Posture Related to Myoelectric Silence of Erectores Spinae During Trunk Flexion

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Electromyographic activity of erectors spinae exhibits points of abrupt change during trunk flexion from the erect position and return extension. This study examined the positions at which the myoelectric activity suddenly disappeared and later reappeared. Forty adults were investigated to define accurately the inclinations of the trunk, pelvis, and vertebral column at these positions. The positions at the commencement and cessation of the period of electrical silence both occurred at two-thirds of maximum trunk flexion ($x = 80° ±13°$ SD). At these positions, all flexion measurements were significantly less than their maxima ($P <0.001$). Hip flexion at the commencement of electrical silence was slightly above one half its maximum range, and similar to the position at the commencement of electrical activity ($x =40° ± 12°$ SD). The most reproducible measurement ($r = 0.88$) in both positions was vertebral flexion (89% Max.; $x = 48° ±6°$SD). Eleven of the male subjects repeated the experimental task holding 10.1 kg in their hands. The effect of this was to produce inhibition and reactivation of erectors spinae at a greater degree of vertebral flexion. [Key words: lumbar spine, erectors spinae, electromyography, posture, electrical silence, reflex inhibition]1

Trunk flexion from the erect position is produced by the weight of the upper body and controlled by eccentric activity of the hip and vertebral extensors. At a certain position of trunk flexion, there is a sudden onset of electrical silence of erectors spinae. At this position, it has been proposed that vertebral stabilization is provided totally by connective tissue structures. The implication of this theory is that towards the extreme of trunk flexion, there is some surrender of muscular control of the movement.

Decreased neuromuscular control of trunk movements is potentially hazardous as the force in the ligamentous structures may be double that in the muscular system just before activity ceases because of the smaller average moment arm of the postvertebral ligaments. Specific definition of trunk postures related to the absence of active vertebral support could be applied in various situations. For example, such knowledge is important in the design of manual handling tasks where the weight of the load is variable. Also, information on the effects of variation in physical characteristics on the muscular control of the trunk is important to those involved in the prescription of exercise in rehabilitation and sport.

Some have claimed that the cessation of erectors spinae activity, when observed, occurs at maximum trunk flexion. Others, however, recognize that erectors spinae inactivity may occur before full trunk flexion, while assuming that it corresponds to a position of maximum vertebral flexion. During extension from the fully flexed position, there is a position corresponding to the sudden activation of erectors spinae. This may occur at the same position as during flexion although this is not necessarily the case.

This study is concerned with the postural definition of certain positions during flexion of the trunk and its return to the erect position. For a simple mechanical model, the trunk may be considered as an inflexible rod rotating about a single axis. Anatomically, however, this may be an oversimplification as trunk position is basically determined by movements about the hip joint and the combined movements of the intervertebral joints.

No information had been found that simultaneously defined the position of the vertebral column and pelvis at the boundary points of the period of erectors spinae inactivity. Therefore, the purpose of this study was to use a technique that allowed comparison of the postures of the trunk, pelvis, and thoracolumbar vertebral column at these positions, with their postures at the ends of the range of trunk flexion.

METHODS

Forty-two subjects, 24 men and 18 women aged 18-49 years, were chosen randomly from a group of volunteers who had been informed about the experiment. None had a history of chronic back pain or any obvious spinal deformity. To perform the experimental task, each subject maximally flexed the trunk from the erect position, maintained full flexion and then extended to the initial position. The total movement time for each trial was

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approximately 10 seconds. Eleven of the male subjects repeated the experimental task holding a 10.1 kg mass.

Electromyographic activity of erectors spinae was recorded utilizing surface electrodes placed bilaterally at the level of the spinous process of the third lumbar vertebra, approximately 5 cm from the midline. Surface electrodes provide a good representation of erectors spinae activity especially when placed at the third lumbar level and are considered adequate for movement studies involving timing information. The direct electromyographic activity was observed on the oscilloscope of a Medelec DG6 electromyograph. Maximum amplitude of the signal on the oscilloscope screen was about 4 cm, and when this abruptly decreased to zero during flexion, the experimenter activated a 35-mm camera placed 4 meters to the left of the subject at the level of the hips. This dramatic change, as illustrated in Figure 1, occurred in all but two subjects, a 35-year-old man and an 18-year-old woman who did not exhibit a silent period.

The posture at the commencement of myoelectric silence was termed silent position one (SP1). Silent position two (SP2) was recorded similarly when erectors spinae activity suddenly increased above baseline. The static end-points of the experimental task, the erect position (E), and the position of maximum forward flexion (MFF) also were recorded. Forty subjects were photographed twice in each of the four positions. Eleven men also were photographed in the erect and silent positions while holding a weight.

Each subject wore a swimming costume that allowed the surface marking of the knee, hip, anterior and posterior superior iliac spines, and the spinous process of the first thoracic vertebra. Trunk angle (TA) was measured as the angle between the long axis of the thigh and the plane of the trunk (Figure 2). Vertebral angle (VA) was the angle between the long axis of the thoracolumbar vertebral column and the plane of the pelvis, represented as a line through the superior iliac spines. The angle between the plane of the pelvis and the long axis of the thigh was the hip angle (HA). The erect position was used as the reference for the calculation of trunk flexion (TF), hip flexion (HF), and vertebral flexion (VF). All flexion values at the boundary positions of the period of myoelectric silence were expressed as a percentage of their respective values in the position of maximum forward flexion.

Analyses of variance indicated differences between the flexed positions and the effect on the two trials for each measurement. The effect of holding a weight also was analyzed. Where appropriate, Newman-Keuls posthoc tests determined statistical significance. Correlations between the different measurements and the two trials at each position also were calculated. In some cases, the four correlations between two factors were reduced to a single figure and corrected for attenuation using the reliability coefficients of each angle. Both analyses of variance and the Pearson product-moment correlation matrices were calculated using a Digital PDP10 computer.

RESULTS

The Reference Positions

There were no significant differences between the means of the first and second trials for any measurements in the reference positions, erect (E) and maximum forward flexion (MFF), as determined by analysis of variance. The high test-retest correlations confirmed the good reproducibility of the measurements (Tables 1,2).
In the erect position, there were significant correlations between trunk and hip angles (r = 0.49; P<0.01), and hip and vertebral angles (r=-0.75; P< 0.001). The latter high correlation supported the proposal that inclination of the pelvis affects posture of the vertebral column. The negative correlation indicated that anterior pelvic tilt was accompanied by vertebral extension, probably compensatory increased lumbar lordosis. In contrast to the previous significant correlations, the correlation between trunk and vertebral angles was not significant (r=0.11). Hip flexion was the major determinant of trunk flexion (r = 0.84; P<.001) at maximum forward flexion as vertebral flexion was not correlated with trunk flexion (r = 0.00). There was a negative correlation between hip and vertebral flexion (r = -0.48; P<.01), indicating that flexibility is not a general trait.

The Boundary Points of the Silent Period
Positions of the trunk, pelvis and vertebral column were represented by absolute and relative values, indicating the excursion of these body segments from both the erect and maximally flexed positions. All flexion values at maximum forward flexion were greater than at the silent positions (P< 0.001; Figure 3). There were no significant differences between the two boundary positions in terms of trunk or pelvic inclination, however there was a significant difference with respect to vertebral flexion (Table 3). Vertebral flexion was greater at the recommencement of myoelectric activity. The silent positions occurred at approximately two-thirds of maximum trunk flexion, at which the hips were flexed slightly more than one-half their maximum range, while the thoracolumbar vertebral column was near its extreme range of flexion (Figure 3; Table 3). This indicates that maximum vertebral flexion may occur before maximum trunk flexion.

Both silent positions were defined reliably by the value for vertebral flexion (Table 3). The test-retest correlations for trunk and hip flexion did not reach the criterion level of 0.80, although all were significant at the 0.01 level. For all flexion measurements, there were no significant differences between the means of the first and second trials. Correlations between equivalent measurements at the two positions of electrical silence were not significant for trunk and hip flexion, however they reached the 0.001 level for vertebral flexion (Table 3). Variability for both trunk flexion (SD = 12.8°) and hip flexion (SD = 12.4°) was high in comparison to vertebral flexion (SD =6.4°; Figure 3). Hip flexion was again the major determinant of trunk flexion (SP1, r = 0.91; SP2, r = 0.89), while vertebral flexion was a poor indicator of trunk flexion (SP1, r = 0.12; SP2, r = 0.36).

**Table 1. Angle Measurements in the Erect Position**

<table>
<thead>
<tr>
<th>Angle Measurement</th>
<th>Angle (°)</th>
<th>Test-retest correlation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trunk</td>
<td>195±4</td>
<td>0.90</td>
</tr>
<tr>
<td>Hip</td>
<td>84±5</td>
<td>0.91</td>
</tr>
<tr>
<td>Vertebral</td>
<td>102±6</td>
<td>0.92</td>
</tr>
</tbody>
</table>

**Table 2. Flexion Measurements in the Position of Forward Flexion**

<table>
<thead>
<tr>
<th>Flexion Measurement</th>
<th>Angle (°)</th>
<th>Test-retest correlation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trunk</td>
<td>118±10</td>
<td>0.93</td>
</tr>
<tr>
<td>Hip</td>
<td>72±11</td>
<td>0.96</td>
</tr>
<tr>
<td>Vertebral</td>
<td>55±6</td>
<td>0.91</td>
</tr>
</tbody>
</table>

**Effects of Additional Weight**
There were no differences between the means of the test and retest measurements of the 11 subjects who participated in this phase of the experiment. Mean trunk flexion at the positions of myoelectric silence was 81.5°. There was no difference between the two silent positions, and the addition of a hand-held weight did not affect the trunk measurement. The mean hip flexion was 39.4°, which also was unaffected by the factors investigated. The effect of the weight on vertebral flexion was to significantly increase these measurements at the silent positions (Table 4; SP1, P< .01; SP2, P< .05). Vertebral flexion was greater at the second silent position in the unweighted condition (P<0.01), however there was no difference in the weighted condition (Table 4).

**DISCUSSION**
For simple mechanical modeling, the thoracolumbar vertebral column may be considered as a rigid bar and was represented as such in the measurement technique used in
Table 4. Mean Vertebral Flexion (°) at the Silent Positions in Both the Normal and Weighted Conditions for Eleven Male Subjects.

<table>
<thead>
<tr>
<th>Condition</th>
<th>Normal</th>
<th>Extra weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>SP1</td>
<td>49.1</td>
<td>52.1</td>
</tr>
<tr>
<td>SP2</td>
<td>51.5</td>
<td>52.6</td>
</tr>
</tbody>
</table>

maximum. Using the same pelvic landmarks as in the present study, Okada found that the positions of silence occurred when the pelvic plane was inclined 80° to the horizontal. This compares with a mean value of 40° of hip flexion for the 40 adults analyzed in this study, although all exhibited anterior pelvic tilt in the erect position.

Between the erect position and the position of cessation of erectors spinae activity, vertebral flexion appeared to be the major contributor to trunk flexion. Hip flexion was then predominant to maximum flexion in agreement with one previous study, although it did not account for all the movement as previously suggested. Trunk extension from the fully flexed position previously has been shown to be initiated by posterior pelvic rotation. The present results support these findings as hip extension was 46% complete while vertebral extension was an only 10% complete at the recommencement of erectors spinae activity. This latter result suggests that the vertebral extension was initiated by rebound of the stretched connective tissue structures.

Analyses of the differences between means suggest that the relationship between vertebral and pelvic movements during flexion were reversed fundamentally during extension. However, correlations between equivalent measures at the two silent positions indicate that the relationship did not follow an exact inverse pattern. The test-retest correlations for trunk and hip flexion indicate that individuals may vary the dynamic relationships during different trials. However, it was always the position of the vertebral column that determined the large myoelectric changes in erectors spinae, as expected from basic anatomy and as proposed by Floyd and Silver.

The onset of electrical silence, and particularly resumption of activity during extension, was so spontaneous that voluntary inhibition and activation is a less reasonable concept of a position of full flexion, probably equivalent to the silent position, and a position of forced flexion, may be appropriate. The silent position may be one of passive equilibrium between the flexor torque due to gravity and the extensor torque provided by the stretched postvertebral ligaments. The present authors have confirmed a previous observation that abdominal muscle activity is required to overcome the restraint of the ligaments at maximum flexion.

Okada found that the onset of electrical silence occurred at between 45 and 90° of trunk flexion. This range included 35 of the 40 subjects in the present study. Another study stated that electromyographic silence of erectors spinae commenced most commonly between 80 and 90° of trunk flexion. The mean of 81° in the present study, and the values for one-half the subjects, fell within this range.

The photographic data showed further that at the silent positions, hip flexion was approximately 56% of maximum, and vertebral flexion was approximately 89% of its
explanation than reflex control, although there is still no
direct evidence for this assertion. It has been shown, using
fine wire electrodes, that the myoelectric silence extends to
the depth of the transversospinal group.3,18,19,33 One of the
few factors that inhibits this flexion-relaxation is pain.20

In any static position of trunk flexion, spinal posture is
maintained by balance of the torque of the upper body
weight resisted by a combination of tension and compression
of post- and prevertebral structures, respectively. The silent
period was obvious with the additional weight in this study,
however it occurred later in the vertebral flexion phase and
earlier in the extension phase. This indicates that there is a
complex mechanism of stress detection determining the
transition between partially active stabilization of the
vertebral column and wholly passive support. A number of
physiologic mechanisms have been proposed to explain this
phenomenon. The inhibition of erectores spinae must be of
functional significance as failure to inhibit these muscles
would result in vertebral extension rather than continued
trunk flexion19 if the silent position is one of passive
equilibrium. Therefore, it is of interest to speculate about the
possible sites of the receptors at the g sensory end of an
inhibitory reflex arc.

Proprioceptors monitoring changes during trunk flexion
and affecting vertebral extensor activity could be situated in
a number of structures and positions. Pressure transducers in
the abdominal cavity are unlikely to be responsible for
inhibition of erectores spinae as pressure changes are small
when no weight is held in the hands10 and may be zero in the
static maximally flexed position,24 Pressure changes also occur in the intervertebral
disc during flexion, however it appears that there is no
simple correlation between disc pressure and myoelectric
activity of erectores spinae.7

Although the thoracolumbar vertebral column is being
considered as a single structure, the recorded values reflect
mainly lumbar motion as mobility in the sagittal plane
generally decreases from the lower lumbar to the upper
thoracic regions.2,40,45,46 During flexion, compression of the
intervertebral disc7,30,33 and separation of the spinous
processes25,47 occur, as the axis of flexion remains essentially
within the intervertebral foramina throughout the range of
movement.38,46 Posterior vertebral ligaments therefore will be
stretched, and the strain to which they are subjected will
depend on their perpendicular distance from the axis of
flexion. Receptors in the posterior vertebral ligaments have
been proposed as the sensory end of an inhibitory reflex
arc.8,19

Because of the high elastin component of ligamentum
flavum32 and its close proximity to the axis of flexion, it is
likely to resist, but not limit, vertebral flexion. In fact, it
provides most of the initial resistance, but less than one-
seventh of the total resistance at maximal flexion. Its role
may be to reduce extensor muscle activity during trunk
flexion38 and to aid in return to the erect position.38,44,48
Ligamentum flavum has a poor nerve supply although the
few nerve endings in its periphery3 may have an important
function in positional control.32

Table 3. Means, and Differences between the means, of measurements at the silent positions. Test-retest correlations
and correlations between the same measures at the two silent positions are included.

<table>
<thead>
<tr>
<th>Measurement</th>
<th>SPI</th>
<th>Corr</th>
<th>SPI</th>
<th>Corr</th>
<th>X/SP2</th>
<th>Corr</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trunk flexion (°)</td>
<td>81.1</td>
<td>0.73</td>
<td>79.0</td>
<td>0.76</td>
<td>2.1</td>
<td>0.46</td>
</tr>
<tr>
<td>Trunk flexion percentage maximum</td>
<td>69.1</td>
<td>0.70</td>
<td>67.2</td>
<td>0.80</td>
<td>1.9</td>
<td>0.49</td>
</tr>
<tr>
<td>Hip flexion (°)</td>
<td>42.0</td>
<td>0.77</td>
<td>38.4</td>
<td>0.70</td>
<td>3.6</td>
<td>0.42</td>
</tr>
<tr>
<td>Hip flexion percentage maximum</td>
<td>58.3</td>
<td>0.68</td>
<td>54.2</td>
<td>0.75</td>
<td>4.1</td>
<td>0.32</td>
</tr>
<tr>
<td>Vertebral flexion (°)</td>
<td>47.8</td>
<td>0.85</td>
<td>49.1</td>
<td>0.90</td>
<td>-1.3*</td>
<td>0.95**</td>
</tr>
<tr>
<td>Vertebral flexion percentage maximum</td>
<td>87.8</td>
<td>0.78</td>
<td>90.0</td>
<td>0.72</td>
<td>-2.2***</td>
<td>0.82**</td>
</tr>
</tbody>
</table>

*P < 0.05; ** P < 0.01; *** P < 0.001.
contain both free and complex unencapsulated nerve endings, which probably do not play an important role in proprioception.

A muscle lengthening reaction has been proposed to explain the inhibition of erectors spine[37, 38] and, indeed, it is possible that the muscle fibers are stretched more than other muscle groups at their end of range. The flexion limiting role of the erectors spine musculature has been proposed but, unfortunately, the bending moment resisted by the connective tissue component was not included in the figures of Adams and associates. However, there is clinical evidence that patients with restricted vertebral flexion still exhibited a silent period while some patients with greater mobility did not. The two subjects whose data were not included for analysis in the present study both exhibited ranges of vertebral flexion within one standard deviation of the group mean.

Zygapophysial joints are synovial with the normal mechanoreceptors, and it is possible that their sensory input is responsible for inhibition of the vertebral extensors. There is also evidence that the capsular ligaments of the zygapophysial joints provide the greatest resistance to vertebral flexion at its extreme range. It is obvious from the preceding review of the biomechanical and neural evidence that further research is necessary to elucidate the mechanism of erectors spine inhibition during trunk flexion from the erect position. The present authors are continuing analysis of the control of trunk movements under various conditions.

CONCLUSIONS

The onset of electrical silence of erectors spine occurs at approximately two-thirds of maximum trunk flexion. At this position, hip flexion is almost 60% complete, and vertebral flexion is almost 90% of its maximum. This latter result indicates that at maximum forward flexion, postvertebral connective tissue structures are stretched beyond the point at which they assume the role of total vertebral support. During extension, the cessation of myoelectric silence occurs at the same trunk and hip angles as during flexion. However, vertebral flexion is slightly greater at the second silent position. Vertebral flexion is less than maximum, however, suggesting that rebound of postvertebral ligaments initiates vertebral extension. The most reliable measures at both silent positions are the vertebral values, indicating that receptors in the vertebral column, or related structures, are involved in the determination of erectors spine activity. This proposal is supported by the effect of increasing the trunk flexor torque. Addition of weight produces positions of myoelectric silence at greater vertebral flexion. In this situation, connective tissue tension is unable to entirely replace muscular contraction until the tissues are subjected to increased stress, which occurs when they are stretched further than in the normal condition.

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