offered by non-medical professionals or organisations
- ☐ Some health/medical information is not attributed to an author

Clear Selection

Principle 2. Complementarity/Mission/Assistance

3. A statement declaring that information provided on the site is meant to complement and not replace any advice or information from a health professional is clearly provided

◯ Yes ◯ No

Clear Selection

4. A statement describing the intended mission of the site is provided on the site

◯ Yes ◯ No

Clear Selection

5. The site clearly mentions the intended audience of the site (general public, health professionals, students…)

◯ Yes ◯ No

Clear Selection

Principle 3. Privacy - Confidentiality

6. My Privacy/Confidentiality Policy regarding e-mail addresses, personal and medical information is displayed on my website

◯ Yes ◯ No

7. Do my site and its mirrors respect the legal requirements, including those concerning medical and personal information privacy, that apply in the country and state of their location?

◯ Yes ◯ No ◯ Don't know

Clear Selection

Principle 4. Information must be documented: Referenced and dated

8. Is the last modification date provided for the site?

◯ Yes, for the site as a whole
◯ Yes, for each page containing health/medical content
◯ Yes, for all the pages of the site
◯ No (explain as necessary below)

Clear Selection

9. Does my site contain information from external sources?

☐ Yes, but no reference to the source is made

☐ Yes, an HTML link (valid and regularly checked) is provided to the source data

☐ Yes, a bibliographic reference to the source data is given

☐ No, the content of my site is original, written by the editorial website team

Clear Selection

Principle 5. Justification of claims

10. Does my site make claims relating to the benefit or performance of a specific medical treatment, commercial product or service?

☐ Yes, all claims are supported by clear references to scientific research results and/or published articles

☐ Yes, my claims are based on my personal research or opinions

☐ No

Clear Selection

Principle 6. Website contact details

11. A valid email address for the webmaster or a link to a valid contact form is easily accessible throughout the site?

◯ Yes ◯ No

Clear Selection

Principle 7. Disclosure of funding sources

12. Is the source of the funding of my site clearly described?

for commercial or non-commercial organisations:
◯ Yes ◯ No

for personal or private sites, or those hosted without charge:
◯ Yes ◯ No

[Clear Selection]

Principle 8. Advertising policy

13. My site displays advertising that, is a source of income:

- ☐ A page provides a description of our advertising policy
- ☐ Separation between editorial content and advertising is clearly stated
- ☐ No explanation regarding banner advertising is given
- ☐ All ads banners are clearly identified as advertising with the word 'advertising'
- ☐ Advertising is not identified as such

14. My site is part of a link/banner exchange:

- ◯ Yes, a statement describes precisely the relationship between my site and the other websites
- ◯ Yes, a statement describes precisely the relationship between my site and the other websites mentioning any economic benefit derived from the exchanges
- ◯ Yes, but there is no specific description about our policy
- ◯ No

15. My site does not display advertising:

- ◯ There is a clear statement explaining that my website does not accept or host any advertisement
- ◯ There is no statement displayed

[Clear Selection]

[Next step : verification] [Clear Selection]

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/cgi-bin/HONcode/Inscription/site_evaluation.pl last modified: May 15 2014