

Spinal Deformity and Athletics

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Abstract: Exercise and athletic competition for the young individual has become increasingly more important in society. Scoliosis and Scheurmann kyphosis are spinal deformities prevalent in up to 2% to 3% and 7% of the population respectively, requiring nonoperative and occasionally operative treatment. Curve progression and patient physiologic age dictate treatment regimens. Bracing and physical therapy is the mainstay for nonoperative treatment, whereas soft tissue releases and fusion with instrumentation are used for operative correction. Athletic activity and sports participation is usually allowed for patients undergoing nonoperative treatment. Return to sport after surgical correction is variable, often decided by the treating surgeon, and based on the level of fusion and sporting activity. Although most treating surgeons promote some form of activity regardless of treatment modality chosen, caution should be taken when deciding on participation in collision activities such as football and wrestling.

Key Words: scoliosis, kyphosis, deformity, bracing, fusion, athletics

(Sports Med Arthrosc Rev 2008;16:26–31)

Sporting activity has increasingly become more important in children and adolescents. Children are participating in sports and other athletic activities at an earlier age, with an increase in female participation over the past 30 years.^{1,2} Scoliosis and kyphotic spinal deformities are concerns for both females and males, and many of these patients participate in sports and other forms of athletic activities before implementing treatment, and would like to return to sport afterward. Despite well-known treatment protocols for both clinical problems, there has been little in the literature documenting appropriate guidelines for athletic participation after nonoperative and operative treatment.

SPINAL DEVELOPMENT

The spine exhibits both latitudinal and longitudinal growth by a combination of appositional growth and endochondral ossification that starts around 2 to 4 weeks

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The authors did not receive any institutional, pharmaceutical, or industry support for this manuscript.

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of gestation. The spherical ossification center enlarges circumferentially toward the vertebrae and the intervertebral discs, increasing in size until the parallel growth plate is clearly delineated both superior and inferior.

At birth, the vertebrae are composed of 3 ossification centers joined by cartilage. Longitudinal and circumferential growth continues posteriorly until the first decade, whereas anterior longitudinal growth ceases between 16 and 18.³

Latitudinal growth of the vertebral body originates centrally from the physis, and from the surrounding perichondrium. The ossification centers unite with bony bodies by age 25, doubling the height of the thoracic spine between birth and skeletal maturity. As with any other bone, vertebral body and subsequent spinal column growth is responsive to physiologic and mechanical stress.⁴

SPINAL DEFORMITY: SCOLIOSIS

Scoliosis is a frontal plane deformity, defined by lateral curvature of the spine > 10 degrees as measured by the Cobb method⁵ (Fig. 1) and vertebral rotation producing a 3-dimensional deformity. The concave side demonstrates a wider spinal canal, thicker lamina, and deviation of the spinous process. Conversely, the spinal canal is narrower and the vertebral body is rotated toward the convex side. Most idiopathic curvatures are right thoracic curves, with left thoracic curves far less common. Spinal rotation creates a “hump” observed on forward bending, and this may cause pain, although usually nondysfunctional.⁶ The prevalence of scoliosis in the general population is approximately 2% to 3%,⁷ although as the curve progresses beyond 20 and 30 degrees, the prevalence decreases from 0.5% to 0.3%, respectively. Larger, more progressive curves are typically observed in females, with nearly a 7:1 female to male ratio for curves requiring orthopedic intervention. Neuromuscular disorders, spinal cord abnormalities, and connective tissue disorders are identifiable causes of scoliosis. Most athletes seen for scoliosis, however, will demonstrate idiopathic curves. Females with curves > 15 degrees have nearly a 30% prevalence of scoliosis in their daughters, thus demonstrating a potential genetic etiology.

Typically, idiopathic scoliosis is a painless condition, with most patients unaware of curves of < 30 degrees. Curves are often first detected on a routine physical examination or as a result of school screening. Patients may notice a waist asymmetry from a thoracolumbar curve or a thoracic prominence from rib rotation associated with a thoracic curve. Significant pain should prompt further evaluation for an underlying cause of the

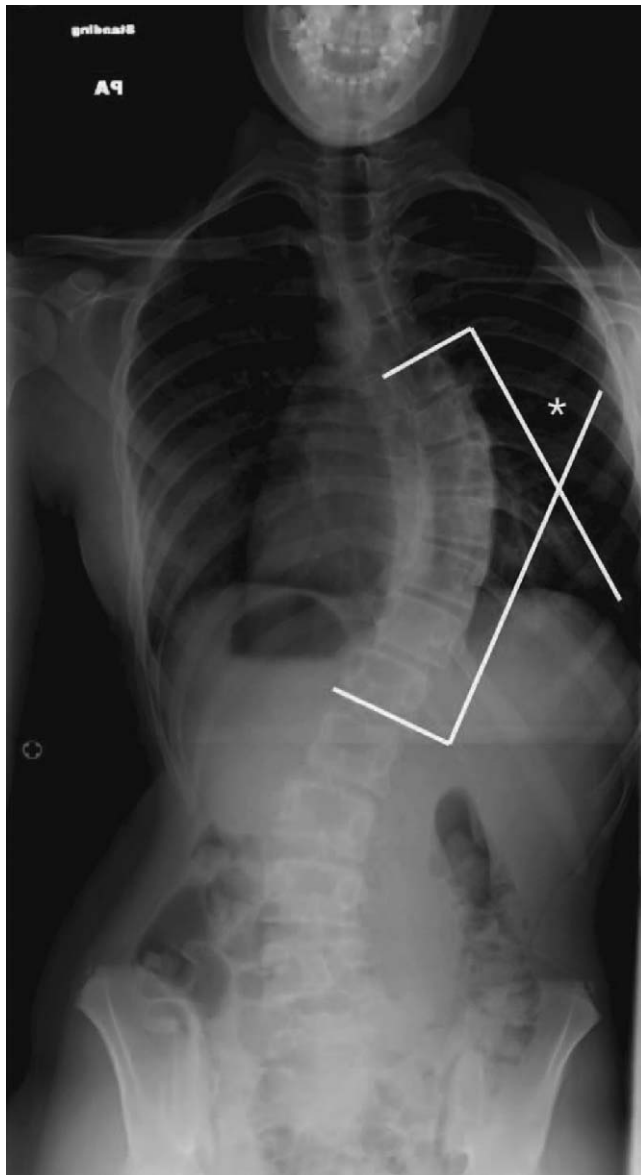


FIGURE 1. Cobb Angle. Lines are drawn parallel to the end plates of the most tilted vertebrae above and below the apex of each curve. The angle formed by the intersection of the lines drawn perpendicular to the end plate lines is the Cobb angle (*).

scoliosis, such as spinal dysraphism, tumor, or hydro-myelia. One third of patients with idiopathic scoliosis may report mild symptoms of pain, subsequently, a history of numbness, bladder dysfunction, headache, weakness, or dysesthesia should be sought.⁸ A family history of scoliosis, connective tissue disorder, or neurologic disorder is also relevant.

Physical examination should include a thorough examination of the nervous system, including reflexes. The abdominal reflex is performed by stroking each quadrant of skin above and below the umbilicus. The umbilicus should move toward the stimulus symmetri-

cally. An asymmetric reflex may indicate the presence of a syrinx. Spinal examination includes the assessment of spinal flexibility and tenderness to palpation. The Adams forward bending test is performed by having the patient stand with his or her feet together and knees straight, the patient bends forward with the arms hanging, and an asymmetry in rib or lumbar paraspinal muscle height is sought, representing a rotational deformity of the spine. The skin is examined for signs of systemic disease (Figs. 2A, B). Testing for ligamentous laxity is performed to look for evidence of a connective tissue disorder.

Standing posteroanterior and lateral radiographs of the entire spine are obtained, and scrutinized for evidence of congenital abnormality, and also for the presence of curvatures, which are quantified using the Cobb method. The pelvis is analyzed and the Risser sign determined, as a guide to maturity (Fig. 3). The lateral view is inspected for evidence of spondylolysis or spondylolisthesis, and the sagittal curvature measured also using the Cobb angle. Indications for magnetic resonance imaging (MRI) in scoliosis are based on the presence or absence of certain “red flags.” These include young age (< 10), left-sided thoracic curves, rapid progression of a curve, large curve at presentation without prior history of scoliosis, abnormal neurologic examination, unilateral acquired foot deformity such as a cavus foot, atypical pain, and others. The MRI is of the entire spine and brainstem to identify spinal dysraphism, a tethered spinal cord or lipoma of the cord, syrinx, or Chiari malformation.

Curve progression is related to the size of the curve, the portion of the spine involved, and the physiologic age of the child. Larger curves are more likely to progress than smaller curves, and thoracic and double primary curves progress more than single lumbar or thoracolumbar curves.⁹ Patients with a Risser stage 0 or 1 and curves between 20 and 30 degrees have a risk of progression > 65%, whereas Risser stages 2 to 4 have > 20%.¹⁰ Curve progression and physiologic maturity using the Risser stage dictate nonoperative versus operative treatment.

Treatment options for scoliosis can be divided into 3 options: observation, bracing, and surgery. Skeletally mature patients with curves < 40 to 50 degrees, or

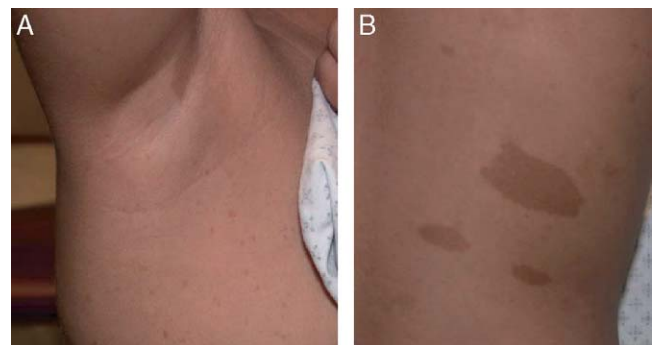


FIGURE 2. A, Axillary freckling associated with neurofibromatosis. B, Café-au-lait spots seen in neurofibromatosis.



FIGURE 3. Risser stage. Before the appearance of a “cap” on the iliac wing, the patient is referred to as Risser Zero. Upon closure of the apophysis, the patient is Risser V. As the apophysis ossifies, it moves from lateral to medial, with progression into each quadrant signifying the next Risser stage. The arrow on the left ilium points to the apophysis, roughly Risser II in this patient. Risser IV signifies the end of spinal growth in girls, with boys often growing through Risser V.

immature patients whose curves are < 25 degrees can usually be observed. Brace treatment is reserved for immature patients whose curve on initial presentation is > 30 degrees, or for patients who progress > 5 degrees during observation to a curve > 25 degrees.¹¹ Immaturity is defined as Risser 0 or 1, or in a girl, having the onset of menses within 6 months. As for all treatments, there is some debate regarding these specific guidelines, and occasionally an older patient or one with a smaller curve will be braced. Bracing attempts to control the curve until skeletal maturity, thus reducing the need for surgery, however, compliance is paramount. Contraindications to bracing are curves exceeding 45 degrees, extreme thoracic hypokyphosis, high thoracic or cervithoracic curves, and a patient who finds the brace emotionally intolerable. It is important to emphasize to patients and their families that despite anecdotal reports of curve correction in a brace, this is unusual and the goal is to prevent progression.

The Boston, Charleston, and Providence braces are the most commonly used orthoses in the adolescent patient. The Boston brace, worn 18 to 20 hours daily is the current standard, although night-only braces such as the Charleston and the Providence brace are also used successfully.^{9,12–16} Andersen et al¹⁷ found that activities of daily living did not differ from healthy controls when they examined the outcome at 10 years in patients with a Cobb angle exceeding 30 degrees treated with Boston bracing. Danielsson et al¹⁸ found that lumbar spinal mobility and muscle endurance were reduced more than 20 years after completing Milwaukee bracing and thereafter a Boston brace, though a correlation could not be found between reduced lumbar spinal mobility and higher pain intensity, larger extension of lumbar back pain, and larger extension of pain all over the body. These studies seem to confirm the notion that the patient undergoing brace treatment for scoliosis can expect to perform activities of daily living without much difficulty, but in the athletic population the loss of mobility may be noticeable. We recommend flexibility training for athletes who wish to

participate in sports during the treatment interval. Even with full time bracing regimens, ample time exists for sports participation during “off hours.”

Indications for surgical treatment of scoliosis include curves > 45 to 50 degrees, or curve progression after maturity (Fig. 4). The goals of these procedures are to arrest curve progression, avoid potential cardiopulmonary compromise associated with large curves, and to provide a balanced spine to theoretically preserve functional spinal motion segments below the fusion. Although improved appearance is also a consideration, it should be stressed that it is not the primary goal. Engsborg et al¹⁹ prospectively examined spinal range of motion in patients undergoing instrumented spinal fusion from either an anterior or posterior approach. Results demonstrated loss of motion for both the fused and unfused segments of the spine in the coronal and sagittal planes, suggesting early postoperative range of motion therapy to facilitate postoperative motion between unfused segments. This may be important in the athletic population after spinal fusion.

SPINAL DEFORMITY: KYPHOSIS

The most common form of a structural thoracic and thoracolumbar kyphosis was first described by Scheurmann in 1920.²⁰ Commonly seen in skeletally immature adolescents, Scheurmann kyphosis is a rigid, sagittal, bony deformity with no clear etiology, though an autosomal dominant inheritance pattern has been suggested.²¹ Additionally, there is a decreased collagen to

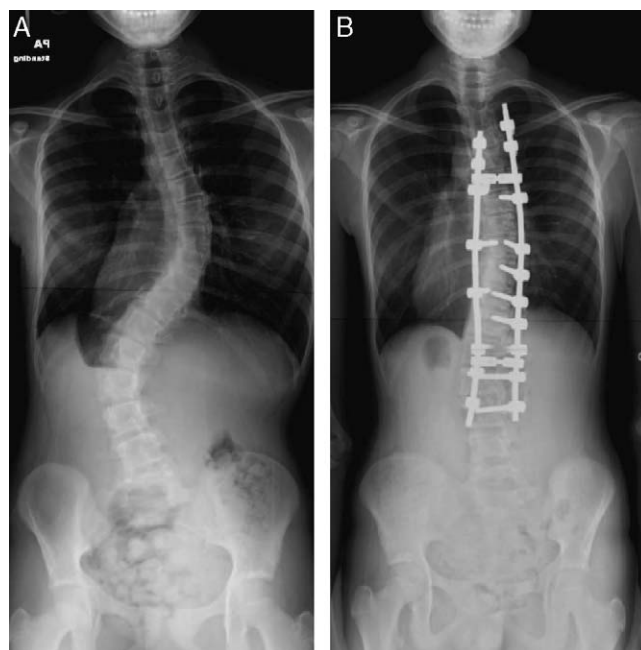


FIGURE 4. A, Preoperative film of a young girl with a double major curvature. B, Postoperative film demonstrating balanced fixation of both curves. This represents standard “hybrid” instrumentation of scoliosis with pedicle screws below the apex of the thoracic curve and hooks above.

proteoglycan ratio seen in patients with Scheurmann kyphosis, which may explain the altered vertical growth of the vertebral body.²² Anterior wedging of > 5 degrees of 3 adjacent vertebral bodies, associated with end plate irregularities, Schmorl nodes, thoracic kyphosis > 45 degrees, and thoracolumbar kyphosis > 30 degrees is diagnostic (Fig. 5). Varying degrees of scoliosis are seen in approximately 33% of patients. The prevalence of Scheurmann's is between 4% and 8%, and considered to be more common in males.²⁰ This must be differentiated from the flexible kyphosis often seen in adolescents, which corrects with hyperextension. This is commonly seen in athletes with significant pectoral development, such as breaststrokers. It is also important to note that Schmorl nodules are often seen in the normal population; an increased incidence in adolescent athletes has been reported.²³

Scheurmann kyphosis is characterized by a round-back deformity, activity-related pain over or distal to the apex of the kyphosis, hyperkyphosis that does not correct with hyperextension, poor posture, and associated hamstring tightness. Neurologic deficits are uncommon, though extradural cysts or acute disc herniations may predispose the patient to neurologic complaints.²⁰ Parental concerns over cosmetic deformity are common, and often the inciting reason for diagnosis. Usually seen in athletes, lumbar Scheurmann's is less common than thoracic kyphosis, and consists of end plate changes, Schmorl nodes, decreased disc height, and mechanical back pain, though no anterior wedging. Mild thoracic and lumbar deformities may have few clinical complaints with pain subsiding at the end of skeletal growth, however, if the curve progresses or includes the lumbar

spine, deformity and disabling pain may prompt further treatment.

Nonoperative treatment for Scheurmann kyphosis has been based on the natural history of the deformity. Pain usually subsides at the completion of growth unless there is severe deformity. Kyphosis < 50 degrees in young adolescents without evidence of progression may be observed. Exercise and stretching of the hamstrings, abdominal, and paraspinal musculature may prevent excessive lordosis and hamstring contractures, and may effectively treat the kyphosis.²⁴ Painful curves between 50 and 70 degrees can be braced, even beyond skeletal maturity. Patients with progressive deformity > 60 to 65 degrees are often braced, even without pain. A Milwaukee brace is required for thoracic curves, whereas a thoracolumbar-sacral orthosis is useful for curves below the eighth vertebrae. Brace compliance in a skeletally immature patient leads to a better prognosis, and can be expected to achieve 50% correction of the deformity in the brace, but a gradual loss of correction later.^{24,20} After being followed for 5 years after bracing, Sachs et al²⁵ observed maintained improvement of 3 degrees or more from initial presentation in 69% of patients using a Milwaukee brace, however, 33% of patients with curves > 74 degrees at presentation failed brace treatment and required surgical correction. It should be noted that belief in bracing for Scheurmann kyphosis is not universal.

Patients with large deformities > 75 degrees, often associated with pain, often undergo surgical correction of their curves. A posterior only approach or a combined anterior-posterior approach may be used to facilitate correction. Combined release of the anterior longitudinal ligament followed by posterior interbody fusion has been classically used in more rigid deformities that fail to correct to < 50 degrees on hyperextension. More recently, posterior only correction with pedicle screws and multiple posterior osteotomies has been used to avoid the morbidity of anterior surgery.²⁶ This may be important in the athletic population (Fig. 6).

SPINAL DEFORMITY AND ATHLETICS

The developing spinal column is influenced by forces from muscular exertion, body motions involving torque, and repetitive loading, and theoretically may result in growth-related deformities like scoliosis and kyphosis.²⁷ Young skeletally immature female gymnasts have greater thoracic kyphosis and lumbar lordosis than nongymnasts, which correlates with increased training time.^{28,29} Similarly, Hellstrom et al³⁰ reviewed 143 radiographs in athletes and found vertebral end plate irregularities in male gymnasts and wrestlers. Conversely, Bulgarian rhythm gymnasts were found to have a 10-fold increase in the rate of scoliosis. Despite the literature demonstrating permanent spinal changes in various sports involving severe torque, such as gymnastics, ballet, swimming, wrestling, and javelin throwing, these activities have not been shown to directly accelerate or worsen

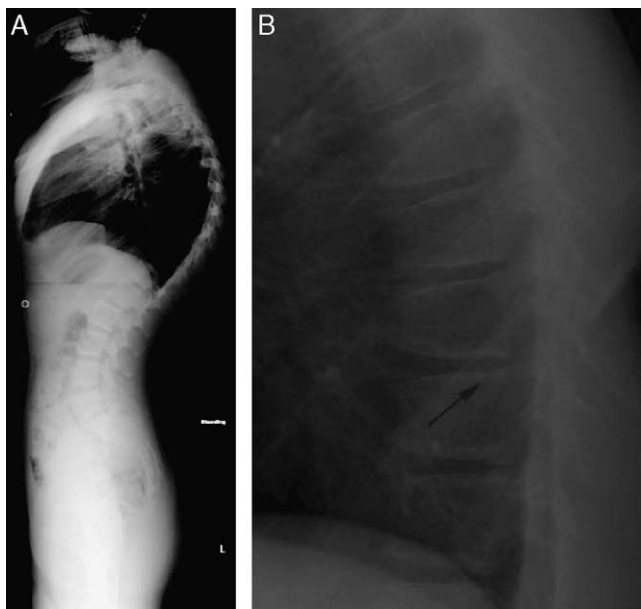


FIGURE 5. A, Lateral radiograph of patient with Scheurmann kyphosis. B, Enlarged view of the kyphotic segment, demonstrating wedging and Schmorl nodules (black arrow).



FIGURE 6. Postoperative lateral of patient in Figure 5. Despite minimal flexibility on preoperative hyperextension radiographs, satisfactory correction was obtained using posterior pedicle screw instrumentation and multiple Smith-Petersen osteotomies.

scoliotic or kyphotic deformities, and thus are permissible for patients with spinal deformity.^{24,27}

Patients with scoliosis or kyphosis treated nonoperatively can participate in all sporting activities. Scoliosis requiring bracing should be reminded that unlike most orthoses used in sport, spine braces have no protective effects on the spine. Patients with scoliosis wear braces when growth remains and the potential for curve progression exist. Wear schedule typically permits at least 4h/d for sports and physical therapy out of the brace, though participation while wearing the brace has been advocated and should not be limited.^{24,31} As skeletal maturity approaches, time spent in the brace can decrease, though regardless of the amount of brace wear, physical therapy and exercise such as swimming has been considered important in successful brace treatment.²⁷ Conditioning, especially in the preseason, should focus on

flexibility of the spine and hamstrings, as well as core strengthening. Power lifting and aggressive plyometric exercise programs should be added to the athlete's regimen only after a proper conditioning program. Patients undergoing treatment for scoliosis may suffer from decreased athletic performance. Masso et al³² retrospectively reviewed 52 patients with juvenile-onset scoliosis and found intermediate physical function and sports participation scores in the braced group; however, these results were better than the surgical group. However, Parsch et al³³ assessed long-term sports activity in 92 patients with idiopathic scoliosis treated operatively and nonoperatively and found decreased sports scores in both groups. Despite these results, many patients with spinal deformity participate actively in athletics, and should be encouraged to do so.

When bracing fails to control curve progression, or spinal deformity is too advanced to be effectively braced, surgery is indicated. Modern rigid instrumentation, may permit earlier return to athletic participation than was the case with Harrington instrumentation.²⁷ Rubery and Bradford³⁴ received 218 surveys from members of the Scoliosis Research Society and found the majority of surgeons return their patients to gym in 6 months, noncontact sports in 6 months to a year, and contact sports at least 1 year postoperatively. Additionally, 35% never allowed patients to return to collision sports, and 20% observed notable adverse outcomes attributable to athletic activity. Parsch et al³³ found Cobb angles, not the number of segments fused, correlated with sports score, and sports activity was not more restricted after fusion compared with bracing. Patients with fusion into lower lumbar levels may be asked to avoid contact sports, or activities involving vigorous twisting.²⁷ In general, participation in athletics after spinal fusion is at the discretion of the treating surgeon. This may be an area of disagreement between the surgeon, team physician, and patient. As in all areas of medicine where there is an absence of data to define what is "safe," the decision is best made by weighing the level of contact against the type of implants used, extent of the fusion, and time since surgery. A patient wishing to participate against the advice of the surgeon should be fully informed as to the potential implications. As more data are obtained from patients treated with modern instrumentation methods, more comprehensive recommendations may be forthcoming.

More recently, interest in spinal growth modulation has raised the possibility of fusionless surgical control of scoliosis.³⁵⁻⁴¹ Theoretically, this would avoid bracing and use the growth of the spine to correct the curve without fusion. Stapling or flexible tethering of the spine on the convexity has the potential to allow growth on the concavity, thus decreasing the deformity. More work remains to be performed in this area before widespread usage.

CONCLUSIONS

Scoliosis and kyphosis should not impair participation in exercise and athletic competition, though

frequency of back pain and functional impairment limit patient activity level. Conditioning should focus on spine and hamstring flexibility and strengthening, and can be performed while wearing a brace. Bracing and physical conditioning have proven to be effective nonoperative treatment regimens, preventing progression of the deformity, and allowing participation while wearing the brace, thus improving overall function and potentially leading to resumption of all pretreatment sporting activities. Soft tissue release and fusion with instrumentation are indicated for patients with progressive deformity, pain, or neurologic compromise. At the discretion of the treating surgeon, patients who undergo surgery may be allowed to return to their sport postoperatively. Athletes should be encouraged to aggressively condition in the preseason to prevent difficulties during their active sports season, and should be prepared to discontinue vigorous or collision type activities if undergoing surgical correction. However, athletic participation in most activities despite surgical intervention is encouraged. New technology holds the promise of increased athletic function in patients treated for spinal deformity.

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