Clinical Biomechanics of Orthotic Treatment of Thoracic Hyperkyphosis

J. Martin Carlson, CPO

NORMAL SPINE MECHANICS AND GEOMETRY IN THE SAGITTAL PLANE

Sagittal curvature of the lumbar spine is discussed in terms of how it relates or responds to the thoracic spine. Unless otherwise specified, geometric and mechanical analyses refer to upright stance posture in the sagittal plane.

To analyze the abnormal, we must first be familiar with what is normal. In the normal spine, there exists a long-term equilibrium between the bending moments imposed by body weight and the spine's ability (together with its attached musculature) to resist those loads. The spine maintains its configuration within the limits of normal sagittal curvatures.

Gravitation forces acting upon the head, arms, shoulders, and thorax result in a flexion moment on the thoracic spinal column for virtually all common standing and sitting postures. The spine extensors act in tension, pulling the posterior elements of the neighboring vertebrae toward one another, generating a thoracic extension moment to maintain equilibrium (Figure 1). The intervertebral disks act as compression elements, maintaining space between neighboring endplates. The disks and endplates are loaded quite evenly under normal conditions of adequate bone and muscle. That is because of the partially hydraulic nature of the nucleus pulposus component of the disk.

Spine geometry in the sagittal plane can be described as a combination of four elements:

1) Sacral anterior tilt
2) Lumbar lordosis
3) Thoracic kyphosis
4) Cervical lordosis

The author is not aware of any accepted criteria for normal but estimates a normal posture to consist of a sacral anterior tilt of about 40°, lumbar lordosis of 40° to 60°, and thoracic kyphosis of 20° to 45°.

Because the patient tends to stand in a balanced, comfortable posture, these four postural elements are not independent. They are strongly interrelated.

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ABNORMAL SPINE MECHANICS AND GEOMETRY IN THE SAGITTAL PLANE

Excessive thoracic kyphosis results from a failure of the thoracic spine complex to respond effectively to the flexion moments imposed by body weight (Figure 2). Flexion moments related to body work may be a part-time factor. Theoretically, failure may be in the anterior compression elements (ie, the anterior vertebral bodies or disks), in the posterior tension elements (ie, spine extensor muscles), or both.

Of the two types of thoracic hyperkyphosis presenting in the adolescent, posterior roundback is less severe. The lateral x-ray does not show pathological changes in the vertebral bodies. The kyphotic curve is long and smooth, and the patient usually can actively extend her/his spine to bring the kyphosis to within normal limits.

However, Scheuermann's disease is characterized on the lateral x-ray by wedging and other pathological changes, such as Schmorl's nodes, to the vertebral bodies (Figure 3). These changes are localized in two to four neighboring vertebrae. Vertebrae above and below the affected zone appear normal. This creates a localized, sharply angulated hyperkyphosis, that is very noticeable on forward bending (Figure 4). The patient is unable to actively correct this condition to within normal limits.

The human spinal support system, because of its vertical orientation, is in a sense an unstable system. As a deformity develops, the mechanical advantage of the original deforming force grows larger.

To come up with some numbers to illustrate how this works, the author has calculated the approximate spine forward-bending moments caused by gravity forces on segments of the upper body. Those approximate calculations indicate that an increase in thoracic kyphosis from a value of 40° to a value of 65° will increase the deforming bending moment by about 50 percent at the T10 level. In other words, a spinal support system inadequate to prevent the initiation of a hyperkyphosis becomes less and less adequate as the deformity grows. Intervention must force a strengthening of the extensors, passively improve alignment, or both.

As the vertebrae angle forward on one another, the range of motion of the disk is exhausted, the nucleus pulposus can no longer equalize pressure, and compression loading is more and more shifted toward the anterior edge (Figure 2). The excessive/unrelenting compression slows (Hueter-Volkmann variation of Wolf's law) growth in the anterior portion of the ring apophysis. Gradual wedging occurs (Figure 3). The spine system is naturally most unstable during the growth

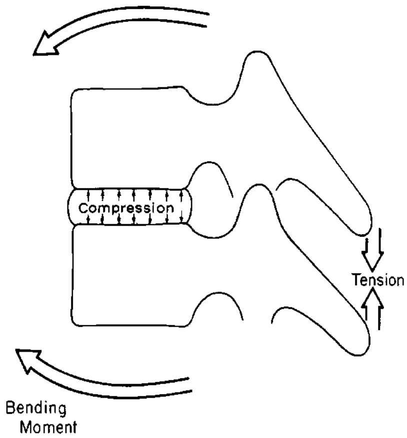

Figure 1. Active extensors adequately balancing gravitational bending moments.

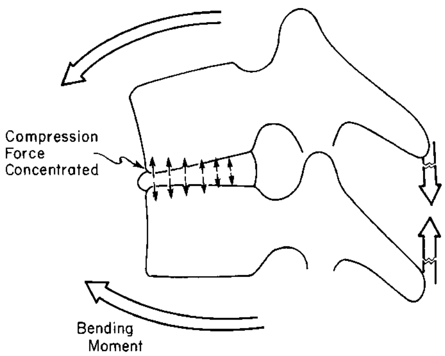

Figure 2. The consequence of inadequate extensor activity/strength.

Figure 3. Lateral radiograph showing wedging and Schmorl's nodes typical of Scheuermann's disease.

Figure 4. Typical lateral, forward-bending profile of a youngster with Scheuermann's disease.

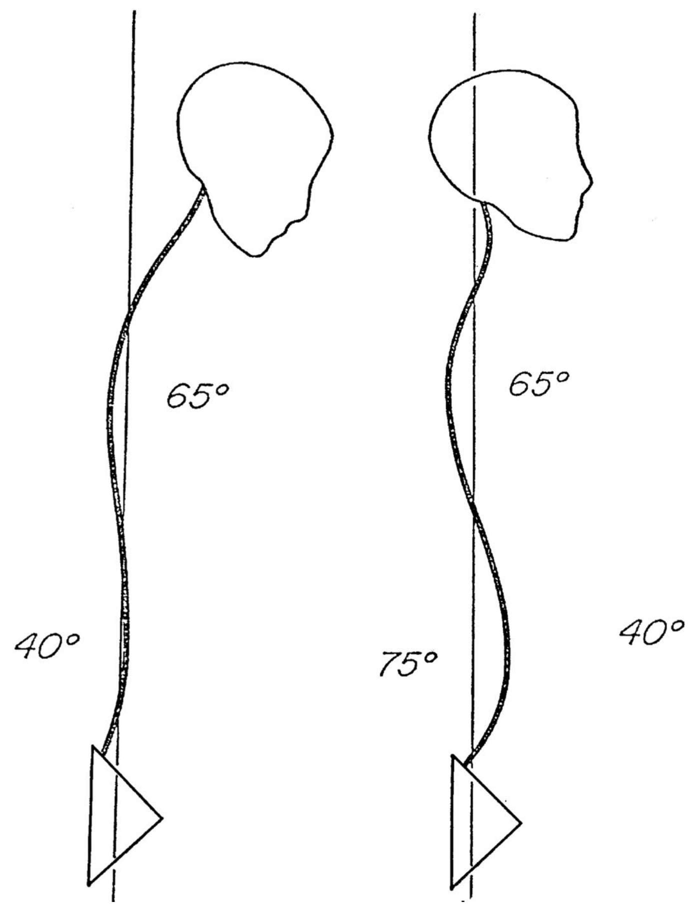

Figure 5. A: Sagittal spine posture if thoracic hyperkyphosis developed without compensation. B: This diagram illustrates how a level gaze and sagittally balanced alignment are maintained when compensating lumbar lordosis develops close behind thoracic hyperkyphosis.

years and the geriatric years when bone is most likely to respond unfavorably to this excessive loading.

As mentioned, thoracic kyphosis is only one member of an interrelated family of curves that together comprise spinal posture. Deformity in one area of the upright spine requires compensation in one or more other areas of the spine. If

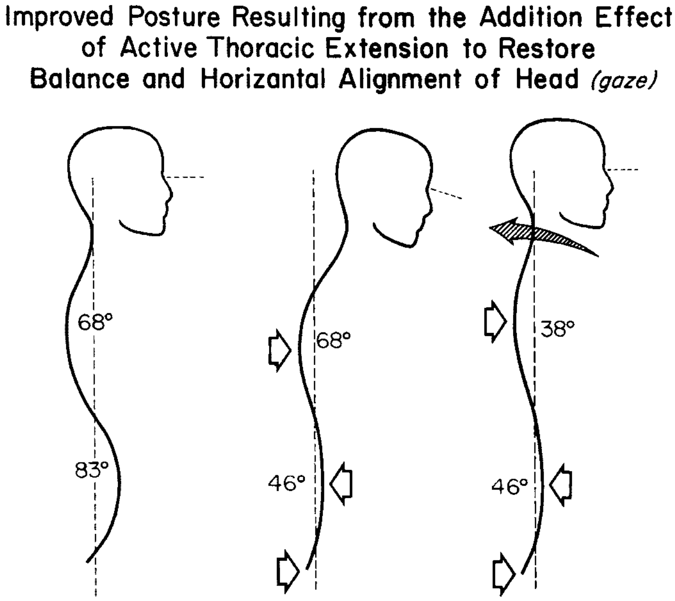

Figure 6. The active reversal of thoracic kyphotic collapse when lumbar spine compensation is passively prevented.

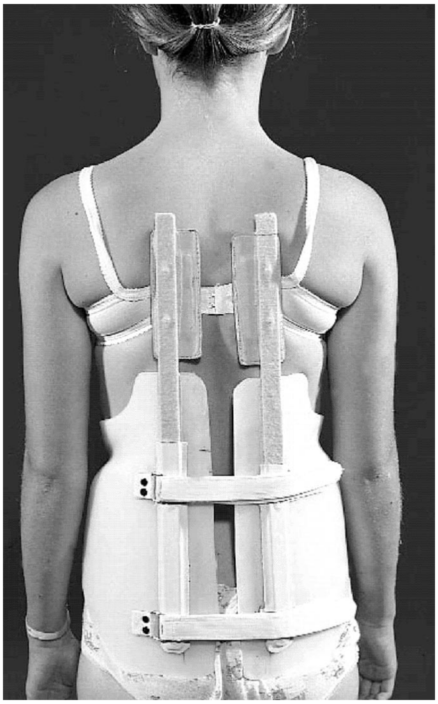

Figure 7. This thoracolumbosacral orthosis corrected the patient's postural roundback. There is no anterior orthosis element above the xiphoid process.

thoracic hyperkyphosis developed as an isolated entity without compensation somewhere else in the body, it would cause the head and shoulders to be brought forward and downward to an awkward, poorly balanced position (Figure 5A). To prevent this, the body usually compensates by developing increased cervical and lumbar lordosis to bring the upper thorax and head back into balanced alignment (Figure 5B).

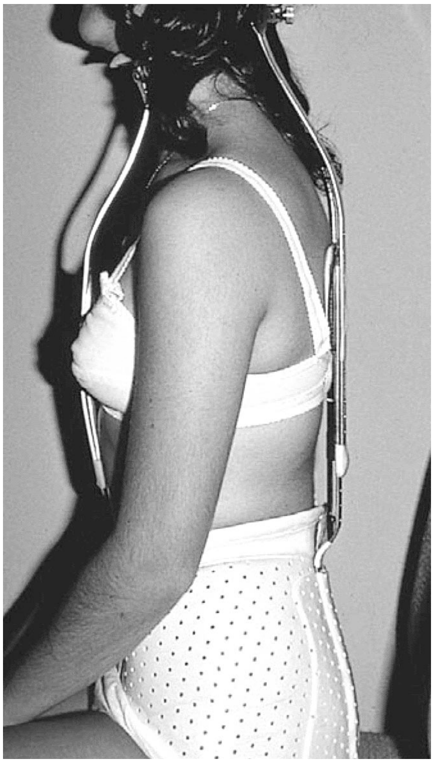

Figure 8. This photograph perfectly illustrates proper anterior cervical stimulus and adequate posterior superior space needed for active hyperkyphosis correction.

An additional compensating mechanism used to move the upper thorax back into balance is increased extension at the hip joint (this reduces the amount of anterior sacral tilt).

HYPERKYPHOSIS CORRECTION

The most effective treatment of thoracic hyperkyphosis consists of creating a situation whereby the thoracic spine extensors are forced to work and thereby strengthen. They are thus (re)habilitated to a condition of adequacy, able to maintain active thoracic extension moments equal to the gravitational bending moments.

The interrelationship of thoracic kyphosis and lumbar lordosis can be used to advantage in accomplishing this goal. Passive reversal of the lumbar lordosis compensatory mechanism obviously tends to pitch the patient's head and shoulders forward and downward. The patient who is neurologically normal will be induced to actively extend his thoracic spine to bring his head and shoulders up and back to a more balanced, more normal position (Figure 6).

This may be all that is necessary orthotically to correct, over time, a flexible, postural roundback type of hyperkyphosis. Remember that this correction mechanism is not operating when the patient is recumbent, nor is it operating in many sitting postures. Figure 7 shows a patient with roundback wearing a thoracolumbosacral orthosis that simply reduces her lumbar lordosis. An induced strengthening of her thoracic extensors corrected her thoracic hyperkyphosis.

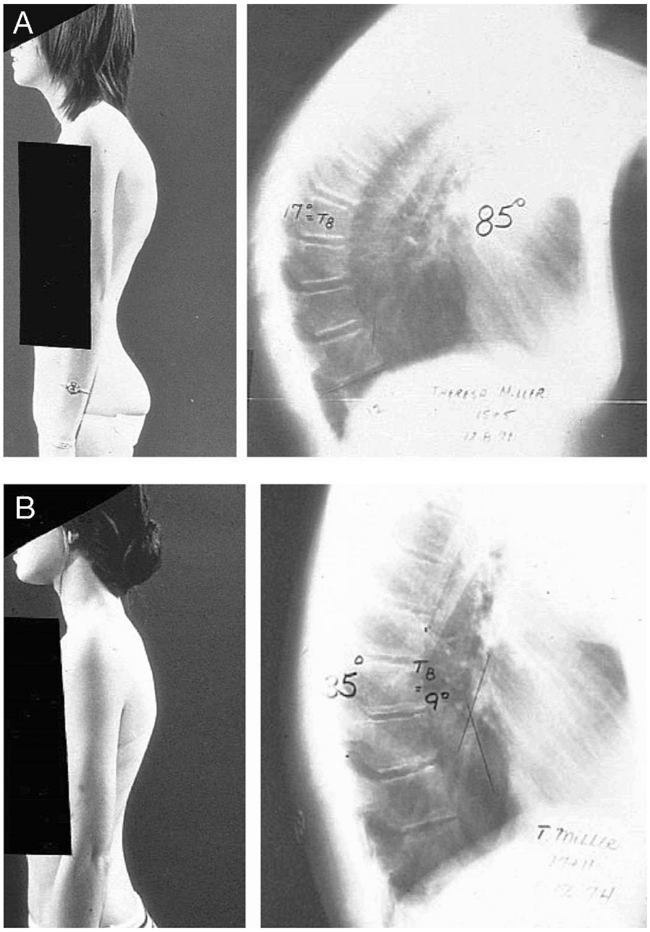

Figure 9. A: T.M. presented with a thoracic kyphosis measuring 85° (Scheuermann's disease). B: T.M.'s lateral photo and radiograph at the end of orthotic treatment (Milwaukee orthosis fitted as in Figure 8) 18 months later.

Scheuermann's disease is a more difficult problem because of its severity and rigidity. As noted, in Scheuermann's disease the vertebral bodies have become wedged. Correction involves reducing the compression stress on the anterior portion of the growth plate of the vertebral bodies so that corrective growth will occur. The patient has a much more difficult task in extending the thorax. However, by strong passive reduction of lumbar lordosis and by using an anterior cervical or sternal component as a positive, ever-present stimulus, the thoracic extensors can be forced to exercise and dramatically strengthen. In a relatively short time, thorax extension range of motion increases, and the hyperkyphotic deformity lessens. To give the corrective growth process enough time, the preferred alignment must be maintained when the patient is recumbent and sitting, as well as when she/he is standing. The orthosis must provide space in the posterior neck and shoulder area so the patient can pull up and away from the anterior neck aspect of the orthosis (Figure 8). This is an example of a proper fit. When the orthosis is properly configured and fit, remarkable results are achieved (Figures 9 and 10).

Occasionally, the kyphosis is aggravated (or perhaps even initiated) by tight pectoral muscles. When this is the case, physical therapy exercises and/or some type of shoulder pad or harness are indicated to stretch the pectorals. One option is to use a shoulder sling-type accessory. This consists of a plastic cap molded to the anterior deltoid surface. The cap extends inferiorly and then posteriorly through the axilla. It is shaped to bridge over the pectoralis major tendon with minimum pressure. Dacron straps extend posteriorly from the top and bottom to the deltoid cap to separate outriggers attached to the posterior upright (Figure 11).

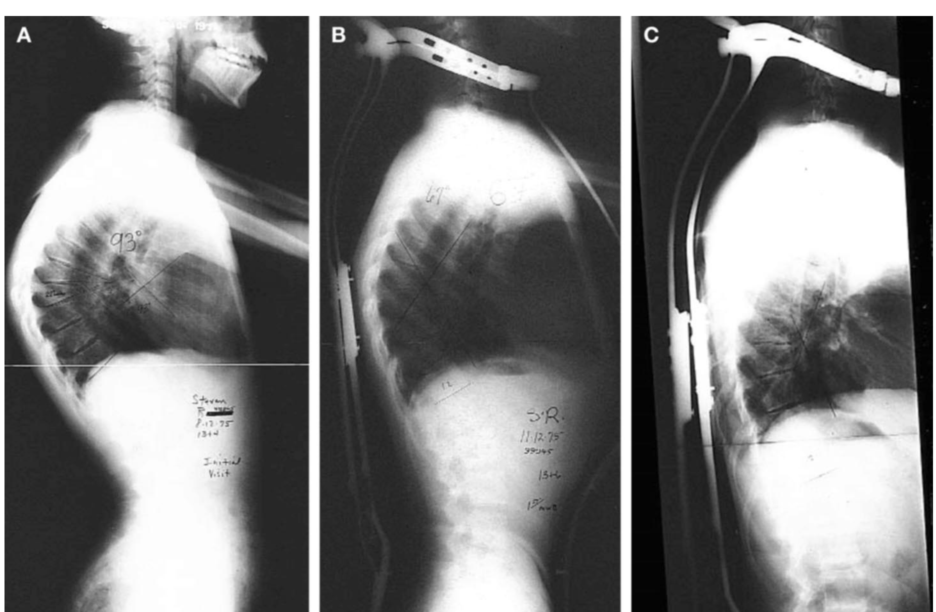

Figure 10. Left: S.R. presented with a 93° Scheuermann's. Center: Three months later in his orthosis (67°). Right: His in-orthosis correction later during treatment.

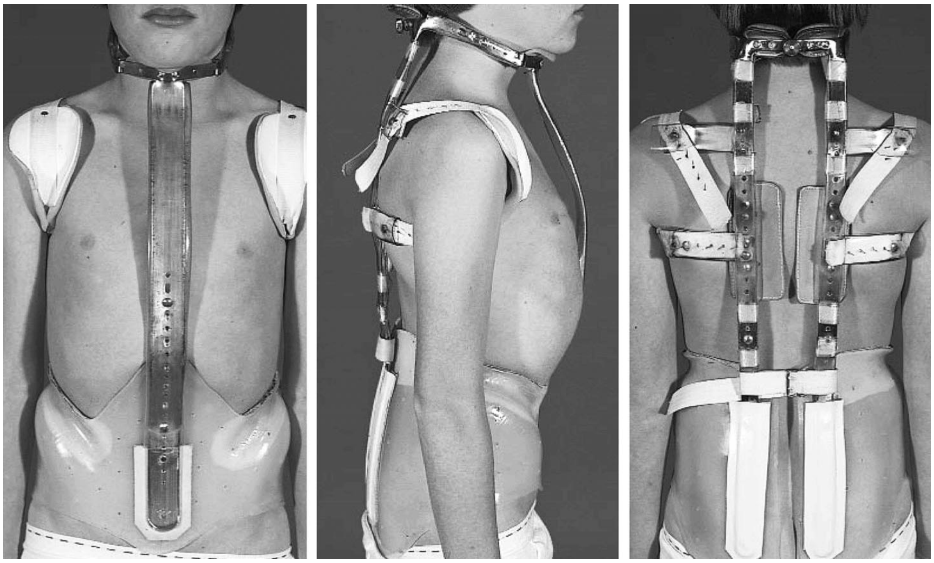

Figure 11. When tight pectorals are a part of the hyperkyphosis presentation, it is important to somehow stretch them. Orthotic stretching presents a difficult design challenge.

Again, the thing to remember about postural roundback and Scheuermann's disease is that correction is an active mechanism. We use passive pressure on the sternal and/or subclavicular area to correct hyperkyphosis in paralytic cases only. Such forces have little or no legitimate role in the treatment of postural roundback or Scheuermann's disease. Passive forces are much less efficient than the correction effected by the neurologically normal patient actively pulling up and back, away from uncomfortable contact with an anterior cervical or sternal component. Such components must be made as forceful and comfortable as possible for the patient with neuromuscular difficulties, but that is not necessary or appropriate for the patient with idiopathic hyperkyphosis.

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This document includes some excerpts, photos and drawings which were published in 1980 and 1981 by Gillette Children's Hospital within a set of booklets, *A Thoraco-Lumbo-Sacral Orthosis for Idiopathic Scoliosis*, part I and part II, which were authored by J. Martin Carlson. The biomechanical principles illustrated in the photos and drawings are as accurate today as they were 20 years ago. The Gillete staff have continued to evolve and change material and design details to further improve cosmesis and orthotic options. Mr. Carlson and the JPO thank Gillette Children's Specialty Health Care for their permission to republish.

There are some excerpts, photos and drawings in this document which were published in Orthopädie-Technik in articles authored by J. Martin Carlson, October 1991. Mr. Carlson and JPO thank Verlag Orthopädie-Technik for their permission to republish.