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Physical Examination in Adolescent Idiopathic Scoliosis

Mohammad Diab, MD

Pediatric Orthopedics, University of California, San Francisco, 500 Parnassus Avenue, San Francisco, CA 94143, USA

The following distinguish the physical examination in scoliosis: it is extensive, it is revealing, and it influences treatment. Throughout this discussion, reference frequently is made to evaluation for underlying neural disease. Idiopathic scoliosis is a diagnosis of exclusion, and a neural etiology of spinal deformity must be ruled out in every case. Before laying hands on the patient, note the patient's age and gender. Observe gait, and explore whether the patient complains of significant pain. Start with the upright back. Determine spinal balance. Palpate the spinous processes from the vertebra prominens to the sacrum. These give an indication of curve magnitude and rotation. Look for signs of truncal distortion, including rib or flank prominence, shoulder elevation, flank flattening or indentation, scapular rotation or elevation, and iliac crest prominence or elevation. Evaluate the upright side to look for atypia in sagittal contour and sagittal imbalance. Perform an Adams forward bend test, during which the patient bends forward until the spine is horizontal, with the neck relaxed, knees fully extended, feet together, upper limbs dependent, and palms opposed. Evaluate truncal rotation; limitation or asymmetry of forward bending, which may be seen in painful or neural conditions that produce scoliosis secondarily; and sagittal contour, which may be exaggerated with forward bending. Perform a neural examination to rule out a lesion of the neuraxis, of which the primary or only manifestation is spinal deformity. The four principal lesions associated with so-called "idiopathic" scoliosis are Chiari malformation, syrinx, diastematomyelia, and tethered cord, in which the filum terminale is thickened and restricts proximal migration of the spinal cord in the vertebral canal during growth. Inspect the skin for stigmata of other diseases. Determine maturity. In the setting of the physical examination, this may be based on peak height velocity, menarche, and secondary sexual characteristics. Assess and discuss the importance of appearance. Points in this discussion include breast shape, rib prominence, shoulder height, and future surgical scars. Examine the whole patient to rule out stigmata of other diseases that would disqualify the diagnosis of idiopathic scoliosis.

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Before laying hands on the patient, several factors may be taken into account

1. Age. This is one measure of maturity, and therefore aids in determining risk of progression. Children in the first decade of life have a higher risk of an associated neural lesion, and thus must be screened with MRI of the neuraxis.
2. Gender. Although idiopathic scoliosis (defined as curvature greater than 10°) shows no gender preference, likelihood of progression is greater in girls than in boys, producing an operative rate in girls more than six times that of boys.

E-mail address: diab@orthosurg.ucsf.edu

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3. Gait. Watch the child as she or he walks into the examining room. The surgeon may see signs of neural disease, such as ataxia; look for antalgic gait, and evaluate skeletal balance.
4. Pain. The incidence of pain in children with idiopathic scoliosis is no greater than in the general population of children, of whom approximately one third report back pain at some time [1]. Pain may arise during phases of rapid progression, which should alert the surgeon to observe more closely for an intervention opportunity, such as bracing, or it may be a sign of underlying neural disease, which warrants further evaluation, such as with MRI.

Characteristics of back pain that should elicit concern for another primary etiology include the following [2]:

- Pain associated with other symptoms or signs
- Pain that arouses a child from sleep, in contrast to pain that delays falling asleep, which falls into the common and benign category of "overuse"
- Constant pain

Start with the upright back

Determine spinal balance in two ways (Fig. 1):

1. Drop a plumb line from the inion or vertebra prominens. Deviation more than 2 cm from the natal cleft is atypical in idiopathic scoliosis and may be a sign of underlying neural disease.
2. Identify the back midpoint at the level of maximum width of the thorax, and determine deviation from the natal cleft. This is a measure of truncal decompensation. It is seen in single curves more frequently than in double curves and is a risk factor for progression [3].

Palpate the spinous processes from the vertebra prominens to the sacrum. These give an indication of curve magnitude and rotation. The latter is always toward the concavity of the curve. Absence of spinous processes corresponds with spina bifida occulta. Palpation of the spinous processes is a direct measure of scoliosis.

Look for secondary signs of scoliosis producing truncal distortion (Fig. 2) [4]. These include rib or flank prominence, shoulder elevation, flank flattening or indentation, scapular rotation or elevation, and iliac crest prominence or elevation. Rib or flank prominence is a sign of the spinal

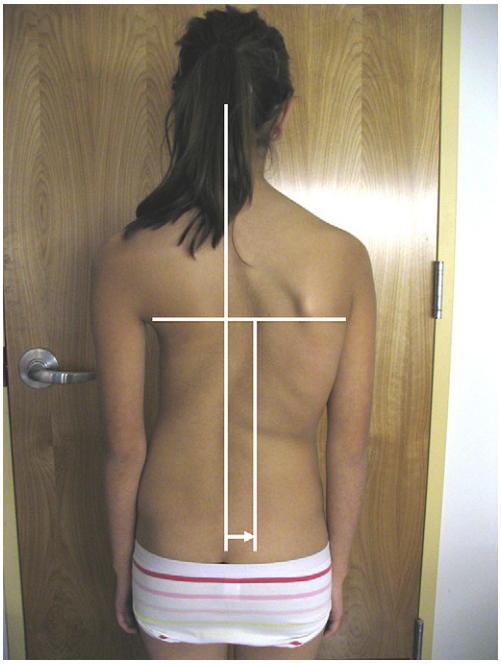

Fig. 1. Spinal balance. The trunk is imbalanced to the right in this patient with a single thoracic curve, whereas the inion is centered over the natal cleft.

rotation in the transverse or axial plane that accompanies curvature in the coronal plane, and it occurs on the convexity of the curve. Flank asymmetry may be the only sign in an overweight child, in whom chest asymmetry is more easily obscured. Iliac crest asymmetry may be a sign of lower limb length discrepancy, which may be neutralized by placing blocks under the foot on the side of the lower iliac crest. Once the iliac crests (and therefore the pelvis) are leveled, a true assessment of spinal curvature is possible.

The secondary signs of scoliosis form the basis of the school screening examination, which is performed in high school twice for girls and once for boys in the United States. A principal reason for the poor yield of such a program [5] is the fact that a certain amount or degree of back asymmetry is normal in the general population (Table 1) [6].

Evaluate the upright side

Although scoliosis is classified in the coronal plane, it is a three-dimensional deformity; as such, it results in an alteration of sagittal contour. Spinal rotation produces a loss of thoracic kyphosis and lumbar lordosis, effectively flattening

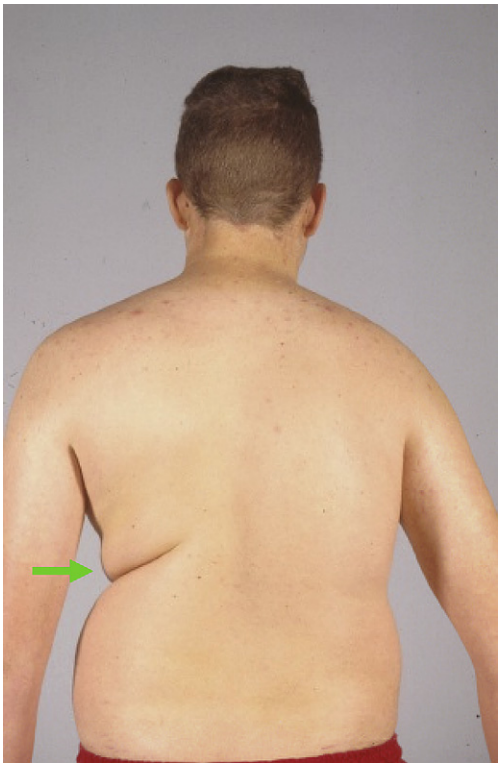

Fig. 2. Flank asymmetry. Cleft on side of curve concavity (*arrow*).

the spine in the sagittal plane (Fig. 3). The importance of this is threefold:

1. As stated previously, idiopathic scoliosis is a diagnosis of exclusion, and any sign of atypia should prompt a quest for the underlying etiology. A particularly important atypical sign is increased thoracic kyphosis, which is one of the most sensitive indicators of underlying neural disease [7].
2. Sagittal imbalance is the greatest predictor of pain produced by spinal deformity. Not only is this important in the assessment of a child with scoliosis, but restoration of physiologic balance in the sagittal plane is critical in surgical reconstruction of the spine.
3. Sagittal imbalance may be an indicator of more global disease beyond the confines of the spine. For example, hip flexion contracture may tip a patient forward. Thus, just as iliac crest asymmetry should prompt an evaluation of the lower limbs for length discrepancy, sagittal imbalance necessitates an examination of the lower limbs for contracture or primary deformity.

Table 1
Normal variation of trunk measurements in Belgian school children

Shoulder	≤10 mm
Scapulae	≤10 mm
Flank	≤15 mm
Pelvis	≤10 mm
Rib hump	≤8 mm
Lumbar prominence	≤5 mm

From Vercauteren M, van Beneden M, Verplaetse R, et al. Trunk asymmetries in a Belgian school population. Spine 1982;7(6):559; with permission.

Perform an Adams forward bend test

The patient bends forward until the spine is horizontal, with neck relaxed, knees fully extended, feet together, upper limbs dependent, and palms opposed [8]. The patient may be assessed from the back or the front. Although the former is less awkward, the latter is easier, because the examiner, typically seated on a mobile stool, is able to assess thoracic and lumbar regions

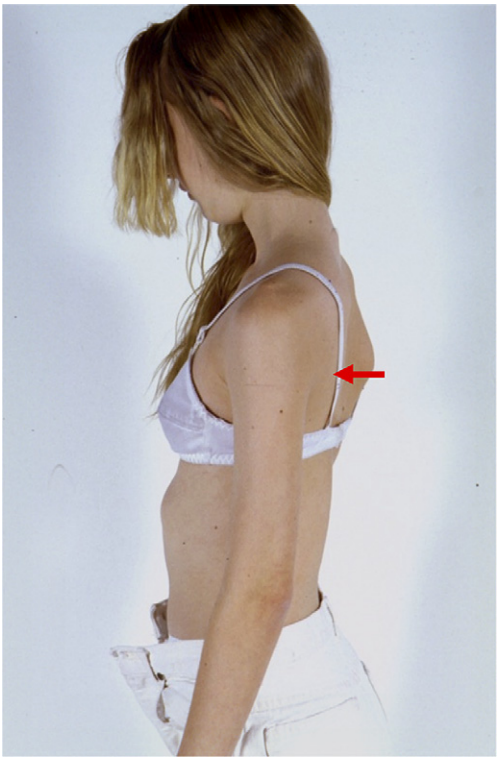

Fig. 3. Thoracic hypokyphosis (*arrow*).

Fig. 4. Thoracic prominence on side of curve convexity (*arrow*).

without changing position (Fig. 4). The following may be assessed from the Adams test:

1. Truncal rotation. The chest and flank may be seen in profile, thereby exposing any prominence. The prominence may be quantified with an inclinometer or spirit level designed for scoliosis (the so-called "scoliometer") (Fig. 5) [9], which is centered over the apical spinous process (at the maximum degree of rotation and prominence). Seven degrees of rotation corresponds with approximately 20° of coronal deviation and is the point at which the referral rate crosses the miss rate, thereby minimizing, although not compromising, both (Fig. 6).
2. Other etiology of scoliosis. For example, scoliosis arising from a painful condition of the spine, such as osteoid osteoma or spondylolisthesis, or occurring in the setting of a more global neural disease, such as might be characterized by hamstring contracture, may be uncovered by limitation or asymmetry of forward bending.

Fig. 5. Scoliometer.

3. Sagittal contour. For example, thoracic kyphosis, as in Scheuermann disease, in which scoliosis is a feature in one third of cases, may be amplified by forward bending. In fact, it is not uncommon for a child to be referred to a spinal surgeon for scoliosis when the primary condition is osteochondrosis of the spine producing juvenile thoracic hyperkyphosis.

Perform a neural examination

In idiopathic scoliosis, it is imperative to exclude a lesion of the neuraxis, of which the primary or only manifestation is spinal deformity. Evaluate sensory and motor function in the lower limbs. Evaluate reflexes, including those of the patellar ligament and Achilles tendon, and the abdominal reflex. The latter is a screen of the thoracic division of the spinal cord. It is performed by stroking the skin of the abdomen in four quadrants toward the umbilicus. Normal includes symmetric contraction of abdominal muscles bringing the umbilicus toward the side stroked, bilateral absence of reflex, and variable contraction on each side. Abnormality is consistent contraction on one side and consistent absence on the other [10]. Finally, look for upper motor neuron signs, such as ataxia and clonus. An abnormal neural finding should be followed up with MRI from the occiput to the sacrum, looking for four principal lesions:

1. Chiari malformation. Type I is defined as displacement of the cerebellar tonsils caudal to the foramen magnum occipitale.
2. Syrinx, defined as fluid in the spinal cord "distinct" from expansion of the central canal (hydromyelia).
3. Diastematomyelia, or splitting (stemato-) apart or in two (dia-) of the spinal cord (-myelia).

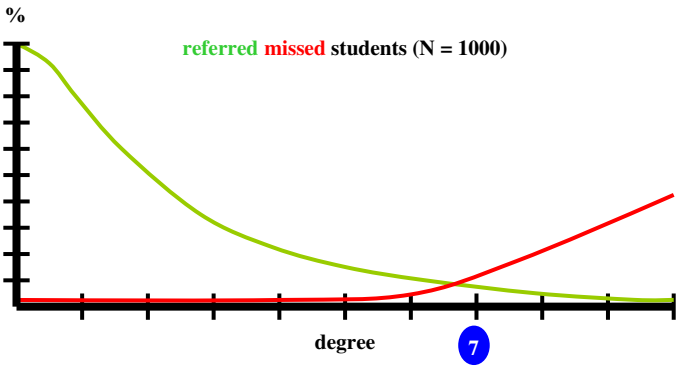

Fig. 6. Seven degrees of trunk rotation corresponds with approximately 20° of Cobb angle and minimizes the referral/missed ratio. (*From* Bunnel WP. An objective criterion for scoliosis screening. J Bone Joint Surg Am 1984;66(9):1384; with permission.)

4. Tethered cord, in which the filum terminale is thickened and restricts proximal migration of the spinal cord in the vertebral canal during growth.

Inspect the skin

The skin has been described as the window to disease. Two features of the skin are important to the evaluation of the child with idiopathic scoliosis:

1. Stigmata of dysrrhaphism, including abnormal hair, angioma, lipoma, and dimple. Although it has been estimated that up to 50% of patients with diastematomyelia manifest a cutaneous sign [11], a simple midline lumbosacral dimple occurs in up to 5% of normal children and, per se, is not a sign of neural anomaly [12]. As a result, judgment must be exercised in pursuing this finding. Unless an ultrasonogram of the spine is obtained in the neonate before ossification of the posterior elements is complete, MRI is the usual screening modality for the neuraxis and requires an anesthetic agent in early and midchildhood.
2. Stigmata of nonidiopathic spinal disease, such as café au lait spots or axillary freckling in neurofibromatosis (Fig. 7).

Determine maturity

The two principal determinants of progression are curve magnitude (measured on a roentgenogram) and maturity. The latter may be assessed by a roentgenogram (eg, Risser sign [13,14], presence or absence of triradiate cartilage [15], shape of distal phalangeal epiphysis [16]) or during the history and physical examination. Three elements of the latter assessment, which is the focus of this discussion, are important:

1. Peak height velocity (Fig. 8). This occurs during the approximately 6 months that precede

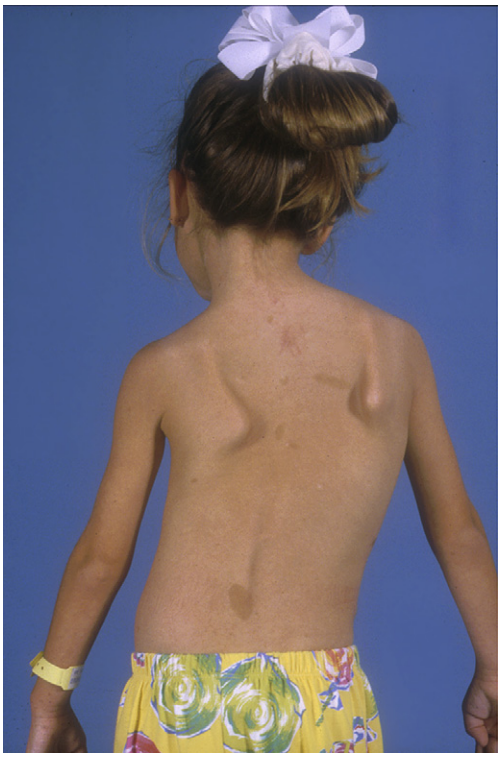

Fig. 7. Examination of the skin reveals café au lait spots of neurofibromatosis.

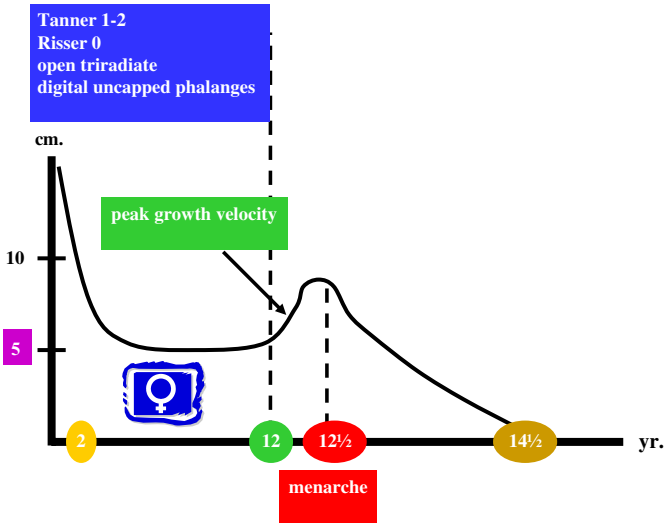

Fig. 8. Summary of typical growth pattern for a girl.

menarche in girls and represents the period of greatest risk for progression. Although height is easy to calculate (by the clinic nurse during intake), the difficulty in using this measure of maturity rests on the facts that follow-up of scoliosis typically occurs every 4 to 6 months (thus, encompassing most of this growth window) and that it is recognized retrospectively.

2. Menarche. This represents the end of peak height velocity and signals the beginning of slowing down in growth, which reduces the utility of this measure because it occurs after the period of highest risk of progression (“after the action,” so to speak). Other problems with this measure include the fact that it applies to one gender only and the fact that it varies greatly (eg, it may be delayed or suppressed by vigorous activity).
3. Secondary sexual characteristics. As we search for the quintessential measure of maturity, the staging system of Tanner [17,18] remains the simplest, fastest, and least expensive method available. It may be performed in the office by the surgeon or physician extender, and it is the least morbid (eg, no radiation as in roentgenograms, no blood draw as in a serologic marker).

It should be noted that in addition to menarche, the iliac apophysis is absent (Risser stage 0) and the triradiate cartilage is open at the conclusion of the peak height velocity phase, making these poor differentiators during the most critical period for progression (Fig. 9). The conclusion of peak height velocity corresponds roughly with Tanner stage 3.

Assess and discuss importance of appearance

Until recently, little attention has been given (or perhaps more honestly, little admission) to appearance in idiopathic scoliosis; however, this is the greatest concern to an adolescent in a period of development that is focused on body image [19]. It also is not new, having been recognized throughout the ages and across all societies [20]. As a result, it is the responsibility of the surgeon to address this issue because it is central to

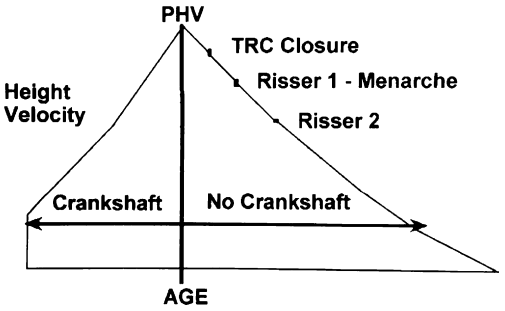

Fig. 9. Menarche, the iliac apophysis (Risser sign), and triradiate cartilage (TRC) closure occur after peak height velocity (PHV). (*From* Sanders JO, Browne RH, Cooney TE, et al. Correlates of the peak height velocity in girls with idiopathic scoliosis. Spine 1987;31(20):2293; with permission.)

outcome and to not do so is a disservice to the patient. The four germane components are the following:

1. Breast shape. The surgeon should admit that correction of spinal deformity, including direct vertebral rotation with pedicle screws and other so-called "modern" surgical techniques, may not significantly improve breast asymmetry. In certain cases, this is so important to a girl that a consultation with a plastic surgeon is not unreasonable.
2. Rib prominence. This may be the only thing that an adolescent, and an adolescent's friends, notice through clothing. A discussion of surgical correction should include possible thoracoplasty for patients for whom this is of sufficient importance.
3. Shoulder height. Like breast asymmetry, this is what the patient sees every time she or he looks in the mirror. The surgeon must take great care to level or at least reduce, and certainly not to increase, shoulder height difference during surgical correction of scoliosis. Unlike breast asymmetry, there is no secondary fix for this if it remains a concern to the patient after the operation.
4. Surgical scar. It has been said that one advantage to anterior surgical correction of scoliosis is the saving of fusion levels. Although this has come under dispute recently with the widespread use of posterior pedicle screws, whether the saving of fusion levels is a long-term functional advantage (eg, reduced back pain) remains controversial. This controversy needs to be balanced against the greater dissatisfaction associated with anterior oblique thoracolumbar scars compared with posterior midline linear scars among adolescents undergoing surgical correction of idiopathic scoliosis [21].

Examine the whole patient

As stated previously, idiopathic scoliosis is a diagnosis of exclusion. In addition to inspection of the skin, the surgeon must look for stigmata of other diseases that may be remote from the spine and trunk. Tall stature, dolichostenomelia, arachnodactyly, and a high-arched palate suggest Marfan syndrome. Scapular elevation associated with restricted range of motion of the shoulder is the hallmark of Sprengel deformity. Cavus foot may signal a spinal cord lesion ("the arch points to the problem") [22].

Finally, the art

Because the physical examination in scoliosis includes inspection of the trunk, including the rib cage and breasts, and because it may include evaluation of secondary sexual characteristics to determine maturity, and therefore risk of progression, it requires delicacy in execution. The special consideration that must be afforded the adolescent, who is in a critical developmental period of which body image is a significant component, must not preclude thoroughness and completeness, however.

1. In the examination room, the surgeon must make the child comfortable and win her or his trust and must gain the confidence of the accompanying parent(s). Sit down, and take some time.
2. Minimize traffic. The period in life, the diagnosis, and the physical exposure may lead to a sense of vulnerability in the child, and the last thing she or he wants is a cast of characters streaming in and out of the room to view her or his naked body. Retain the parents, whose presence may reassure the child and whose input is essential to a complete assessment, unless the child asks for one to leave (eg, the father of an adolescent girl).
3. Close the door. The child needs to feel safe.
4. Encourage the child to wear a swimsuit (two-piece suit in girls) that she or he is accustomed to revealing in public.
5. Talk to and involve the patient directly before consulting with the parent(s). This is a general rule of caring for children and is especially relevant to scoliosis, because the diagnosis is emotionally charged.
6. Speak in English, and choose your words carefully. For example, avoid medically acceptable but potentially insulting terms, such as "deformity."
7. Be honest and open. Although you ought not to dwell on the scary and the weird, with which the world of spinal deformity and surgery is replete, the tradition of sequestering the child from the negative is at best unproductive and at worst can undermine your care.
8. Be as nonthreatening as possible. This includes evaluation of parts of the body remote from the focus and examining the younger child in the security of a parent's lap. Remember, the child is exposed during your examination, and the spine is scary even to a child.

9. Take every and all opportunities to examine the child. Watch the child walk into the office (eg, gait, affect, pain, stature, proportion). Assess how well a child who complains of pain moves about in the room, including how easily she or he gets up from a chair and onto an examining table. Ask the child to walk on the heels and toes, perform a deep knee bend, and walk "like a duck," thereby testing strength against body weight and doing so without touching the child.
10. Do not objectify the child with a spinal deformity. Not only is the diagnosis often heavily laden with emotion, but the child may be less able (compared with an adult) to approach her or his condition "rationally" and dispassionately. To this end, spend at least as much time on the child and parents as on the imaging studies, which can be a challenge, given the extensive imaging that is often necessary in evaluating and treating scoliosis.

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