The Multifidus Muscle Integrator (MMI)
Developed By:

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And

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Participants in the Project

Roy Bechtel, PT, PhD

Dr. Bechtel graduated from the University of Maryland with a BS in PT in 1979. He received an MS in PT from New York University in 1981 and a PhD in Biomechanics from the University of Maryland in 1998. He teaches in the Department of Physical Therapy & Rehabilitation Science and has conducted continuing education courses nationally and internationally. His research interests are in manual physical therapy assessment and treatment of pain of spinal origin, and biomechanical modeling of forces applied to spinal and sacroiliac joints. Recently Dr. Bechtel published a paper on the tolerance for isokinetic testing pre and post lumbar fusion.

Scott Benjamin, PT, DScPT

Dr. Benjamin received his undergraduate training from the Michigan Technological University in 1982 and his physical therapy BSc from the University of Illinois at Chicago. His graduate work was completed at the University of Maryland. He has authored papers on lateral epicondylitis, modalities, isokinetic testing and aquatic therapy. His areas of interests are biomechanics of the spine, sacroiliac joint, manual therapy and rehabilitation.

The History and Need for the Multifidus Muscle Isolator (MMI)

Low back pain (LBP) is the most common condition for which people seek medical advice (Eisenberg, 2007) and 70-80% of American's will do so at least once in their lifetime. (Kovacs, 2007)

Scientists are still struggling to answer questions like: What puts people at risk for developing LBP ? What structure or structures may contribute to the LBP ? How can we reduce a person's risk for developing LBP ? How can we prevent a recurrence of LBP and time lost from work ?

Recently, it has been demonstrated that a deep muscle in the spine called the multifidus can generate pain in and of itself. (Cornwell, 2006)

The multifidus muscle is an important stabilizer of the spine (Hides, 1996). Like all muscles, with reduced activity, the multifidus muscle loses cross sectional area (Rantanen, 1993). It has also been demonstrated that a reduction in multifidus cross-sectional area occurs in patients with LBP Hides, 2001). So, with LBP there is a decrease in the stabilizing function of multifidus.

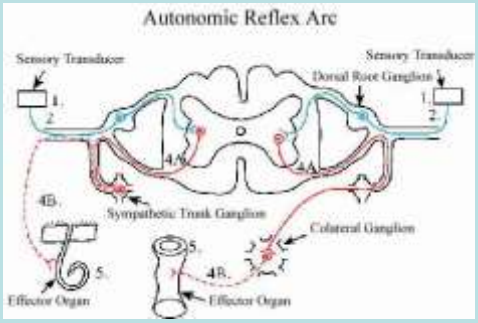
The Inhibition Model and the theory of exercises

Most exercise equipment on the market today has been designed for one purpose, to strengthen "weak" muscles. This strengthening model has worked well for a portion of the population.

However, the strengthening model has some flaws. Chief among them is the assumption that "weakness" arises from disuse and resulting changes within the muscle's internal structure. While this scenario is certainly true in some special cases, spinal cord injury, nerve injury, and muscle injury, for example, it is unlikely to explain the majority of cases of idiopathic LBP encountered in the population at large.

More common, is the scenario of **"inhibition"**, whereby certain muscles, and we are now beginning to know which muscles in particular (transversus abdominus, multifidus, pelvic floor muscles and diaphragm), (Richardson et al, 2006) are prevented from working normally by changes in nerve signaling. It is not the "weak" muscle we should attempt to "strengthen". It is the altered nerve signaling that we should attempt to correct.

The Inhibition Model and the theory of exercises



Where does the inhibition come from ?

Muscles are regulated by the brain and spinal cord.
The brain makes a plan and sends it to the spinal cord.
The spinal cord relays the plan to the muscles.
But the spinal cord can change the plan, based on **feedback** it receives from receptors in the body.

The Inhibition Model and the theory of exercises

Where does the inhibition come from ?

There are many types of receptors, but chief among them are pain receptors, called nociceptors, and movement receptors, called proprioceptors. The proprioceptors allow the brain and spinal cord to monitor spine movements.

The Inhibition Model and the theory of exercises

Stimulating pain receptors inhibits muscle activity, (Verbunt et al., 2005) but we hypothesize that a lack of proprioceptive input can have the same impact.

The brain and spinal cord depend on feedback from the joints to regulate muscle force. If the joint feedback is missing, the spinal cord shuts down the muscles as a protective measure, to avoid causing injury.

The Inhibition Model

The **inhibition model** allows trained health professionals to attempt to remove the problem causing the muscles to be inhibited. Then, inducing specific exercises directed at the previously inhibited muscles retrains them to participate in movements with appropriate timing and force. For complete rehabilitation, i.e., to reduce the likelihood of recurrence, a patient also needs to incorporate a comprehensive program involving aerobic exercises to improve tissue resistance to the stresses of daily life or the specific demands placed on the body by the athlete or physical performer (musician, actor, dancer, etc.). Almost no currently-available exercise equipment is fabricated to address the inhibition issue.

Our **Multifidus Muscle Integrator** incorporates design principles which allow a person to retrain inhibited muscles, and strengthen aerobically, while avoiding positions and movements likely to cause inhibition to recur. This strategy should result in both short and longer-term patient satisfaction and a reduced burden on the healthcare system overall.

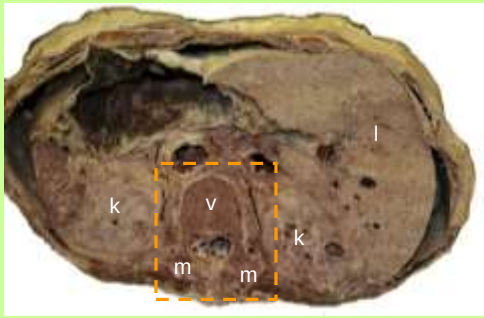
Multifidus anatomy and function

Multifidus traverses from the spinous processes of L1 to L5 to connect to mamillary processes of the next vertebra below. Multifidus fibers also run from the spinous processes to the sacrum, posterior superior iliac spine (PSIS) and the sacral spines. (Bogduk, 2005) The multifidus muscle is innervated by the medial branch of the dorsal ramus of the spinal nerve at each segment.

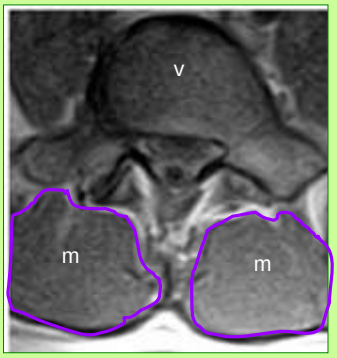
The efficiency of spine motion relies on both local and global control. (Bergmark, 1985; Richardson, 2004; Hides, 1996)
The global action of the multifidus is to aid with spine lateral flexion, rotation and extension. It also controls local sliding motions between the vertebral segments to prevent injury. (Panjabi, 1989; Richardson, 2004; Urquhart, 2005)

Any disruption of multifidus function could lead to loss of intersegmental control, potential injury, and pain, as well as changes in the global motions of the spine. (Richardson, 2004, Cornwell, 2006, Beeton, 2003, Indahl, 1997)

Multifidus Muscle Anatomy



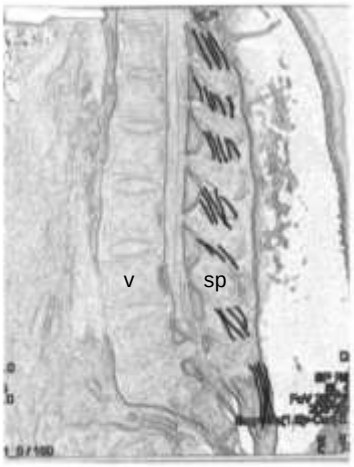
Cross-section cut showing the location of multifidus (m), in the body. v - vertebral body of spine; k – kidney; l - liver



Cross-section MRI showing the location of multifidus (m), relative to: v - vertebral body of spine.

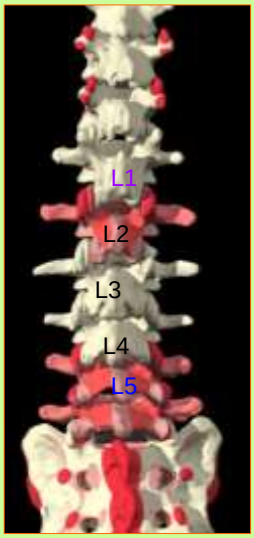
Multifidus Muscle Anatomy

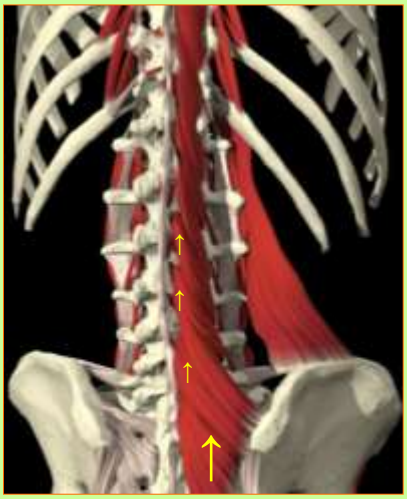
Spine MRI. Multifidus muscles indicated by arrows. v - vertebral body; sp – spinous process.



Schematic of left panel. Dark lines indicate multifidus fiber directions.

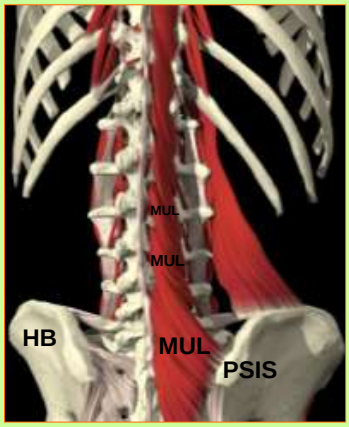
Vertebral column, lumbar spine and sacrum, showing multifidus muscle attachments.





Multifidus muscle and attachment to the lower segmental level and into the sacrum.

Multifidus attachment and points from the spinous process to the mamillary bodies on the adjacent vertebrae below.



Legend:

sp: spinous process

MP: mamillary processes

PSIS: Posterior Superior Iliac Spine

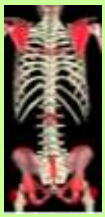
MUL: Multifidus Muscle

HB: Hip Bone

The multifidus spirals obliquely downward from each spinous process to the mamillary process below, but also traverses downward to the sacrum and the posterior superior iliac spine on the pelvis.

The origin of LBP is multifactorial. Muscle injury, disc bulge or ligamentous sprain, can cause pain and resulting multifidus inhibition. The pain is usually self-limiting. But when the episode of pain is gone, the muscle remains inhibited. The neutral control system "learns" not to activate the multifidus even though the pain may be lessened or gone. (Hodges, 2006)

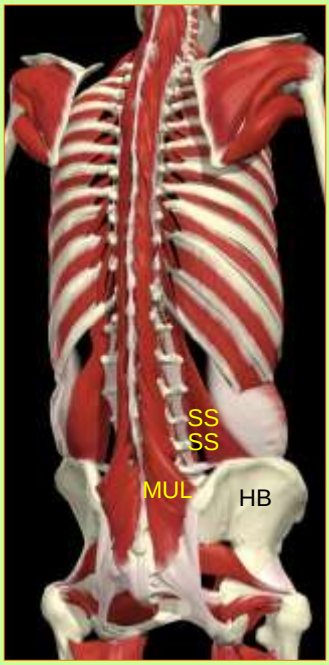
As you experience more and more episodes of low back pain, changes can occur in the muscle fiber themselves (Yoshihara, 2001) The muscle fibers that change most readily are those responsible for the local control of segmental motion.



So, step 1 of the rehabilitation program aims to take away pain. However, taking away pain is not enough. Step 2 aims to decrease inhibition and restore normal muscle function. This requires specific exercises directed at multifidus. (Hides, 1996)

Richardson and Jull (1995) reported that when multifidus is inhibited, other supporting cast muscles will attempt to increase activity to control spinal motion. However, no other muscle is as ideally positioned to control segmental motion as multifidus.

O'Sullivan, et al (1997) demonstrated that two major factors contribute to produce chronic low back pain: 1) De-conditioning and 2) dysfunction in the neural control system. If both of those situations are in place, then the person is at high risk for LBP.



The “global” muscle system is designed to move the body in space. It must rely on the neural control system to activate “local” muscles with appropriate timing and force to provide strong segmental stability as the spine moves. The safety and efficiency of spine motion relies on both local and global control. (Richardson, 2004, Hides, 1996)

Legend:

HB: Hip Bone

Multifidus: MUL

Spine segments: SS

Is Exercise Dangerous for Patients with LBP ?

Studies have shown that the best way to treat incidents of LBP is to keep as active as possible. This strategy reduces the length of the painful incident, compared to rest. So, exercise should be a great idea for someone with LBP, either before or after disc surgery. (Ostelo et al., 2003)

There are two problems with this idea, however. On the one hand, most exercise equipment for the back allows and even encourages patients to go through full range spine flexion. Repeated full-range flexion movements have been shown to produce inhibition of the lumbar stabilizing muscles, leaving the back vulnerable to injury from the very exercise meant to help it. (LaBry et al., 2004)

On the other hand, LBP is frequently associated with segmental dysfunctions between the vertebral bodies, either entailing reduced or excessive segmental motion. Reduced motion inhibits normal stabilizing muscle activity by eliminating proprioceptive feedback. Lack of normal stabilizing muscle activity commonly results in excessive segmental motion which can lead to injury. (Hodges and Moseley, 2003)

Design Principles of the Multifidus Muscle Integrator (MMI)

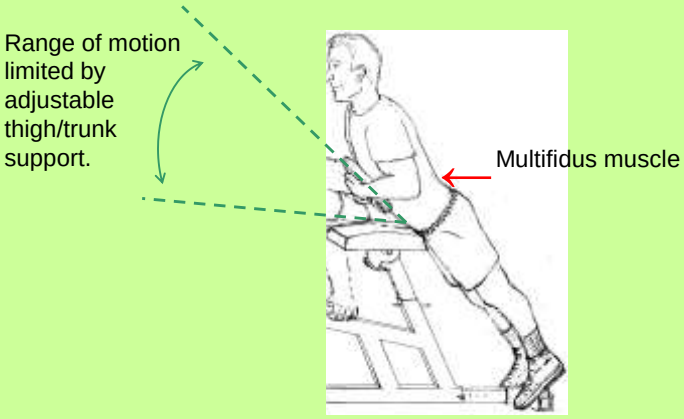
1. For exercise to be effective, it must target the muscle(s) of interest. The exercise must activate the targeted muscle more effectively than other types of exercise. For patients with LBP or healthy people wishing to avoid LBP, this means concentrating on multifidus. (Hodges, 2006, Choi, 2005, Hyun, 2007 Hodges, 1996)
2. For the back, effective exercise must avoid movements and positions that cause inhibition of the targeted muscles, since this prevents the muscles from getting stronger in spite of practice (Hides, 2001).

Design Principles of the Multifidus Muscle Integrator (MMI)

In practice, an effective and safe exercise machine for the back must encourage performance of an activity that elicits multifidus muscle activity, while limiting the amount of flexion the spine can be permitted to reach.

The MMI achieves these goals by taking a basic exercise with proven effectiveness, back extension against gravity, and modifying the exercise with a unique thigh and trunk support that limits overall flexion, and can be adjusted to accommodate increased flexion as the exerciser improves.

Schematic of the MMI: The multifidus muscle controls the motion from extension to flexion and back. The optional weight adds more resistance and allows aerobic training to create muscle hypertrophy and tissue resistance to physical stress.



Before we explore the MMI further, let's look at how our competitors handle the problem of safe and effective back exercise. . .

We used a real-time ultrasound probe to see how well different exercises recruited multifidus.

Real-Time Ultrasound

Ultrasound imaging (US) has been in the recent literature as a reliable way to look at how muscles work in real time. (Whittaker, 2007a; Whittaker, 2007b; Wallwork, 2007) Previous researchers have also used US to measure muscle cross-sectional area. (Wallwork, 2007, Stokes, 2005, Hides, 1994) US has also been used to measure multifidus muscle performance. (Hodges, 2006)

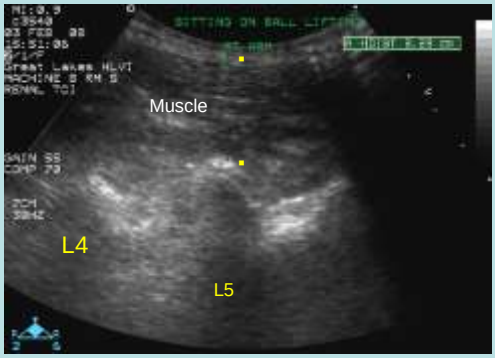
Left panel: real-time Ultrasound System.*

Right panel: experimental set-up, monitoring right multifidus during left leg exercise.

*Mettler Instruments Marietta, GA USA

Multifidus activation on the Exercise Ball

Exercise balls are used clinically, but do they really achieve the best multifidus contraction for a patient? Research shows (Drake, 2006) that "no" exercise balls do not isolate the multifidus more than other exercises. Our US experiments confirmed this result.



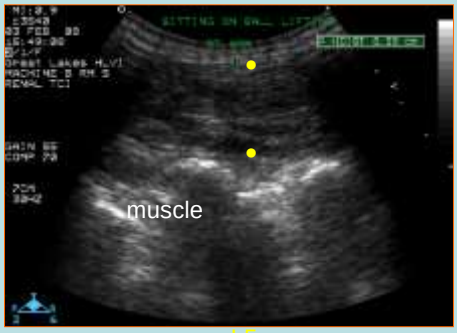
Exercise: lift right arm sitting on ball

Legend:

L5: L5 spinous process

L4: L4 spinous process

2.29 cm measurement of multifidus contraction between the yellow dots.



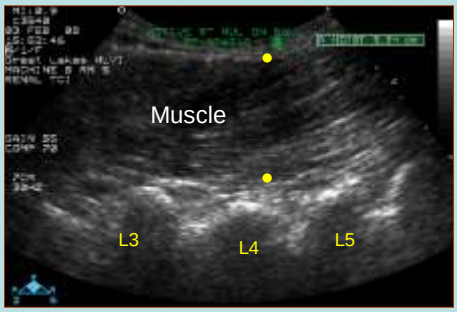
Exercise: lift right arm sitting on ball

Legend:

2.35 cm multifidus contraction

L5: L5 spinous process

L4: L4 spinous process.



Exercise: Prone on ball, lift trunk

Legend:

3.24 cm multifidus contraction.

L3: labeled spinous process shown

L4: labeled spinous process shown

L5: labeled spinous process shown

From the evidence, we know that trunk extension against gravity effectively focuses on multifidus. Let's look at exercise devices designed specifically for this purpose.

Roman chair fixed at 45 degrees.

The **Roman Chair** is used to strengthen the back muscles. However, studies show that the angle of the chair and the position of the exerciser is specific to emphasize the hip extensors, not the low back muscles. (Verna, 2002).

What concerns us most about the **Roman Chair** is safety: 1) the extremely angled position the exerciser's trunk is allowed to assume causes concomitant compression of the anterior elements in the spinal column and increases the pressure on the intervertebral disc, causing it to bulge backward into the spinal canal. (Sparto, 1998; Panjabi, 1992a; Panjabi, 1992b) 2) Repeated flexion through this range has been shown to inhibit the low back stabilizing muscles.

Summary of the Roman Chair

The competition, in this area of low back strengthening attempts to isolate the low back muscles but only partially achieves that goal. By supporting a person's thighs and not the pelvis, strain is placed on the hip extensor muscles. **The trunk is not supported fully and the pivot point of motion is from the hips with no stops or checks for trunk motion**. If a person moves too far down into flexion, they are actually putting pressure on the ligamentous structures within the lumbar spine and pelvis and inhibiting the very muscles it is desired to strengthen (Chow, 1989, Yamamoto, 1990, Vleeming, 2002) Over a long period of time, the result is not strengthening the low back, but compromising the stability of the spine.

Pivot point shown supported at the thighs

PP

Roman Chair

How would we improve the design of the roman Chair ?

1. Make the supporting frame adjustable to accommodate exercisers of different body types easily. This will focus more of the activity on the low back and less on the hip extensors.
2. Move the thigh pad and make it adjustable so that it both supports the pelvis and limits trunk motion. This will help to minimize inhibition of the low back stabilizers.

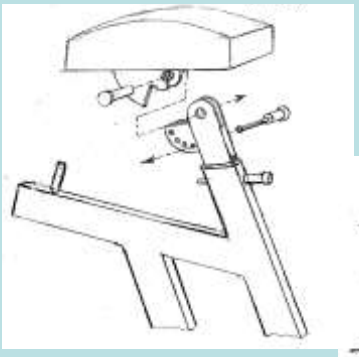
"Coming together is a beginning…keeping together is progress…Working together is success" John Maxwell

The purpose of the MMI is to restore strength and control of the spine by integrating the deep stabilizing muscles (**multifidus**) of the spine into a healthy exercise program. After using the MMI, you can function better and improve the quality of your life with easier motion, strength for your daily life, and with significantly fewer episodes of disabling low back pain.

The Multifidus Muscle Integrator (MMI)

Differences from Competition:

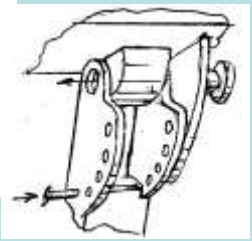
The MMI is a revolutionary multidirectional machine that allows the user to isolate the multifidus muscle in your lumbar spine. (deep back muscle) The MMI is preset to work the deep spinal stabilizing muscles at three different angles, which are easily set by moving a pin to the corresponding angle.



Left panel:

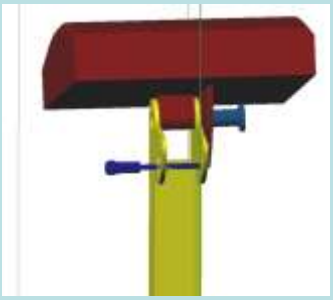
a. Support pad curves to contour the pelvis

b. An adjustable pin and cam system for angle adjustment.



Right panel: The configuration of the pivoting pad design for the MMI showing the variable angle positions from the front.

3D CAD drawing of the pivoting pad and MMI pin system.

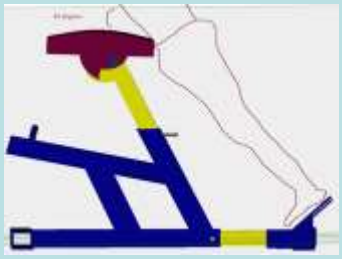


Pivoting trunk support

Fully adjustable

The MMI with the angles shown and a person's torso as the are shown at each angle with pad checking the motion that the person can perfrom.

← 15 degree pad placement as shown



↑ 30 degree pad angle placement as shown above.

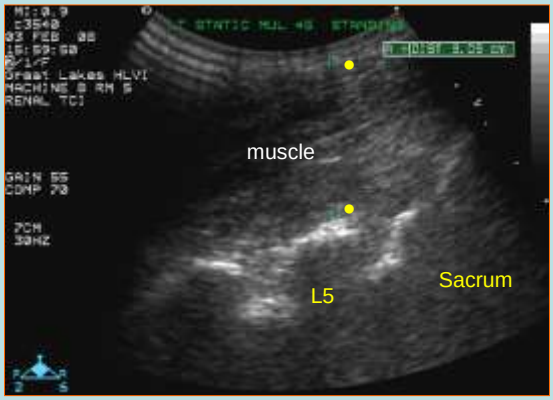
45 degree angle of the pad →

Differences from Competition

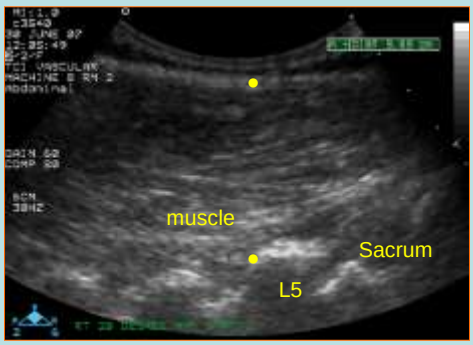
The MMI affords the user the opportunity to isolate their low back muscles at three distinct angles which can be related to functional movements. The MMI safely supports the spine and pelvis, while the user improves endurance and power in the deep multifidus and other back muscles. The market today has many stand-alone back strengthening machines, but none that adjust for a person's body dimensions. There is nothing that can both change its range of motion and adjust to an individual's dimensions. Research suggests that in order to keep your back healthy, you must isolate the multifidus and keep the mechanics of motion correct. Today's market will dictate current trends, but we believe the MMI is the only device that allows you to accomplish both these goals at once.

US on the MMI

The multifidus muscle being shows via US analysis to the right.

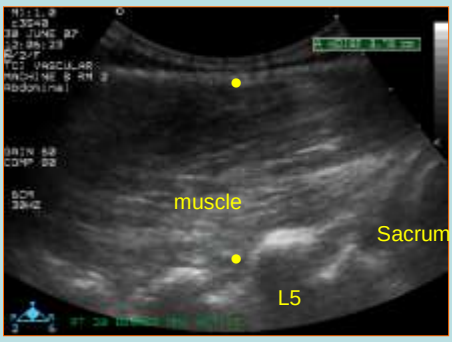


Exercise: MMI, 45 degree flexion angle. Left multifidus shown. 3.05 cm contraction.



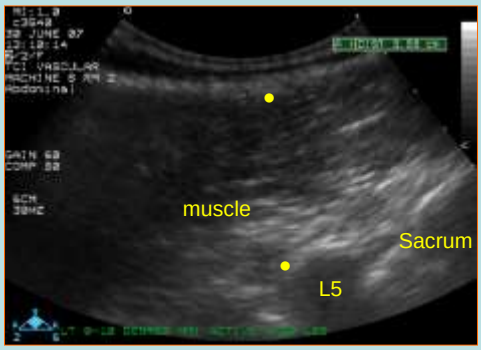
Exercise: 20 degree angle isometric.

3.69 cm right multifidus contraction.



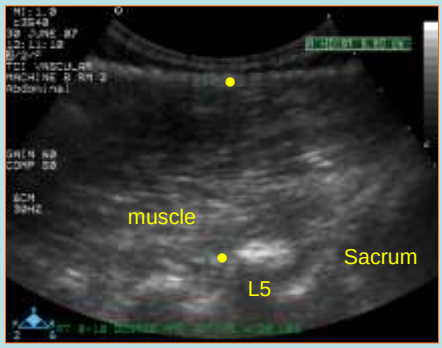
Exercise: 20 degree concentric/eccentric.

3.79 cm right multifidus contraction.



Exercise: 10 degree angle concentric/eccentric with 20# in hand.

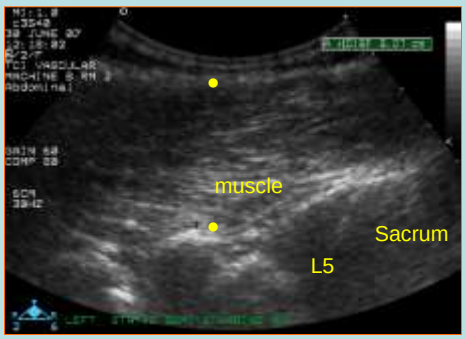
3.58 cm contraction left multifidus.



Exercise: 10 degree angle concentric/eccentric with 20# in hand.

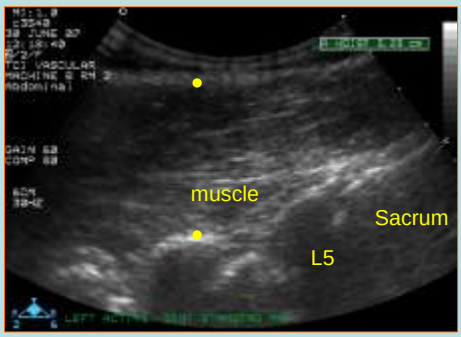
3.80 cm contraction right multifidus.

This subject has a left-sided weakness due to a sports injury but the MMI exercise position has helped the muscle contraction return almost to the level of the uninvolved (right) side.



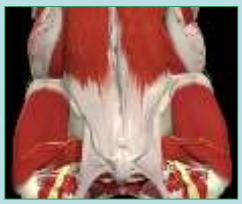
Exercise: 0 degree angle. Isometric contraction.

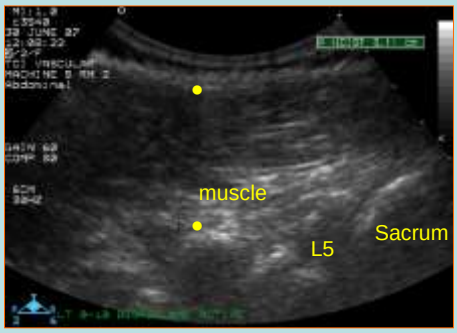
3.07 cm left multifidus contraction.



Exercise: 45 degree angle. Isometric contraction.

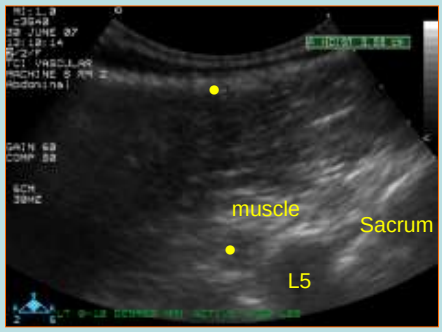
3.28 cm left multifidus contraction.





Exercise:10 degree angle. Concentric/eccentric contraction.

3.11 cm left multifidus contraction.



Exercise: 10 degree angle with a 20# weight in hand. Concentric/eccentric contraction.

3.58 cm multifidus contraction.

MMI Summary

The MMI device will allow the user to isolate and integrate the multifidus muscle so that there is local control of motion in the lumbar spine. We have shown that the MMI is at least as effective as the Roman Chair at isolating the multifidus. Research suggests that the design principles of the MMI will also allow multifidus function to be integrated into a healthy low back exercise program by avoiding potential sources of multifidus inhibition, to which devices like the Roman Chair, are prone. We believe the MMI represents the leading edge of the next generation of safe and effective exercise equipment for the 21st century.