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SPECIAL ISSUE

Correcting Abnormal Lumbar Flexion Surface Electromyography Patterns in Chronic Low Back Pain Subjects

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The flexion relaxation phenomenon refers to a stereotypical surface electromyographic (SEMG) pattern of initial contraction followed by relaxation of the low back muscles while bending. This pattern is demonstrated by most pain-free subjects but is often absent in chronic low back pain (CLBP) subjects. An SEMG-assisted stretching protocol is presented, which has been used successfully over several years in an interdisciplinary chronic pain management program to address fear-avoidance and pain inhibition, to help normalize flexion relaxation, and to help CLBP patients achieve effective stretching and increase range of motion.

Fear-Avoidance and Physical Deconditioning in Chronic Pain

In the fear-avoidance model of chronic pain, first proposed by Lethem, Slade, Troup, and Bentley (1983), fear of pain leads to a cycle of decreased physical activity and increasingly exaggerated pain perception. As chronic pain develops, pain behavior becomes less a reaction to nocioceptive pain signals and more of a fear-avoidance response to prevent further pain. A study by Klenerman (1995) offers support for the fear-avoidance model of chronic pain. They collected a large amount of psychosocial and physiological data on 300 acute low back pain measures and determined that fear-avoidance measures were the best predictor of the development of chronic pain (correctly predicting chronicity in 66% of those patients who became chronic). Interestingly, very little direct relationship has been found between pain severity and level of disability (Waddell, Newton, Henderson, Somerville, & Main, 1993; Vlaeyen, Kole-Snijders, Boeren, & van Eck, 1995), leading some researchers to conclude that fear of pain is more important than actual pain in maintaining disability (Waddell et al., 1993; Crombez, Vlaeyen, & Heuts, 1999).

As pain becomes chronic, inhibited movement, avoidance of normal daily activities, and physical disuse will inevitably result in physical deconditioning, which is characterized by decreased muscle strength, decreased elasticity of muscles and tendons, decreased range of motion (ROM) of joints, weakness of the cardiovascular system, and impairment of normal healing (Bortz, 1984; Mayer, 2000; Mayer, Polatin, & Gatchel, 1998). As deconditioning worsens, the chances of having pain flare-ups, muscle spasms, and muscle strains increases when one attempts to engage in normal activities (Mayer, 2000). The relationship between pain, fear-avoidance, and physical deconditioning can create a cycle that maintains chronic pain and disability.

The Flexion Relaxation Phenomenon

Normal, pain-free subjects show a stereotypical surface electromyographic (SEMG) pattern of initial contraction followed by relaxation of the low back muscles when bending completely into maximum voluntary flexion (MVF). This pattern has been referred to as the flexion-relaxation (FR) phenomenon (Schultz et al., 1985; Sihvonen, 1988). Numerous studies have demonstrated that most chronic low back pain (CLBP) subjects show an abnormal FR pattern and a lack of relaxation during MVF (Triano & Schultz, 1987; Ahern, Follick, Council, Laser-Wolston, & Litchman, 1988; Shirado et al., 1995; Sihvonen, Partanen, Hänninen, & Soimakallio, 1991). A recent meta-analysis of SEMG and chronic pain found that assessment of FR produced a very large effect size (d = -1.71) in identifying CLBP versus pain-free subjects (Geisser et al., 2005).

A number of studies have demonstrated that fear of pain and reinjury is correlated with increased inhibition of movement and physical activity, decreased ROM, and FR abnormalities. Self-report measures of fear of pain and reinjury have predicted decreased behavioral performance with CLBP subjects in a lifting task (Vlaeyn et al., 1995), decreased ROM in chronic and acute low back pain subjects during a standard straight leg raise test (McCracken, Gross, & Sorg, 1993), and increased SEMG and decreased lumbar ROM during MVF in CLBP subjects (Geisser, Haig, Wallborn, & Wiggert, 2004).

We are aware of only 2 treatment outcome studies of FR: by our group (Neblett et al., 2003a) and by Watson, Brooker, and Main (1997). Watson et al. tested a group of CLBP subjects before and after a standard multidisciplinary chronic pain management program. They assessed subjects on ROM and lumbar SEMG using an FR ratio (FRR), in which the SEMG level during the flexion movement is divided by the SEMG during MVF (Watson, Brooker, Main, & Chen, 1997; Geisser, 2007). The use of the FRR has been recommended in the assessment of lumbar flexion to help correct for individual differences in adipose tissue and skin impedance between subjects (Geisser et al., 2005). Pain-free subjects tend to have higher FRR scores than chronic pain subjects, indicating a larger difference in SEMG levels between the flexion movement and MVF. Watson et al. found that higher pretreatment measures of fear of pain and reinjury predicted lower FRR scores. Following treatment, positive changes in fear and self-efficacy beliefs were correlated with higher FFR scores. Despite significant changes in FRR scores between pre and post, the group SEMG levels during MVF remained above 15.0 microvolts root mean square, which indicates that lumbar relaxation and FR were not achieved.

Functional Restoration

The author provides biofeedback services within an interdisciplinary *Functional Restoration* treatment program that specializes in treating injured workers who have developed chronic pain and disability (Mayer et al., 1998). The general treatment goals are to help patients regain normal functioning and re-enter the workforce. When patients enter the program, objective measures of physical deconditioning, including ROM, strength, and cardiovascular testing, are performed. These measures are repeated periodically to assess progress as patients are moved through a program of physical exercise, educational classes, and individual treatments. Psychological components (depression, anxiety, etc.) are assessed and treated, and secondary obstacles to increased function, such as workers' compensation case issues, are addressed. The general treatment philosophy is that as patients regain normal strength, normal ROM, and normal cardiovascular functioning, and as depression, anxiety, and fear are reduced, and as secondary obstacles to increased functioning are resolved, then patients will feel better, will experience less pain, and will be able to function more normally.

The foundation for increasing physical functioning and for successfully increasing strength through physical exercise is to regain normal movement. This is achieved by stretching. The primary purpose of muscle stretching is to lengthen shortened muscles so that joints can move within normal ROM, allowing joints to function as they were designed. Regaining ROM is a precursor to achieving optimal success with muscle strengthening. When muscles are short and inelastic due to inactivity and deconditioning, muscle strengthening exercises can result in increased soreness, spasms, and pain flare-ups, further re-enforcing a cycle of pain, inhibition, and fear avoidance.

Though stretching and increasing ROM motion is strongly emphasized from the first day of *Functional Restoration* treatment and throughout the program, many patients have great difficulty overcoming fear-avoidance beliefs and movement inhibition to achieve effective stretching. This can create a significant obstacle to treatment success, but it can also provide a great opportunity for psychophysiological intervention and SEMG biofeedback training in helping patients overcome this obstacle.

Surface EMG-Assisted Stretching

Over the last several years, the author has developed an SEMG-assisted stretching treatment protocol to help chronic pain patients overcome pain/fear-related movement inhibition, learn effective stretching techniques, and achieve more normal ROM (Neblett, Mayer, & Gatchel, 2003b; Gatchel & Mayer, 2003c). This protocol involves education, SEMG biofeedback, and supportive counseling components. This protocol has been used successfully to address movement inhibition in a number of muscles and joints, including wrists, shoulders, knees, hamstrings, necks, and low backs.

Patients who are inhibited and/or are not stretching effectively are identified by an SEMG assessment. In this assessment, the target muscle(s) are measured while the patient performs the target stretch. Elevated SEMG during the stretch, as well as visual observation of strain and breath holding, suggests inhibition and decreased stretch effectiveness. The treatment protocol involves the following steps:

1. Explain the rationale for stretching a relaxed muscle versus stretching a contracted muscle. Patients will often say "that's as far as I can go." The SEMG signal provides objective evidence of inhibition during stretches. ("The computer shows that your muscles are holding you back from reaching the end-range of the stretch. If you relax your muscle during the stretch, then you will go further.")
2. Identify if the patient is concerned about increased pain or reinjury when performing the stretch. Fear of reinjury can be addressed by reviewing the patient's diagnostics

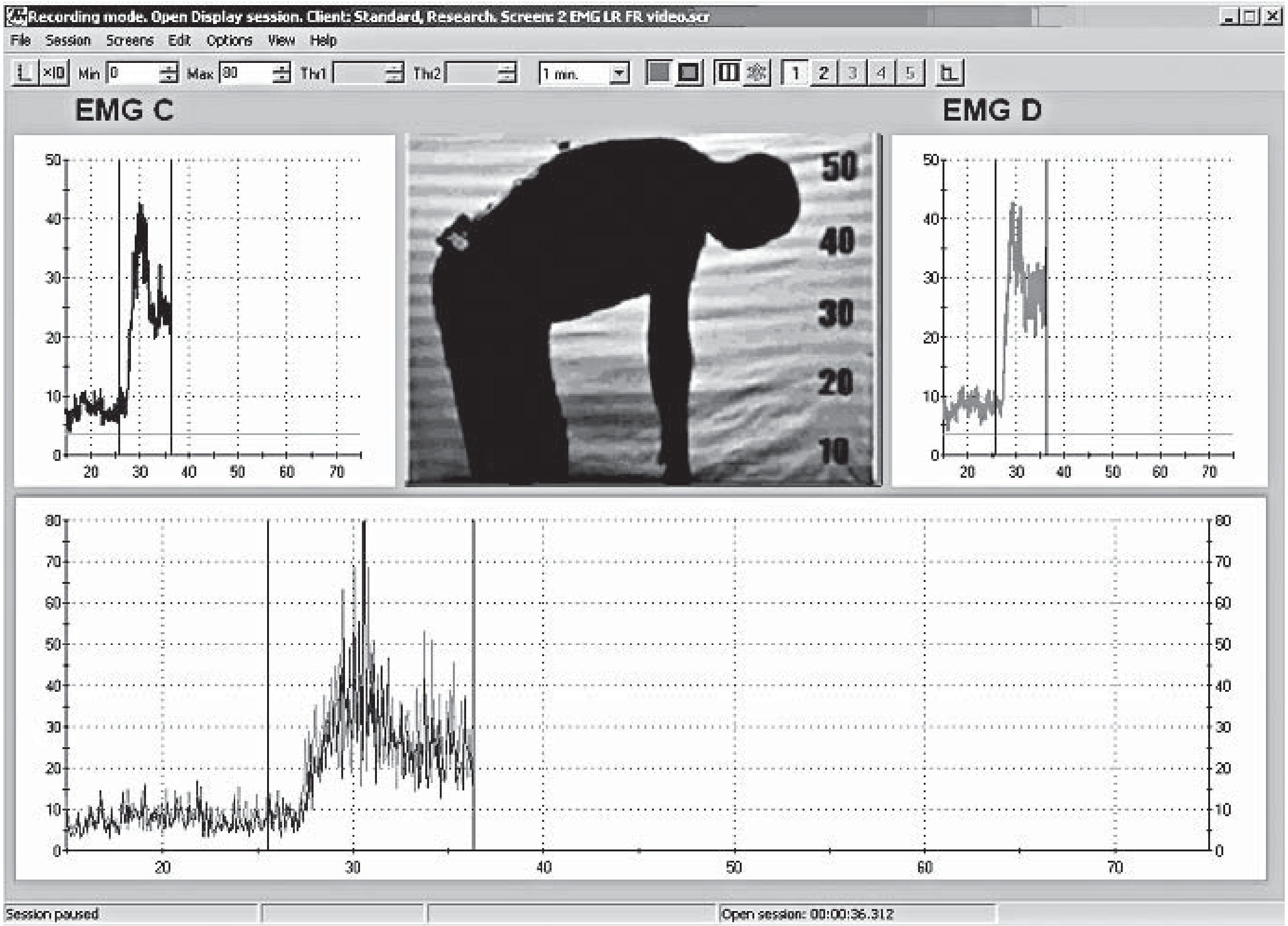

Figure 1. Baseline Flexion 7-19-06. SEMG was measured from left and right paraspinal muscles at L3. The darker line represents the left side, and the lighter line represents the right side. This subject reported a 6 out of 10 pain during this bend. ROM was assessed directly following this measure. He demonstrated 66° of gross, 45° of pelvic, and 21° of true lumbar flexion.

(assuring that the joint is structurally okay to perform the target movement) and by providing reassurance ("Your doctor and therapists wouldn't ask you to stretch if they thought that it would harm you"). Fear of increased pain can be addressed by citing the therapist's experience ("In my experience, patients who learn to relax during their stretch often report less pain") and by providing logical rationale ("If your stretch remains inhibited, then it's going to interfere with you getting better. I am confident that effective stretching is going to help you").

3. Provide specific strategies for achieving relaxed stretches, including verbal cues and demonstration of proper technique. Focus on breathing and "letting go" with each exhale.
4. Practice relaxed stretching technique with visual and/or auditory SEMG feedback. Analyze and discuss progress and success after each trial, and offer additional cuing to help shape success with each successive attempt. Identify the patient's perception ("How did that stretch feel different from your baseline stretch? Did you have more pain or less pain when you relaxed into the stretch?").
5. Recommend frequent follow-through with relaxed stretching. Explain that if the patient stops stretching (or stops stretching effectively), the muscles will tighten up again. ("If you keep stretching effectively every day, then the muscles will loosen more and more, the stretch will become less and less uncomfortable, and it will begin to feel good.")

Clinical Results of SEMG-Assisted Stretching

The author's group has previously demonstrated that *Functional Restoration* treatment, with SEMG-assisted stretching as a treatment component, was effective in

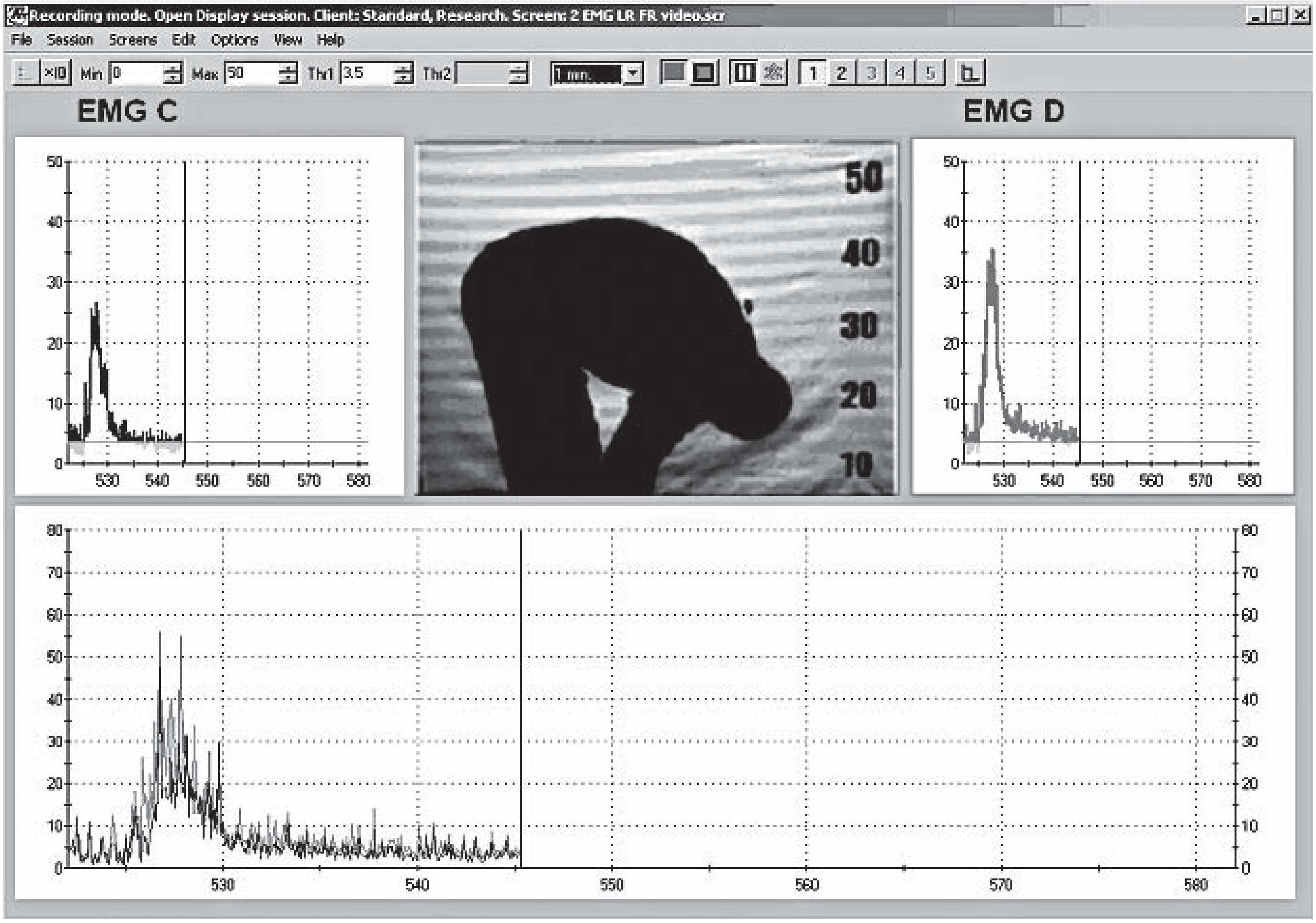

Figure 2. After training 7-19-06. SEMG was measured from left and right paraspinal muscles at L3. The darker line represents the left side, and the lighter line represents the right side. This subject reported a 3 out of 10 pain during this bend. ROM was assessed directly following this measure. He demonstrated 105° of gross, 65° of pelvic, and 40° of true lumbar flexion.

normalizing abnormal FR patterns in 20 of 22 CLBP subjects who completed the treatment program (Neblett et al., 2003a). Since that time, the SEMG-assisted stretching protocol has become a standard component of the *Functional Restoration* program. Recently a group of treatment subjects was compared to a separate group of no-treatment control subjects who received all facets of the treatment program, except for the SEMG-assisted stretching protocol. Preliminary results showed that both groups demonstrated clinical changes between pre and post on ROM and SEMG, but those subjects who received SEMG-assisted stretching protocol did better and were comparable to pain-free control subjects at the end of the treatment program. Our no-treatment group appeared similar to the group reported by Watson et al., (1997) in which their subjects showed improved FRR scores, but did not achieve complete FR during MVF at post.

When performing a low back assessment, the author uses 1 cm recessed electrodes from Noromed (Kent, WA) to help eliminate movement artifact, with a fixed, 2 cm spacing. Sensors are placed parallel to the muscle fibers, on the left and right side of the spine at L3, approximately 2 cm from midline. During training, when patients are expected to move around and bend multiple times throughout a session, the author prefers larger cloth electrodes with adhesive gel (# 3SG3-N, Multi Bio Sensors, El Paso, TX). Though more "noise" is introduced into the signal, these sensors tend to stick to the skin much better. Assessment and training is done with a Thought Technology Procomp Infinity (Montreal, Canada) system with a wide band-pass of 20–500 Hz. A ROM assessment is done concurrently with the SEMG measure using a dual inclinometer technique. Degrees of motion are measured from the spine at T12 (identifying gross ROM) and from the sacrum (identifying pelvic ROM). True lumbar ROM is determined by subtracting the pelvic from the gross measure (Mayer, Kristoferson, & Mooney, 1984; Keeley et al., 1986).

Figure 1 shows SEMG readings and a picture of a CLBP patient bending into MVF during baseline assessment at the beginning of an SEMG-assisted stretching training session. Figure 2 shows the same measure at the end of the training session. A significant decrease in SEMG during MVF and a significant increase in ROM are clearly demonstrated. At the end of the session, this patient was asked what kept him from bending further at his baseline. He concluded that he had been using poor technique and had been concerned that his pain would increase if he bent further. He denied fear of reinjury. Of course, not all patients show such dramatic results in just one training session. About one-third of the patients who do not show FR at a baseline measurement are able to achieve FR with one training session. The average number of sessions is about 2, with a standard deviation of about 1.5. Some patients have required up to 6 sessions before achieving consistent success. A small minority of patients have been unable to achieve FR despite multiple training sessions.

Conclusion

Following an injury, a cycle of fear avoidance and decreased physical activity can lead to deconditioning and chronic pain. A clinical protocol has been developed to address fear-avoidance beliefs and movement inhibition and to help chronic pain patients regain more normal movement and ROM. To maximize treatment success, the addition of SEMG-assisted stretching should be considered within interdisciplinary chronic pain treatment.

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