In part 2 of their report, the authors continue to evaluate myoelectric data obtained from spinal motion dynamics involved in clinical rotation tests. They add to the ipsilateral regional analysis of motor performance as previously presented and analyze the total bilateral myoelectric activity gathered concurrently at individual thoracic vertebral segments during simultaneous rotation left and right motion tests.

The authors' hypothetical consideration concerns the nature of composite behaviors at these vertebral segments during active and passive motions and the role that postural dynamics play in movement function. They consider these concepts in the context of the study's experimental design and also within the broader concept of the osteopathic musculoskeletal examination.

Results revealed pronounced similarity in individual spinal electromyographic patterns whether motions were volitional or physician induced. Analysis demonstrates the bell-shaped myoelectric behavior pattern originally reported in part 1. The authors also discuss a functional model for this myoelectric activity involving a helical spinal motor pattern with a focal area of transition that is dynamic in response to postural and motion demands.

Part 1 of our report presented a regional analysis of ipsilateral myoelectric responses occurring in the midthorax during each direction of a rotary test motion. In contrast, the current report focuses on the dynamics imposed by simultaneous co-contraction of bilateral spinal musculature.

Our hypothetical considerations concerned analyzing the distribution of myoelectric activity at the midthoracic vertebral segments of subjects when agonist and antagonist muscles work collectively in response to simultaneous left and right motion tests. Further, we sought to determine whether these segmental behaviors would prove to be consistent during active and passive motion tests.

In addition, this experiment permitted us to assess whether the participation of individual midthoracic segmental motor activity is a primary response to the rotary demands of the shoulders and trunk, a secondary response to the demands of postural support in the seated position, or both. We consider a structural-function model for the vertebral activity involved in spinal motor patterns.

Methods
Michigan State University's Committee on Research Involving Human Subjects granted its approval to this study. The sample population consisted of nine volunteers (8 men and 1 woman) from the Michigan State University community. Ages ranged from 23 to 40 years (mean age, 32 years). All subjects were relatively asymptomatic and had no pain on the routine musculoskeletal test for thoracic rotation.

The procedural routines used in this study are consistent with those described in the Methods section in part 1 (Figure 1). However, in this part of the study, the six electrode sites gathered data for a bilateral experimental condition. That is, sites for electrode placements for the electromyographic (EMG) procedures were bilateral, initially placed at thoracic levels 4 through 6 (T4 – T6); and secondly at T7, T8, and T9. We conducted each rotation left and rotation right motion test three times for active motion and three times for passive motion.

Electromyographic procedures are detailed in part 1 of this report. The arrays of time, frequency, and voltage domain data gathered from the bilateral surface electrode placements reflected the character and composite distribution of muscular activity at the midthoracic region during our test motions with the subjects in the seated position.

Descriptive observations for the subject group addressed the simultaneous left and right myoelectric activity at each vertebral segment. We expressed these data as percentages for comparable assessments. The dependent variable selected for analysis was a quantitative measure of the relative total electric activity during left and right motion tests as gathered at the left and right electrode placement sites at each thoracic vertebral level. This value was expressed in volts. Statistical anal-
The data as percentages indicative of the relative total activity at each thoracic vertebral segment during simultaneous rotation left and rotation right motion tests at levels T4 through T9.

Of the remaining contrasts, the second one compared data from thoracic vertebral levels T4 and T9 with data from T6 and T7. Significant differences between active (P ≤ .001) and passive (P ≤ .002) motions indicate that the profile of myoelectric responses was not flat. The third contrast compared data for thoracic vertebral levels T4 and T9 with data from T5 and T8. Significant differences in active (P ≤ .001) and passive (P ≤ .002) motions further indicated of the shape of the profile. The fourth and final contrast compared data from thoracic vertebral levels T5 and T8 with data from T6 and T7. This comparison was not significant; active motions yielded $P = .23$, and passive motions yielded $P = .24$ (Table 1). Analysis of these results indicates that the active and passive distributions for bilateral segmental motor behaviors are bell-shaped, peaking significantly at levels T6 and T7, with stepwise decreases from T6 to T4 and T7 to T9.

Discussion
Our data again clearly demonstrate the trained examiner’s ability to passively duplicate motor patterns ordinarily expressed actively by a mobile system during volitional motion (Figure 3). The graphs of active EMG patterns demonstrate each subject’s distinctive motor behavior. Despite that singularity and uniqueness, passive patterns consistently reflected the trained examiner’s ongoing ability to intimately duplicate the subjects’ active patterns. By not intruding on subjects’ active, volitional motor behavior, a trained examiner, using a passive gross motion test, can gain reliable information regarding the patterns of vertebral motion being expressed. This information is an integral factor in the osteopathic physical examination, establishing the osteopathic physician’s passive gross motion test of symmetry as a dependable diagnostic tool.

Examination of each vertebral segment’s myoelectric contribution to rotations also revealed unique attributes for evaluating overall thoracic muscular performance. Specifically, subjects’ EMG activity occurred to satisfy two tasks: (1) the mobility required by the test motion protocol, and (2) the midline, erect posture sustained in the seated position. This demonstration of coordinated function results from a particular muscular synergy, the goal of which is the production of an efficient pattern of spinal motor control and local motor behavior sufficient to serve the demands of both tasks.

In part 1 of this report, these tasks took the form of a bell-shaped myoelectric profile that emerged from ipsilateral regional data for each separate direction of motion or motor performance. However, in the current report, we sought additional data that sampled the total, composite bilateral myoelectric contributions of six vertebral segments for combined rotations. Once again, a bell-shaped profile resulted with myoelectric activity peaking at thoracic vertebral levels T6 to T7 and...
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First, each protocol demands rotations about the body’s vertical axis. Second, during these motions, the body must maintain an overall erect posture. That is, demands for motion in the standing or seated positions and during locomotion require spinal muscle contractions to maintain posture. During motion demands, the body must accommodate the composite activity of motion and posture. Third, to function appropriately, the body requires a stable weight-bearing point of contact. Data for locomotion in the kinematic study had contact at the feet, while the seated posture in our myoelectric study provided stable contact at the hips—still permitting the vertebral column to adapt freely to rotary demands around a relatively fixed axis. Fourth, the human body presents a nonuniform structure upon which a mobile system must act. Obvious structural differences (asymmetries) exist in the body (eg, the location and position of viscera; significant variations in vertebral size, structure, and points of vertebral muscle attachment). In addressing the four commonalities between the studies, the T6–T7 apex of myoelectric activity from our bell-shaped profile of these spinal segmental behaviors.

Historically, biomechanical studies describing such spinal segmental behaviors considered structural aspects, forgoing functional considerations or movement dynamics. However, Gregersen and Lucas\(^3\) added a functional element toward understanding vertebral motion dynamics. They studied axial rotations during standing, sitting, side-bending, and normal level walking for seven medical students by measuring angular displacement of Steinmann pins inserted into their vertebral spinous processes. The authors’ findings include this relevant description of vertebral function:

In one-half of a walking cycle during normal level walking on a treadmill, five degrees of rotation occurred at the first thoracic vertebra and, in the opposite direction, six degrees at the fifth lumbar vertebra. There appeared to be a transition point (displacement node) in the sixth to eighth thoracic vertebral region above which rotation was in the direction opposite to that below.\(^3\)

One may ask whether the kinematic data describing alternating directions of rotation about a specific segmental level described by Gregersen and Lucas\(^3\) bear any relationship to the functional behavior expressed by the bell-shaped myoelectric data in our current midthorax study. We believe that a connection does exist. Four specific features appear common to both models.

First, each protocol demands rotations about the body’s vertical axis. Second, during these motions, the body must maintain an overall erect posture. That is, demands for motion in the standing or seated positions and during locomotion require spinal muscle contractions to maintain posture. During motion demands, the body must accommodate the composite activity of motion and posture. Third, to function appropriately, the body requires a stable weight-bearing point of contact. Data for locomotion in the kinematic study had contact at the feet, while the seated posture in our myoelectric study provided stable contact at the hips—still permitting the vertebral column to adapt freely to rotary demands around a relatively fixed axis. Fourth, the human body presents a nonuniform structure upon which a mobile system must act. Obvious structural differences (asymmetries) exist in the body (eg, the location and position of viscera; significant variations in vertebral size, structure, and points of vertebral muscle attachment). In addressing the four commonalities between the studies, the T6–T7 apex of myoelectric activity from our bell-shaped pro-

Table 1

<table>
<thead>
<tr>
<th>Contrasts</th>
<th>Estimate</th>
<th>Standard error</th>
<th>Degrees of freedom</th>
<th>Student t test</th>
<th>(P)†</th>
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<tbody>
<tr>
<td>T4 + T5 + T6 vs T7 + T8 + T9</td>
<td>-1.68</td>
<td>0.131</td>
<td>35.1</td>
<td>-1.28</td>
<td>.21</td>
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<tr>
<td>T4 + T9 vs T6 + T7</td>
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<td>2.23</td>
<td>15</td>
<td>6.48</td>
<td>.44</td>
</tr>
<tr>
<td>T4 + T9 vs T5 + T8</td>
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<td>35.4</td>
<td>15</td>
<td>4.96</td>
<td>.0001</td>
</tr>
<tr>
<td>T4 + T9 vs T5 + T8</td>
<td>5.69</td>
<td>1.08</td>
<td>15</td>
<td>5.27</td>
<td>.0001</td>
</tr>
<tr>
<td>T5 + T8 vs T6 + T7</td>
<td>6.99</td>
<td>1.08</td>
<td>15</td>
<td>3.73</td>
<td>.002</td>
</tr>
</tbody>
</table>

* Data from testing active motion were recorded for all eight subjects. Data from testing passive motion were recorded for subjects 1, 2, 3, and 5 only.
* The motion sequence for active and passive motion was as follows: (1) rotation right for left- and right-side muscles, and (2) rotation left for left- and right-side muscles.
* A indicates active bilateral electromyographic activity; P, passive bilateral electromyographic activity; T and number (eg, T4), thoracic level(s) tested for bilateral segmental motor behaviors; Estimate, estimate of the contrast for least squared means.
* \(P = \text{Level of significance (} \alpha = .05\).}
* A paired, 2-tailed \(t\) test was used.
Figure 2. Bilateral segmental myoelectric activity. Relative total myoelectric activity by percentage of activity for subjects at each vertebral segment during simultaneous rotation left and right motion tests.

Table 2
Profile of Active and Passive Motion*
Bilateral Segmental Motor Behaviors†

<table>
<thead>
<tr>
<th>Thoracic Levels</th>
<th>Mean Square A</th>
<th>Standard Error A</th>
<th>Total Degrees of Freedom A</th>
<th>Calculated F Test Ratio A</th>
<th>P*</th>
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<tbody>
<tr>
<td></td>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T4</td>
<td>4.19</td>
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<td>8.53</td>
<td>2.57</td>
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<tr>
<td>T5</td>
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</tr>
<tr>
<td>T6</td>
<td>7.50</td>
<td>9.53</td>
<td>8.53</td>
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<tr>
<td>T7</td>
<td>8.02</td>
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<td>8.53</td>
<td>4.97</td>
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</tr>
<tr>
<td>T8</td>
<td>7.57</td>
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<tr>
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<td>.0250</td>
</tr>
</tbody>
</table>

* The motion sequence for active and passive motion was as follows: (1) rotation right for left- and right-side muscles, and (2) rotation left for left- and right-side muscles.
† A indicates active bilateral electromyographic activity; P, passive bilateral electromyographic activity.
‡ P = Level of significance (α = .05).
file reflects Gregersen and Lucas’ area of transition, “above which, the rotation was in the direction opposite to that below.”

To consider “an area of transition,” recognize that the motor behavior patterns occurring in the human body, a nonuniform mobile system, contrast significantly with response expectations for rotations in a theoretical uniform mobile system. As a demonstration of this difference, Figure 4 presents a rotation right motion test introduced into a uniform mobile system in which no transition is apparent. This rotation to the right occurs with a consistent response throughout the system. The fact that such consistency is not apparent in our myoelectric data further demonstrates the complex nature of vertebral kinematics in a nonuniform system.

To grasp the concept of an area of transition for nonuniform spinal motion, take the example of coupled motion in which axial rotation is combined (coupled) with lateral side-bending. This recognized coupling phenomenon emerges from many factors, including the geometry of the vertebrae, the ligaments that bind them, and the curvatures of the vertebral column. As an illustration of coupled vertebral motion, when a physician introduces a demand for rotation right to a patient in a neutral seated position, the response of the patient’s vertebrae involves coupled side-bending to the left (Figure 5).

With this side-bending to the left, how is erect posture maintained? The answer may be apparent in the application of Gregersen and Lucas’ transition point (displacement node) and its relevance to our bell-shaped myoelectric profile. Opposing directions of rotation above and below a transition point imply a coupling of opposing directions of side-bending left (above) and side-bending right (below). The concurrence of these opposing side-bending elements creates balance about the body’s midline—and the maintenance of erect posture. Ultimately, the nonuniform mobile systems of the vertebral column and its muscular attachments accommodate the demand for postural stability during movement.

**Figure 3.** Demonstration of the similarity between patterns of myoelectric response invoked by active and passive diagnostic tests at each segmental level.
Vertebral Coupling: Side-Bending During Regional Rotation Left
Vertebral Coupling: Side-Bending During Regional Rotation Right

Figure 4. An example of rotation right introduced into a uniform system.

Figure 5. Side-bending left during regional rotation right. Coupled motion in a nonuniform system.

Figure 6. A concept of helical patterns of spinal motion during regional rotations left and right. Vertebral coupling results in a focal area of transition at thoracic vertebral levels T6 and T7 with opposing directions of rotary response above and below.
As a result, we postulate that the predominant spinal muscle activity at T6 to T7 occurs at an area of rotary transition. Figure 6 demonstrates the helical response patterns that emerge. Note that with the area of transition remaining within the spinal midline, the segmental demand for coupling at the area of transition is minimal. As such, the helical pattern for spinal motion is a natural, functional response to axial rotary demands on this nonuniform system. Two additional three-dimensional radiographic studies have reported transitional aspects of side-bending in cervical and lumbar regions.5,6

Comment
We believe that the similar midthoracic areas of transition common to Gregerson and Lucas3 kinematic and our3 myoelectric studies are coincidental because of the particular rotary motions being performed. In general, the concept of vertebral transition points is functionally dynamic; concentrations of muscular activity will change depending on body positions, different supportive surfaces, and different motion demands. Physical diagnosis, for example, may involve standing, sitting, supine, and side-lying positions—each having specific functional demands. By comparison, everyday human motor activity is even more complex. Accordingly, locations of rotary spinal transition points and their accompanying muscular profiles constantly adjust and readjust to requisite motor demands.

Once an osteopathic physician recognizes that spinal areas of motion transition exist—and that they occur with concomitant patterns of muscle response—he or she develops key insights regarding skillful localization of forces in manipulative methods. Osteopathic physicians should consider the side-lying technique for manipulation in the lumbo-pelvic region. While maneuvering a patient’s shoulders and hips into position to apply counter-rotary forces (ie, “taking out the slack”), the rotary “transition point” continually shifts to coincide with the osteopathic physician’s palpating fingers actively monitoring the dysfunctional spinal segment. Once the osteopathic physician achieves the resulting focus, he or she is able to improve accuracy in the localization of forces during the manipulative procedure.

By training and logic, osteopathic physicians often rely on structural concepts to interpret and treat aspects of segmental dysfunction. An extensive body of literature and decades of empirical knowledge also rely on the structural concept of the joint and its related attachments to constitute a model for movement—and to interpret spinal biomechanics. However, when considering motor performance, this model may be limited. The current report offers objective evidence that expands the structural model to consider functional characteristics of each patient’s unique motor patterns. The integrity of this functional response evolving from a passive gross motion test adds objective physiologic perspective for evaluating physical aspects of each patient’s health.

Summary
During passive diagnostic rotations, individual spinal EMG response patterns consistently reflected the trained examiner’s ability to intimately duplicate the subjects’ customary active EMG patterns. The bilateral spinal EMG activity during combined rotation left plus right diagnostic motions demonstrated unique responses at each of the six vertebral levels. In the resulting bell-shaped profile, the EMG activity occurred predominantly in the midspine (transitional) segments.

A helical pattern of spinal rotations occurred with a coordinated muscle synergy that served both the motion and postural demands of the task.

Acknowledgments
This study was supported by the American Osteopathic Association’s Bureau of Research (Grant No. 8305116). The US Department of Health and Human Services’ Health Resources and Services Administration Academic Administrative Units in Primary Care (Grant No. 5 D12 HP 00101-02) funds the authors’ research division in the Department of Family and Community Medicine at the Michigan State University’s College of Osteopathic Medicine (MSUCOM) in East Lansing.

The authors thank Dan Koop Liechty, PhD, director of the research division, for statistical and editorial support. Sincere appreciation is also extended to Robert P. Hubbard, PhD, and Seth Barry of the Michigan State University Biomechanical Design Research Laboratory, and Annmarie Y. Cook, Graphic Services Coordinator, MSUCOM, for their assistance with the figures in this document.

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