Initial and Treatment induced Changes to Muscle Activation Patterns in Patients with Adolescent Idiopathic Scoliosis Compared to the Frontal Plane Spinal Configuration as Measured with Surface Electromyography

Raymond Wiegand, D.C.

PURPOSE: The purpose of this study is to report paraspinal muscle activity patterns in adolescent idiopathic scoliosis (AIS) patients in comparison to the frontal plane spinal configuration and to report changes to the muscle activity resulting from a multi-factorial treatment program that includes chiropractic manipulation.

SETTING: Private practice.

INTRODUCTION: Scoliosis affects 2-4% of the population in the United States and unfortunately the most common treatment prior to bracing and surgery is no treatment at all. Scoliosis is a three dimensional deformity of the spine which includes lateral bending, rotation and in many instances flattening of the sagittal curves. Mechanical compression and distraction forces are known to modulate growth in vertebral growth plates, and they have been implicated in the progression of scoliosis. When congenital anomaly is present the most common finding is hemivertebra occurring 45% of the time and in general a familiar history of spinal distortion is present in approximately 17% of those affected with congenital scoliosis. In the absence of congenital anomaly much speculation exists as to the cause of developmental scoliosis. Overall the etiology of scoliosis is not well defined. One mechanism may be the accelerated growth of the anterior pillar of the spine in comparison to the posterior pillar. Such an imbalance causes scoliosis deformity in computer modeling and a similar crank shaft phenomenon has been observed following artificial spinal fixation in the premature skeleton.

When a juvenile scoliosis is detected it is more likely to progress, less likely to respond to bracing, and more likely to require surgical treatment than adolescent scoliosis. Curve progression is the major concern irrespective of the initiating cause. In patients with a double thoracic curve the proximal curve is usually smaller but stiffer. Analysis of the pathogenesis suggests that progression is due to an accelerated premature osteoarthrosis induced by insidious tissue fatigue of biomechanical origin.

Muscle and ligaments are both elongated and shortened on the convex and concave sides of a scoliotic curve. Paraspinal muscle imbalance may contribute to progression or maintenance of a scoliotic curve. Electromyographic activities between normal control subjects and patients with pre or post operative scoliosis showed significant differences. In response to these imbalances, various attempts to exercise the paraspinal muscles have been attempted. Torso rotation has been used with patients exhibiting curve ranges from 15-41 degrees. In a trial of 20 subjects, 16 demonstrated curve reduction and no patient demonstrated curve progression. Exercise is recognized as an important adjunct to maintaining curve correction. It is possible that a supervised program of exercise-based therapies can reduce the progression in children with idiopathic scoliosis. Imbalances of type 1 muscle fibers have also been identified with
idiopathic scoliosis however it is thought to be a result from compensatory stretching of muscle and not the cause of the deformity\textsuperscript{17}.

Stretching may be beneficial in the treatment of scoliosis. It has been demonstrated that as few as four stretches will produce maximum alteration of the muscle-tendon unit\textsuperscript{18} and that passive stretching is sufficient to improve hip extension ROM\textsuperscript{19}. However stretch tolerance has the greatest effect to increase joint range of motion\textsuperscript{20}.

In an adult population lumbar misalignment with disc degeneration is known to trigger lumbar scoliosis\textsuperscript{21}. A loss of spinal base support is also thought to result in the promotion of scoliosis development\textsuperscript{22}. These biomechanical factors, in combination with abnormal joint loading, are also associated with spinal injury though no direct observation of injury has been reported proceeding the development of idiopathic scoliosis. Improvement of spinal coupling by manipulative treatment may reduce biomechanical components contributing to idiopathic scoliosis. SEMG has documented that the dynamic thrust of spinal manipulation produces at least a paraspinal reflex\textsuperscript{23} while others have demonstrated improvement of lumbar paraspinal imbalances by mechanically changing the level of the pelvis and sacrum\textsuperscript{24}.

The normal cyclic motion of the inominates and sacrum during gait has been described by Greenman\textsuperscript{25}. For gait to proceed through a normal reciprocating cycle the pelvis and torso must be properly aligned in a neutral start position. With scoliosis the neutral start position of the torso and pelvis are misaligned resulting in an unbalanced gait cycle. Realigning the neutral position of the torso to the pelvis at the start position is proposed as a method to improve altered gait in scoliosis\textsuperscript{26}.

Improving the balance of paraspinal muscle activity may be a viable approach to scoliosis treatment. No literature has reported mapping the paraspinal SEMG activity to the spinal configuration in a multi-curve scoliosis. Neither have the effects been reported of muscle activity changes resulting from a multi-factorial treatment regimen. Because of the multi-factorial components of idiopathic scoliosis a multi-factorial treatment approach is warranted to investigate the potential for improved muscle activation, balance and inhibiting curve progression.

**METHODS:** Nine patients previously diagnosed by orthopedic surgeons with AIS underwent radiographic examination. The purpose was to quantify the geometry of the spinal configuration. The examination included a full spine frontal view and sectional sagittal views of the cervical, thoracic and lumbar regions. Measurements were obtained using a computer-assisted method (Spinal Analysis System, Weldon Spring, MO). Computer-assisted measurements have been reported to be more accurate and a more complete evaluation of the scoliotic spine\textsuperscript{27}. Frontal plane measurements were obtained of the vertebral architecture, intersegmental rotational alignment, disc angles, lateral bends and global balance. Left and right vertebral heights were measured to calculate any potential structural contribution to the scoliosis. In the sagittal plane measurements of architecture, curvature, gravity transfers, disc angles and intervertebral relationships were obtained. Vertebral rotations and their coupling characteristics were assessed to
determine specific spinal manipulation. The goal of the adjustment was to reduce intervertebral rotational differences and establish normal coupling in relation to the scoliosis deformity.

**SEMG EVALUATION:** Bilateral paraspinal surface electromyographic readings were recorded before and after each treatment session over a twenty-four week period. Recordings were taken in a natural sitting posture. The patient was instructed to look forward, hands on their lap palms up and feet flat on the floor. The recording locations were; suboccipital below the mastoid, C5, T1, T3, T6, T9, T12, L3, and L5. These locations were chosen as they represented the normal end and apex points of the sagittal curves. The spinous process locations were marked for reference to ensure repeat electrode placement. A Prometheus MR-25 dual channel SEMG (Dover, NH) attached to a laptop commuter was used to collect the data. The recording for each level was started after a stable signal was observed. This typically took five to ten seconds. Each level was recorded bilaterally for fifteen seconds. The sEMG signal was processed to report the mean, minimum, maximum and standard deviation. The pre and post sEMG values were then plotted to the spinal configuration.

**TREATMENT:** The treatment regimen included and sequenced as follows; 1) unweighted gait training using the Pneumex (Sand Point, Idaho) system which included a torso vest providing horizontal and vertical traction to the scoliotic curve while walking on a treadmill, 2) stretching, using the Back System3 (Fort Worth, TX), 3) vertical traction in a seated posture followed by unilateral resistance exercises on the convex side of the scoliosis curve/s (Pneumex Chair), 4) specific resistance exercises which mirror imaged the scoliosis configuration, 5) cervical curve compression (Posture Pump, Huntington Beach, CA) followed by 6) spinal manipulation. Spinal manipulation included the use of drop tables and hand held instruments. The patient also did home stretching and exercises.

**RESULTS:** The initial SEMG values were plotted to the scoliosis curves. All patients demonstrated an “S” curve configuration spanning the thoracic and lumbar spinal regions. Table 1 reports the spinal configuration, SEMG activity and the patient characteristics. The following abbreviations are used: UCC (upper convex curve), MASO (muscle activation suboccipital), MAU (muscle activation upper), LCC (lower convex curve), MAL (muscle activation lower), MAL5/S1 (muscle activation L5/S1), GA (gender, age).

<table>
<thead>
<tr>
<th>UCC</th>
<th>R 16°</th>
<th>R 20°</th>
<th>R 25°</th>
<th>R 24°</th>
<th>R 26°</th>
<th>L 15°</th>
<th>L 12°</th>
<th>L 12°</th>
<th>L 10°</th>
</tr>
</thead>
<tbody>
<tr>
<td>APEX</td>
<td>T8</td>
<td>T8</td>
<td>T8</td>
<td>T9</td>
<td>T7</td>
<td>T5</td>
<td>T9</td>
<td>T5</td>
<td>T6</td>
</tr>
<tr>
<td>MASO</td>
<td>R</td>
<td>L</td>
<td>L</td>
<td>L</td>
<td>L</td>
<td>=</td>
<td>R</td>
<td>L</td>
<td>R</td>
</tr>
<tr>
<td>MAU</td>
<td>R</td>
<td>L</td>
<td>L</td>
<td>R</td>
<td>L</td>
<td>L</td>
<td>R</td>
<td>R</td>
<td>M</td>
</tr>
<tr>
<td>LCC</td>
<td>L 29°</td>
<td>L 18°</td>
<td>L 24°</td>
<td>L 28°</td>
<td>L 30°</td>
<td>R 9°</td>
<td>R 16°</td>
<td>R 22°</td>
<td>R 23°</td>
</tr>
<tr>
<td>L1</td>
<td>L2</td>
<td>L2</td>
<td>L1</td>
<td>L2</td>
<td>L1</td>
<td>T12</td>
<td>L2</td>
<td>L1</td>
<td>L1</td>
</tr>
<tr>
<td>MAL</td>
<td>M</td>
<td>L</td>
<td>L</td>
<td>R</td>
<td>L</td>
<td>L</td>
<td>R</td>
<td>L</td>
<td>M</td>
</tr>
</tbody>
</table>
Hyperactive muscle activation on the convex side of the curve is indicated in green as it is considered beneficial to inhibit curve progression. Red indicates concave side hyperactivity as it may progress the curve. The initial evaluations demonstrated that seven of the nine patients presented with suboccipital hyperactivity opposite the side of the upper convex curve. Six of the nine had hyperactivity at L5/S1 on the side of the lower convex curve. Six of the nine demonstrated unilateral hyperactivity from C5 to L3. All patients demonstrated hyperactivity on the concave side of one of the two curves while one patient had hyperactivity on the concave side of both curves. One patient had a mix of hyperactivity on the concave and convex sides of both the upper and lower curves. Seven of the nine patients were female.

Following 12 weeks of treatment the following was observed of all patients: The upper and lower curves demonstrated the same left or right distortion characteristics. The left/right suboccipital SEMG values were symmetrical (within 1 μV). The SEMG values across the lower and upper curves were either symmetrical or hyperactive on the convex side. The SEMG value recorded at L5/S1 was on the same side as the lower convex curve. In all but one patient the amplitude of the lateral curves remained stable within ±2°. A paired T test of the initial and final SEMG values for locations where hyperactivity crossover occurred from concave to convex demonstrated an alpha value of $p<0.001$. Within two weeks, six treatments, inhibition of hyperactivity was noted of all patients. Inhibition of hyperactivity, in comparison to original values was noted throughout the treatment regimen. By seven weeks of treatment a crossover of hyperactivity from the concave side to the convex side was noted in all cases. These findings remained constant for the remainder of the twenty-four week treatment period.

**DISCUSSION:** Throughout a twenty four week treatment program the bilateral activity of the paraspinal muscles were recorded pre and post treatment and then plotted to the spinal configuration. This identified changes of muscle activation patterns. Imbalance of the paraspinal muscles is one factor that may contribute to the development and progression of scoliosis. This occurs as hyperactive muscle activity progresses the curve on the concave side of a scoliosis. In this sample of nine patients with “S” curve configurations, 100% demonstrated hyperactivity on the concave side of at least one curve. As one curve compresses the other will reactively compensate in the opposite direction to re-establish spinal balance. This occurs as a result of righting and balance reflexes and causes a vicious cycle of dual curve progression. If the spine does not reactively compensate by progressing the opposing curve then the body will become globally unbalanced toward the side of curve progression.
Sixty-seven percent demonstrated unilateral paraspinal hyperactivity C5 through L3. This indicates that generally a spinal imbalance triggers a unilateral muscle response. In this study where a multi-factorial treatment approach was used, inhibition occurred to the concave sided hyperactive muscles resulting in either bilateral balancing or convex sided hyperactivity. Once established, inhibition and crossover continued throughout the treatment program.

Changes of muscle activation patterns resulting from treatment regimens that impose physiological demands suggest unorganized spinal biomechanics, inappropriate muscle activation and soft tissue deficiencies are at work in adolescent idiopathic scoliosis. Changing activation patterns demonstrated that in eight out of nine patients, curve progression diminished and halted. The author believes this to be more than coincidental but only further study with a control group will validate this assumption.

CONCLUSION: Paraspinal activation patterns were identified using SEMG on nine patients with AIS having “S” type spinal configurations. All patients demonstrated hyperactivity on the concave side of at least one curve. The patients were treated with a multifactorial regimen that included unweighted gait training, stretching, vertical traction, unilateral resistance exercise on the convex side of the curves, specific mirror image resistance exercises, cervical curve compression and spinal manipulation. In all patients inhibition occurred to the concave side hyperactivity with bilateral balancing or convex side hyperactivity. Once established, inhibition and crossover continued throughout the duration of treatment.

In eight out of nine patients curve progression halted. Additional case studies are warranted using this multi-factorial treatment approach to assess effectiveness and consistency over a broader range of scoliosis deformities. If consistency can be demonstrated this new approach gives hope to halting and improving spinal deformities in adolescent idiopathic scoliosis while isolating some of the components contributing to its onset.

REFERENCES


26. Pneumex. Sand Point, ID.