The Application of Osteopathic Treatments to Pediatric Sports Injuries

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KEYWORDS

• Biomechanics • Osteopathic manipulation
• Pediatrics • Sports injury

There is little published evidence to support the use of osteopathic techniques in the treatment of pediatric athletes. Despite this, sports medicine practitioners commonly relate stories where a doctor with training in manual techniques "popped" something and an athlete was "cured." Considered alternative medicine by most allopathic physicians, there are a few instances where manipulation is an accepted treatment; for example, most pediatricians readily accept manipulation of the radial head for the treatment of nursemaids' elbow. Far from being an anecdotal trick, the nursemaids' elbow diagnosis and its treatment by manipulation represent an underlying biomechanical principle, that motion restrictions are often the symptom of a biomechanical deficit. When the deficit is corrected, function is restored. In an age of evidence-based medicine, the lack of solid literature-based evidence gives even the most open-minded pause, especially when application is made to a pediatric population. Those with additional training in manual techniques look for asymmetry and restriction of motion; once identified, a variety of osteopathic techniques can used to address the deficit and affect change.

Practitioners who look at patients through a biomechanical or osteopathic lens may identify motion restrictions that are amenable to osteopathic treatment. Manipulation should not be thought of as a solitary treatment; it is best used to correct motion restriction and then followed by appropriate muscle retraining via physical therapy to facilitate long-term resolution. In those cases where motion asymmetry persists

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or recurs, a structural cause for the repeated dysfunction should be sought. In this article, a general discussion of osteopathic diagnosis and treatment rationale is followed by application to specific conditions associated with sports participation in the pediatric population where manual treatments may be of use.

USE AND COMPLICATIONS WITH MANUAL MEDICINE

A 2008 survey investigated the use of complementary and alternative medicine (CAM) in patients 18 years or younger. The Department of Health and Human Services found that more than 2 million youths (2.8%) had used chiropractic or osteopathic manipulation in the previous year. It was the second most common CAM behind the use of vitamins or other natural remedy. The most common reason cited for seeking care was back or neck pain.[1] Children whose parents used CAM were twice as likely to be treated with CAM. Most who used CAM did so as an adjuvant to conventional medical care.

Manual medicine, spinal manipulation in particular, is not without risk; the risk of adverse events varies by technique and is likely small. Generally, many patients can be expected to experience some discomfort after manipulation. Aggravation of symptoms is usually short lived (1–2 days) and is attributed to changes in soft tissue and ligaments associated with the regions that are mobilized.[2] In a literature review of complications associated with thrust manipulations performed by a therapist or physician and including adult and pediatric patients, catastrophic complications of manipulation were rare and were most commonly vertebral-basilar compromise (cervical manipulation) and cauda equina syndrome (lumbar manipulation).[3] The investigators associated rotatory manipulation of the cervical spine with vascular compromise. Similar results are reported in osteopathic literature, showing that most complications appear as anecdotal case reports, making efforts to attribute risk or prevalence problematic.[4]

In an effort to assess risk of manipulation in pediatric patients, Hayes and Bezilla[5] performed a retrospective chart review of 502 pediatric patients treated with osteopathic interventions (all treatments, including thrust techniques). The investigators defined aggravations as patient complaints or worsening of symptoms after manipulation. Complications were defined as cerebrovascular accident, dislocation, fracture, pneumothorax, sprains and strains, or death as an outcome of treatment. In their review, there were no manipulation-related complications; aggravations occurred and were documented in approximately 12% of manipulations. The average duration of aggravation symptoms was less than 48 hours (evidence level B).[5] In summary, most pediatric patients seem to have mild, short-lived, aggravation-type symptoms after osteopathic treatments. Complications, which seem rare, are likely underrepresented in the literature and usually associated with thrust-type manipulations.

METHODS AND BARRIERS TO SOUND RESEARCH

A paucity of literature regarding manual treatments in pediatric patients exists. Pubmed searches were performed using key words mobilization, manipulation, osteopathic, chiropractic, pediatric, child, and adolescent as well as the specific condition to be examined. The vast majority of articles identified were of an anecdotal nature.

There are many barriers to conducting high-quality osteopathic research. Chief among these is poor research question design. Most reasonable efforts have centered on applying manual techniques to nonspecific symptoms. Research questions, such as, "How effective is spinal manipulation for low back pain (a symptom)?" are unlikely to provide useful information. Such questions are based on a poor assumption, that specific treatments can be applied to general symptoms. The allopathic equivalent is to test the effectiveness of penicillin for sore throat. Penicillin is ineffective for sore throat and highly effective for streptococcal pharyngitis. A specific diagnosis should be paired with a specific treatment with a specific outcome to be measured.

The best research regarding the efficacy of manual treatments would be study of the use of a specific technique for a specific structural diagnosis. Such research is lacking for several reasons. First, there is no standardized allopathic nomenclature for the identification and description of biomechanical symptoms. Although osteopaths may identify a specific issue, for example, 3rd lumbar extended, rotated, and side-bent to the left (L_3 ERS_L), allopathic physicians are not generally trained to evaluate or recognize such segmental motion restrictions. Most osteopathic diagnoses are based on motion restriction, a dynamic problem. Even if a palpation-based structural diagnosis is made, there remains no gold standard (such as dynamic radiology) that can confirm the diagnosis or evaluate treatment success. With the exception of fluoroscopy, radiographic studies do not permit dynamic evaluations. Fluoroscopy is not routinely used in biomechanical analysis because of high radiation exposure. A third barrier is the persistence of methodologic issues that have not yet been overcome. There is no adequate sham manipulation or adequate blinding of patients or doctors to the procedures, which is necessary to avoid bias and improve the strength of a systematic study of specific manipulation techniques. Finally, there are no long-term follow-up studies to address whether or not the manipulation induced permanent change. Each is a significant barrier to performing a specific, highly powered, scientific inquiry into the usefulness of manual treatments.

BARRIER CONCEPTS IN THE EVALUATION OF PEDIATRIC PATIENTS

The rationale for using biomechanical approaches to a specific injury is to restore motion. Conceptually, each joint or body region has a range of motion through which it can pass. There are physiologic and anatomic barriers (**Fig. 1**). As motion in either direction from midline proceeds, ligamentous tension develops. In the case of injury or dysfunction, a restrictive barrier may alter active and passive range of motion. These restrictive barriers are referred to as somatic dysfunctions.

Most techniques used in biomechanical treatments begin with a positional diagnosis. The biomechanical evaluation uses primarily palpatory skills to identify areas of tenderness, tissue texture changes, asymmetry, and restriction of range of motion. Motion at the joint or the body part is assessed in the sagittal plane for flexion and extension, the coronal plane for lateral flexion (side bending), and the transverse plane for rotation. The primary objective of this evaluation is to identify regions that have a specific barrier to motion. For example, evaluating the motion at the 3rd lumbar vertebra in neutral, flexion, and extension, a specific motion restriction can be identified for that particular structure (if dysfunction is present). If the evaluator finds the 3rd lumbar transverse process deeper on the right and more easily rotated on the left, the segment can further be tested in flexion and extension and a positional diagnosis (eg, L_3 ERS_L) can be established.

Once identified, a particular osteopathic technique is chosen with the goal of removing the obstruction and restoring normal motion and function. With normal motion restored, patients are frequently referred to physical therapy for neuromuscular retraining, strengthening, and conditioning to maintain and reinforce restored positioning. It is never assumed that a biomechanical restriction happens in isolation; because of the close anatomic relationships, associated muscle and ligamentous injury requires time to heal regardless of the use of manual treatments.

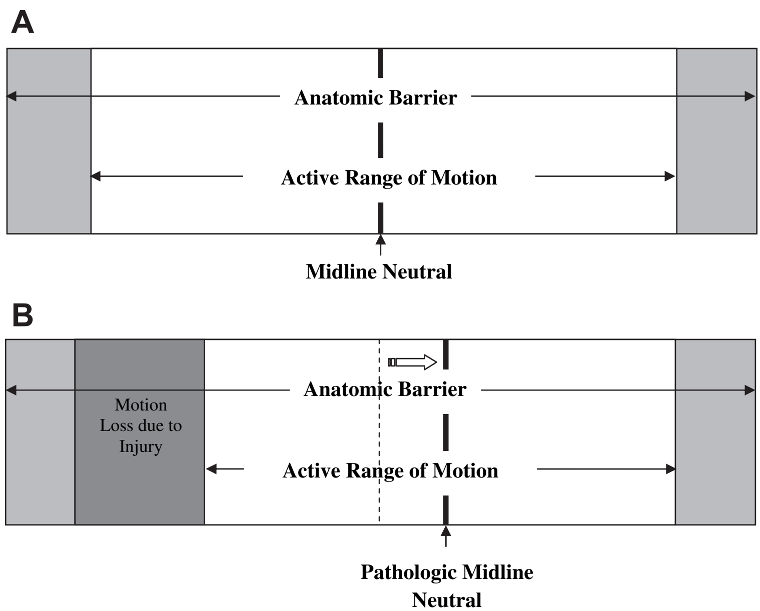

Fig. 1. Motion barrier concepts. (*A*) Normal motion. Active (physiologic) range of motion is symmetric. (*B*) Simplified loss of motion: with injury, motion is lost on 1 side, resulting in somatic dysfunction. Asymmetry results in a new midline formation. Over time, tissue contractures develop in response to motion loss and patients may compensate for lost motion at 1 site with altered motion at a second site. (*Data from* Greenman P. Principles of manual medicine. 2nd edition. Baltimore [MD]: Williams and Wilkins; 1996.)

PEDIATRIC CONSIDERATIONS AND SPECIFIC OSTEOPATHIC TECHNIQUES

Although osteopathic techniques can be applied to infants and young children,[2] this discussion is limited to the application to pediatric patients between the ages of 6 and 18. With any use of manual medicine in the pediatric population, there are key differences between pediatric and adult patients. Joint mechanics are influenced by the maturation of the ossification centers. Pediatric patients with open growth plates are vulnerable to injury; techniques used must be gentle and carefully applied. In contrast to adults, who have well-established movement patterns, children are often in the process of developing such patterns. This is relevant for post-treatment decision making. Children often use new motion patterns readily after restoration of function[2]; adults learn to compensate and must unlearn motion habits. Although complete descriptions of all manual techniques and their theoretic basis is beyond the scope of this discussion, interested readers may find more complete discussions in many sources.[2,6] Several more commonly used techniques are discussed later and listed in **Table 1**.

High- and Low-Velocity, Low-Amplitude Techniques

High-velocity, low-amplitude techniques (HVLA) and low-velocity, low-amplitude techniques (LVLA) are performed to directly engage a restrictive barrier. Using the previously described example of a spinal dysfunction (L_3 ERS_L), the barrier is to motion in flexion, right rotation, and right side bending. Using this technique, patients are

Table 1
Descriptions of common osteopathic manual techniques applied to pediatric sports injuries

HVLA	Direct engagement of a motion barrier using an impulse or thrust
Muscle energy	Uses patient's muscular contraction to precisely direct away from a restrictive barrier against resistance. During relaxation phase, the motion barrier is directly engaged
Counter-strain	Passively placing a patient in a position directly opposite the barrier to indirectly treat motion deficit; typically associated with positioning to achieve maximal relief of a specific painful point
Myofascial release	Indirect technique, which uses lateral stretching, linear stretching, deep pressure, traction, and muscle stretch or compression. Aims to restore motion via tissue relaxation
Lymphatic pump	Gentle rhythmic techniques designed to improve function via improved fluid drainage from the injured area

positioned to engage the barrier at the specific vertebral level, eliminating as much motion of the segments above and below the treatment area as possible. At the barrier, the treatment consists of a quick thrust (HVLA) or a slow deliberate movement through the barrier (LVLA). A release may or may not be felt and is not essential for success of the treatment. As with any treatment, patients should be re-evaluated for improved range of motion after the procedure.

Muscle Energy

A second frequently used technique that directly engages the restriction is muscle energy. In this technique, patients are placed in a specific and controlled position and asked to contract specific muscle groups to generate motion in a particular direction against a precise counterforce.[2] Using the same positional diagnosis (as described previously), L_3 ERS_L, in this approach patients are positioned seated, lumbar spine flexed to the L_3 level, then rotated and side-bent to the right (**Fig. 2**). The treatment is performed using a patient's muscle energy (approximately 5 pounds of force) to sit upright (extension, side bending, and rotation to left) from that position while an examiner resists. This force is held for 5 seconds, then the patient briefly relaxes; during the relaxation, the slack is taken up and a new barrier in FLEXION, right rotation, and right side bending is engaged. This process is typically performed 3 times. This is a technique commonly used by physical therapists in treating motion restriction. Muscle energy poses less risk of injury to patients because they are in control of the treatment. The ability to use this treatment in the pediatric population, however, is dependent on children's ability to follow directions and to precisely control their body movements.

Strain-Counterstrain Techniques

Strain-counterstrain is a gentle indirect treatment of positional diagnosis. The basic underlying principle is that specific tender points on the body, anterior and posterior, are present and associated with specific positional diagnoses throughout the spine.[7] The concept of this treatment is that dysfunctional positioning of a body segment places ligaments and other soft tissues under strain when the body attempts to remain in neutral posture against gravity, producing discomfort in specific palpable locations. In positioning the dysfunctional segment in a position of ease, a counterstrain is applied to the area to be treated. The essence of this technique is to identify a tender point; in

Fig. 2. Muscle energy positioning for patient with 3rd lumbar (L3) vertebrae dysfunction. The patient is positioned at the barrier to motion: flexed until motion is engaged at L3, then rotated and side-bent to the right. The technique is described in the text. Note the evaluator maintains contact with the transverse processes at L3 during the treatment. (*Courtesy of* Quinton Nottingham, PhD.)

the example described previously, the tender point would likely be identified near the transverse process of L_3. The body would be passively wrapped around this tender point until pain was subjective reduced approximately 70%. For this example (L_3 ERS_L), the patient is typically prone and the physician passively wraps around the point in extension, left rotation, and left side bending by controlling the legs. Once the position of relief is achieved, the patient is held in this position for 90 seconds. After the treatment, it is important that the patient be returned to the neutral position without activating muscles.[7] In the neutral position, the tender point and the area of dysfunction should be re-evaluated. This gentle technique can safely be used in children because it does not expose them to any external force other than positioning. Patients must be able to remain still and relaxed for the treatment period.

Myofascial Approaches

Areas of dysfunction may be identified by soft tissue palpation. These myofascial trigger points are discreet, tender, and asymmetric; have altered range of motion; and demonstrate tissue texture changes.[8] These trigger points can be treated with a variety of approaches, including ischemic inhibition, cooling spray with stretch, deep massage, injection, and myofascial release. The trigger points are thought to be related not only to positional dysfunctions but also reflective of muscle and fascial contracture as well as effects on the integrated autonomic nervous system.[9] Manual treatments of the trigger points include compression directly on the trigger point until it relaxes. This treatment is based on the concept of inducing focused regional ischemia in the tissue over the trigger point. The muscle can also be hypercontracted, that is, placed passively in a shortened position, and then manually compressed further.[8] It is thought that this treatment alters neuromuscular patterns within the muscle. A third approach is to unwind myofascial tissues at areas of constriction. This technique is based on the concept that the fascia is a continuous ligamentous stocking that can be twisted or bunched in areas of dysfunction and that unwinding loosens the tissues to allow freer motion.[6]

These 4 approaches are a sample and do not encompass several other techniques that are commonly used for manipulation. Many nonthrust techniques are used in conjunction with regular rehabilitation programs by physical therapists. Although high-velocity techniques are commonly associated with osteopathic or chiropractic adjustments, there are other approaches that can also be safely and easily applied to a variety of patient complaints.

SPECIFIC CONDITIONS

Cervical Spine

Application of manual treatments to cervical spine complaints is common. The most common complaints are headache, neck pain, and torticollis. A complete evaluation should be performed to eliminate underlying orthopedic or medical causes that constitute an absolute or relative contraindication to manual methods. In evaluating patients with headache, neck pain, or stiffness, the biomechanical principle that should be kept in mind is that patients generally position their head to keep their eyes directly in front and parallel to the ground. Historical features and structural evaluation looking for asymmetry of motion, asymmetry of deep musculature tension, and other tissue texture changes should be sought.

A practical approach to gross motion assessment is to measure cervical rotation from the manubrium to the chin on rotation to left and right. Side bending is assessed via measurement of pinna to acromion on lateral flexion. Restriction in motion may also be detected by having patients rotate left and right and returning to midline with eyes closed (while an examiner monitors the midline). This simple test may reveal patients whose sense of midline is altered to the left or right with eyes closed.[10] Compensatory increase in tone of cervical musculature may be associated with patients being off-center.

In addition to gross motion testing, segmental testing at each vertebral level can be performed.[11] It is helpful to understand the mechanics of each vertebral level, which are now well established.[12] The occipitoatlantal joint primarily flexes and extends. Side bending and rotation is coupled and always occurs in opposite directions. The atlantoaxial joint primarily rotates. Typical cervical vertebrae C3-C7 all have coupled motion with rotation and side bending to the same side. The ability to identify the precise location and direction of a segmental motion restriction is fundamental to using osteopathic technique. If there is good correlation with a patient's symptoms, signs, and physical findings, then there is a strong likelihood that improved segment mobility will decrease or even eliminate the patient's symptoms.[11] Specific instruction regarding evaluation procedures and diagnostic interpretation for the cervical spine can be found in several sources.[2,6,10,12]

Motional abnormalities of the upper 3 cervical vertebrae are significant contributors to headache, neck pain, and torticollis. Muscle energy techniques are particularly useful in this region because they avoid positioning patients in extremes of hyperextension and rotation.[11] This position places the vertebral artery and to a lesser extent the internal carotid artery in a position where injury during HVLA could occur.[13] Injury rates with cervical manipulation in children are not known; risk of catastrophic injury is estimated at between 1 in 400,000 to 1 in 2,000,000 for cervical manipulations in all patient age groups.[14,15] The use of manipulation for cervicogenic headache is associated with improvement in symptoms when motion deficits are corrected.[16] Recent systematic reviews for neck pain with or without headache suggests that manual treatments are associated with improvement in symptoms when combined with exercise programs (evidence level B).[15,17] In the treatment of children with neck pain and muscle spasm with or without headache, manipulation may be of use if a specific motion restriction is identified that correlates with symptoms.

Chest Wall Syndromes

Thoracic outlet syndrome

Thoracic outlet syndrome (TOS) is characterized by symptoms of positional parasthesia, weakness, or heaviness of the upper extremity that is associated with cervical hyperextension injury. Ninety-five percent of cases are thought to be neurogenic TOS, with compression of the brachial plexus occurring at the thoracic outlet.[17] The biomechanical basis for the condition is the compression of neurovascular structures, which supply the upper extremity by the narrowing of the thoracic outlet between the clavicle, the middle and anterior scalene muscles, the scapula, and the first rib. The condition is also associated with anomalous first ribs[18] and is common in swimmers and overhead athletes. Historical and diagnostic aspects are extensively reviewed elsewhere.[17] Traditional clinical tests, including Adson and Roo tests, lack specificity for the diagnosis.[19] Although there is no published support, osteopathic positional diagnosis of the first thoracic vertebrae and rib can be helpful when correlated with patient symptoms; the first rib is typically elevated on the affected side.

Nonoperative treatment of neurogenic TOS includes 2 months of conservative treatment with physical therapy using gentle rehabilitative exercises, nonsteroidal anti-inflammatory medications (NSAIDs), trigger point injections, manual therapy, and stretching of the neck and shoulder muscles. In the vascular surgery literature, young adolescent athletes often do not respond well to conservative therapy.[19] Surgical decompression via resection of the first rib with scalenectomy was reported in a series of 18 young (ages 13–19) patients with neurogenic TOS. All patients returned to school and competitive athletics.[20]

The osteopathic approach to patients with neurogenic TOS includes myofasical, muscle energy, and high-velocity techniques (**Fig. 3**). The indication for the use of manual techniques includes reproduction of patient symptoms and the establishment of motion restriction and positional diagnosis for the first rib or first thoracic vertebrae. The treatments usually require no more than a few minutes; patients experience rapid relief of heaviness and positional parasthesia but often experience postmanipulation soreness beginning approximately 10 minutes after the procedure, which is attributed to ligamentous stretch. After manipulation, patients are given brief courses of NSAIDs and referred for postural exercises and neuromuscular retraining at physical therapy. There are no systematic studies of the effectiveness of manual medicine for neurogenic TOS; anecdotal reports describe the successful use of manual therapies in a young athlete[18] and adult patients.[21]

The osteopathic approach (discussed previously) is presented with nothing but scant anecdotal evidence. The paucity of data for manual treatments of neurogenic TOS is in stark contrast to the well-documented evidence presented in the vascular surgery literature. Both focus attention on the thoracic outlet and both agree that the first rib and surrounding tissues can be the source of compression. Resection of the first rib is effective, if highly invasive, in curing the symptoms in young athletes.

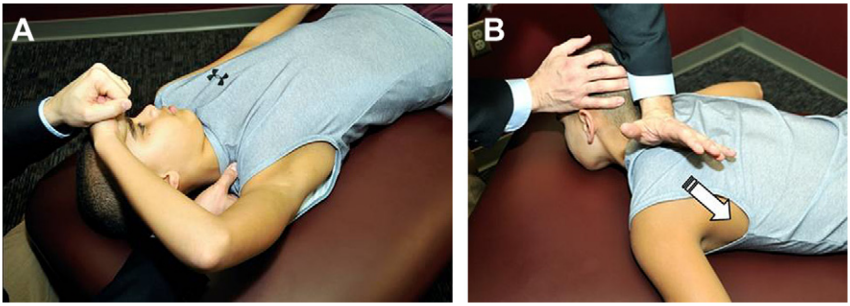

Fig. 3. Treatment of elevated first rib in pediatric patients. (*A*) Muscle energy. The patient is positioned with head rotated and side-bent away from the motion restriction. The physician's hand monitors motion at the posterior aspect of the first rib. The patient gently raises his head and fist against examiner's resistance. On relaxing, the rib is mobilized to engage the new barrier. (*B*) Impulse mobilization (HVLA). The hypothenar eminence is placed on the posterior aspect of the first rib. The patient's head is distracted with the opposite hand (no thrust is applied to the patient's head); at the barrier, a thrust downward and toward the ipsilateral breast is applied. (*Courtesy of* Quinton Nottingham, PhD.)

With advanced diagnostic imaging available, the observation that "many (neurogenic) TOS patients respond favorably to surgery, even in the absence of preoperative objective abnormalities" (quote in[17]) suggests a dynamic deficit may be underlying this condition. To add to anecdotal reports, no patient from the author's clinic has been referred for surgical rib resection with this condition since his initiation of using osteopathic treatment for clinically diagnosed TOS.22. The reconciliation of this observation with published literature awaits further high-quality investigation into the biomechanics of TOS and the effectiveness, if any, of osteopathic techniques.

Chest wall pain

Chest pain in the pediatric athletic population may arise from the ribs, costovertebral articulations, costal cartilage, and supporting structures. Appropriate evaluation and work-up is paramount in establishing musculoskeletal causes of chest pain and excluding other causes. Dysfunctions at lower ribs and thoracic vertebrae (T3-T8) typically cause vague pain between the shoulder blades often radiating around the chest wall to under the armpit or lateral and inferior to the breast. Swimmers and rowers are commonly affected.[22] These dysfunctions may arise from overuse but are not usually associated with specific injury. Examination signs include chest wall pain that is typically reproduced by palpation along involved ribs, at the rib posteriorly, and may also be present anteriorly at the costochondral junction. Palpation of the ribs during inhalation and exhalation may reveal diminished excursion of the ribs. Motion restriction on passive trunk rotation may be observed (**Fig. 4**). Successful resolution of motion restrictions and symptoms after treatment by impulse mobilization[23] or muscle energy techniques[22] has been reported.

Lower ribs may also cause symptoms: the slipping rib syndrome describes vague complaints of abdominal, flank, or low back pain with or without trauma. The symptoms are attributed to slipping of a hypermobile cartilaginous rib under adjacent ribs during muscle activity.[24] The diagnosis is aided with the hooking maneuver, in which the symptomatic floating rib is pulled under the rib above, producing a click and reproducing the pain.[25] Diagnosis is confirmed with an appropriate nerve block. The surgical literature describes several cases in which complete symptom resolution

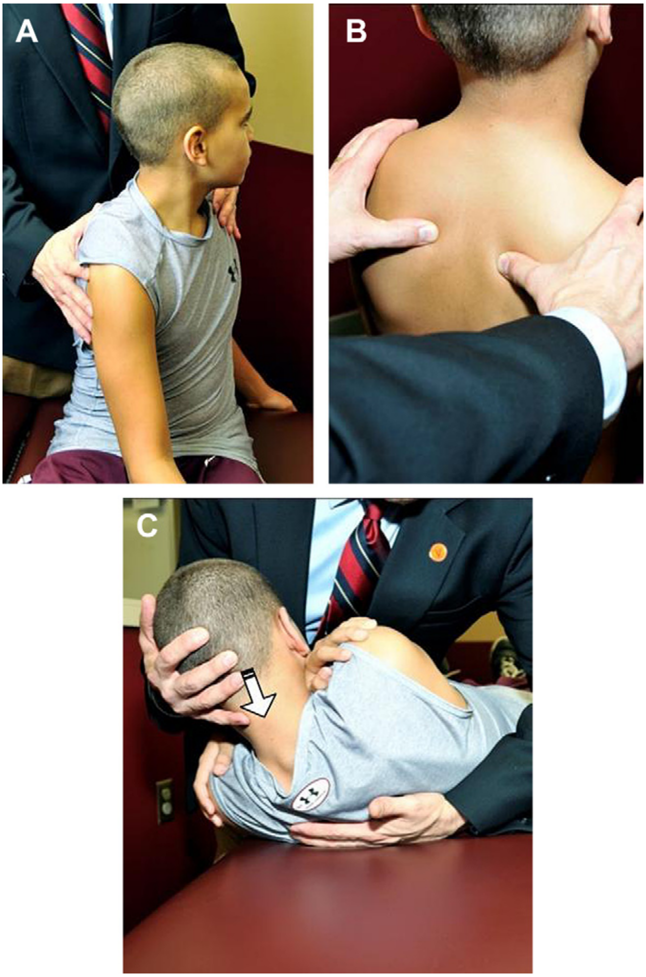

Fig. 4. Osteopathic assessment and treatment of rib and thoracic vertebrae structural issues. (*A*) Loss of passive trunk rotation—most athletic patients can rotate 90° to either side. (*B*) Palpation for relative depth and rotation of rib tubercles and transverse processes and any tissue texture change can point to areas of motion restriction. (*C*) Thrust method for the ribs and thoracic spine manipulation. After a positional diagnosis is confirmed (illustrated: T7 extended, rotated, and side-bent to right), the patient is placed with his arms folded in front. The physician monitors the level of flexion with the posterior hand until motion is engaged at the level to be treated. The patient is instructed to take a deep breath and let it out, not holding his breath, and as exhalation occurs, a quick and gentle impulse is delivered from anterior through to the posterior hand. Motion and symptoms are always reevaluated. This method can be adapted to address lower floating rib dysfunctions. (*Courtesy of* Quinton Nottingham, PhD.)

occurred after resection of the rib tip.[26,27] Findings at surgery reveal torn ligamentous support for the ribs. In the subacute setting, it is possible to gently reposition the floating ribs using HVLA or LVLA maneuvers (see **Fig. 4**). There are anecdotal reports of symptom resolution with return to symptom-free participation even with prolonged symptoms after such treatments.[28]

SCOLIOSIS

Idiopathic scoliosis is a rotational malalignment of the vertebrae that produces a partly fixed lateral curvature of the spine.[2] Usually thoracic spine and rib cage are involved and a compensatory curve is found in the lumbar spine. Girls between the ages of 10 and 16 years are nearly 4 times more likely to develop the condition.[2] The biomechanics of scoliosis and distant claims of cures with manipulation[29] have led to efforts to define the role of manual medicine and its effectiveness. Although the cause of scoliosis is unknown, the biomechanics involved arise from the aforementioned principle that most patients compensate to achieve a position where the eyes are parallel to the horizon and face forward. Certain repetitive activities that involve asymmetric movements may predispose to soft tissue contraction; scoliosis is commonly seen in adolescent softball pitchers who bend toward their pitching arm in an effort to achieve a vertical release. Chronic backpack carrying also has altered spinal curvature over time.[30]

Long-term presence of a curvature in the spine results in fascial and muscular contractures on the concave side of the curve, which resist straightening and promote curve progression. Likewise, the muscles and fascia on the convex side of the curve are overstretched. Starling's law predicts these muscles generate different forces by virtue of their different lengths. Consequently, any attempt to alter the curve via a manipulation intuitively suggests the need for muscle retraining and tissue reorganization to achieve any long-term impact toward straightening the curve. The combination of manipulation with physical therapy has been effective in producing Cobb angle reductions of 16° to 17° with short-term[31] and longer-term[32] treatment. Exercise alone is beneficial in reducing curve progression (evidence level A).[33] This soft tissue and manipulative approach is reported in the literature with anecdotal, although well-documented, improvements in symptoms and spinal curvature for the past 20 years.[34] The addition of manipulation to physical or exercise therapy and other standard treatments may be beneficial in reducing curve progression and perhaps assisting with curvature regression (evidence level B).

LOW BACK PAIN

The sacroiliac (SI) joint and pelvis can be pain generators from the joint proper or its ligamentous attachments. Athletes involved in sports that necessitate unilateral loading of the SI joint, such as kicking or throwing, are at higher risk for SI injury and pain.[35] There are several historical features and physical examination maneuvers that are used by osteopathic practitioners to diagnose a 3-D position of the SI joint. A complete description of these is available from many sources.[2,6,10] Most patients complain of low back pain at the waistline. Historical features suggesting SI involvement include the description of pain at the sacral sulcus and radiation of the pain to the buttocks or down the posterior thigh to the level of the knee. The examination maneuvers commonly used include the standing and seated forward flexion test, palpation of the sacral sulcus and inferolateral sacral angles (ILAs), and the spring test (**Fig. 5**). In addition, the relative positions of the anterior-superior iliac spine (ASIS) and posterior-superior iliac spine (PSIS) and the relative distance of each ASIS from the umbilicus are used to determine the position of the innominate bones (ilium) in anterior or posterior rotation, inflare and outflare, or upslip or downslip.[2] These palpatory measurements are often combined with functional leg length assessment to complete the positional diagnosis. **Tables 2** and **3** summarize how dynamic and static testing is interpreted to make a positional diagnosis.

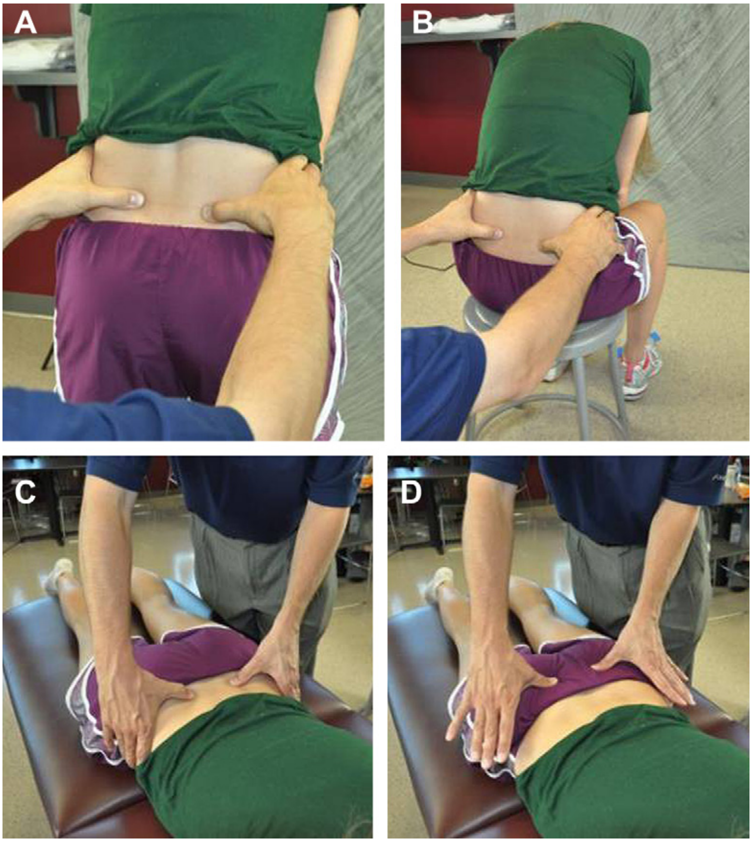

Fig. 5. Dynamic and static testing for sacral dysfunctions. (*A*) The standing forward flexion test. Examiner starts with hands on iliac crests; thumbs naturally fall at the PSIS. With thumbs resting just inferior and medial to the PSIS, have patient bend toward floor. A positive test is indicated by the thumb that moves cephalad earliest. (*B*) The seated flexion test. (*C*) Palpation of the sacral sulcus. With patient prone, the most anterior (deepest) sacral sulcus is noted. (*D*) Palpation of ILA. By palpation, determine which side of the ILA is more posterior. The spring test (not shown) is performed on the prone patient by compression of the L5-S1 junction to see if there is posterior to anterior spring. **Table 2** shows how the tests are interpreted. (*Courtesy of* Virginia College of Osteopathic Medicine.)

A brief description of the osteopathic understanding of sacral mechanics is relevant. The sacrum commonly rotates about an oblique axis left or right; less commonly, the sacrum rotates about a vertical axis left or right. Rarely, the sacrum rotates about a horizontal axis.[36] As summarized in **Table 2**, if the right sacral sulcus was thought more anterior and the left ILA more posterior, the diagnosis is a left rotation of the sacrum. The axis of rotation is determined in part by the forward flexion test results.[2]

Although this description of palpation-based diagnosis of sacral mechanics is commonly taught in osteopathic schools, there remains a discrepancy between the confidence in clinical interpretation of these tests and the literature evidence of their reliability. The palpatory skill of examiners limits interexaminer reliability of commonly used tests.[37] A study of an expert panel's "best" historical or examination techniques for the SI joint failed to identify a single "best" test or historical symptom for diagnosis

Table 2
Summary of the physical examination findings for the SI joint

FF Test Standing	FF Test Seated	Anterior Sacral Sulcus	Posterior ILA	Spring Test	Diagnosis
+L	+L	Left	Right	(–)	Right rotation on a right oblique axis
+L	+L	Right	Left	(+)	Left rotation on a right oblique axis
+L	+L	Left	Left	(–)	Left unilateral sacral flexion
+L	+L	Right	Right	(+)	Left unilateral sacral extension

The tests are as described in the text. Diagnosis is based on combined interpretation of dynamic and static testing.

Abbreviations: FF, forward flexion L, left; spring test, if posterior to anterior compression of the lumbo-sacral junction on the prone positioned patient produces no "spring" or flexible motion, the test is (+) positive by convention; (+), positive. If flexible motion is felt, the test is (–) negative.

of SI dysfunction.[38] The argument has been raised that pain is not a prerequisite for SI joint dysfunction and it is the summation of dynamic and static tests can be used to identify sacral dysfunctions in patients.[36] The dynamic and static sacral screening tests (outlined in **Tables 2** and **3**) continue to be used in the diagnosis of pediatric patients while awaiting more definitive evidence for diagnosis and treatment.

Common manual methods for addressing SI dysfunction include HVLA and muscle energy techniques. The muscle energy technique is illustrated in **Fig. 6**. A Pubmed review of this technique revealed no reports of complications; patients typically complain of soreness for 1 to 2 days after the treatment. Contraindications to the muscle energy technique include patients with suspected fracture, discitis, or herniation and inability to tolerate the treatment. Patients are typically placed on the side of the axis of dysfunction; for example, in **Fig. 6**, the treatment is of a left sacral rotation about a right oblique axis; the patient lies on his right side. The sacral sulcus is monitored by a physician, and the patient is directed to roll his torso in the direction of the sacral rotation; in **Fig. 6**, the patient has rolled his torso face-up or to his left. The muscle energy is provided by the patient gently raising his ankles toward the ceiling while the physician resists. The process is typically performed 3 times. The author has found this method helpful for addressing the abnormal findings on dynamic testing

Table 3
Osteopathic physical examination findings associated with specific pelvic (innominant) diagnosis

FF Test Standing	FF Test Seated	ASIS	PSIS	Leg Length	Diagnosis
+L	—	Left ↑	Left ↓	L < R	Left posterior innominant rotation
+L	—	Left ↑	Left ↑	L < R	Left upslipped innominant
+L	—	Left ↓	Left ↓	L > R	Left downslipped innominant
+L	—	Left ↓	Left ↑	L > R	Left anterior innominant rotation

The side of the positive forward flexion test denotes the side of dysfunction. The leg length discrepancy is a function of the position of the acetabulum relative to the innominant.

Abbreviations: FF, forward flexion; L, left; R, right; up arrow, cephalad or superior relative to the contralateral side; down arrow, caudad or inferior relative to the contralateral side.

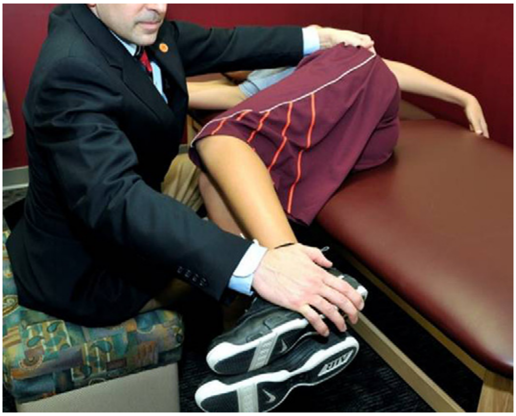

Fig. 6. Muscle energy technique for left rotation on a right oblique axis sacral torsion. Patient is positioned with knees and hips flexed until motion is felt at the sacral sulcus (physician's left hand). The patient is instructed to roll face up but leave his hips and pelvis in place. The treatment is performed by having the patient gently push his ankles toward the ceiling against isometric resistance. After 5 seconds, the patient relaxes briefly and the process is repeated after the physician repositions the legs to engage the new barrier. (*Courtesy of* Quinton Nottingham, PhD.)

(such as those listed in **Table 2**) and normalizing functional leg length discrepancy. These maneuvers are routinely followed by a course of physical therapy for gait and neuromuscular retraining. If manual treatments are used in conjunction with muscle retraining programs and a patient continues to demonstrate abnormal dynamic testing, the patient should be thoroughly re-examined for contributing orthopedic conditions. Anecdotally, the author has identified nearly 40 pediatric and adult patients who demonstrated symptoms of hip impingement and positive findings for SI joint dysfunction. Despite initial relief with manipulations and physical therapy, these patients demonstrated recurrent positive sacral screening tests as well as femoral acetabular impingement signs and ultimately were found to have underlying hip labral pathology with magnetic resonance arthrography. After arthroscopic repair and rehabilitation, the pediatric patients no longer demonstrated positive SI screening tests. This observation is intriguing and awaits further study for corroboration and clarification.

UPPER EXTREMITY

Nursemaids' elbow is probably the best-known diagnosis for which manual treatment is thought curative. The mechanism is a pull usually from above a young child's arm, which subluxes the radial head through the annular ligament. The child usually experiences pain and a loss of function of the arm. Hyperpronation with mild dorsal pressure on the radial head is considered the superior method for reduction (evidence level B).[39]

Older pediatric athletes are more likely to develop radial head symptoms in association with lateral epicondylitis. Tennis players and those athletes who perform repetitive wrist extension are at higher risk. Technical faults contribute to the development of symptoms.[40] Evaluation reveals pain with resisted extension of the wrist and at the origin of the wrist extensors. Motion testing should include pronation and supination with the elbow flexed to 90°. Motion may be limited compared with the contralateral forearm; loss of forearm motion can be associated with radial head dysfunction.[10] Treatment to correct the motion deficit can be accomplished with HVLA or muscle energy methods (illustrated in **Fig. 7**). Manipulation combined with exercise program was superior to steroid injection and exercise program for long-term resolution (after 6 weeks and at 52 weeks) and was associated with a significantly lower regression rate (evidence level A). In a study of patients 18 years of age and older[41] treatment of lateral epicondylitis with manipulation combined with an exercise program was superior to treatment with steroid injection and exercise not only in providing long-term relief (at 6 and at 52 weeks) and but also in preventing recurrence (evidence level A). The study suggests that correction of motion deficits may augment traditional treatment of lateral epicondylitis.

LOWER EXTREMITY

The rationale for manual medicine in lower-extremity injuries may be best understood when looking at the alteration of normal biomechanics that occurs with the inversion ankle sprain. In the subacute evaluation of athletes with an ankle sprain, a subtle loss of range of motion, commonly dorsiflexion, may be observed. Ankle motion loss may arise from fibular or talar malposition.

The loss of motion can be explained by the effect of the inversion mechanism on ankle mechanics. The talus and fibula are the primary contributors due to their coupled motion via the anterior talofibular ligament. The natural motion of the fibular head is to pivot in an anterolateral/posteromedial fashion with ankle motion.[42] At the lateral malleolus, there is slight cephalad motion with dorsiflexion and caudad motion with plantarflexion during gait.[43] Although small in magnitude (approximately 1.5 mm) relative to the motion of the talus, fibular motion has been confirmed radiographically.[44] Talar motion in dorsiflexion involves rotation and slight translation posteriorly into the mortise for maximal stability; in plantar flexion, the talus rotates and translates anteriorly, bringing the narrower posterior talus into the mortise.[45,46] With the inversion mechanism and weight bearing, the talus is plantar flexed and supinated and the force allows for medial rotation and anterior translation, pulling the anterior talofibibular ligament (ATF) anteriorly, and leading to ligamentous sprain. The force of the injury is transmitted to the fibula via the ATF and pulls it into an anterior position. This combination places the talus/fibula in a position that limits the ability to dorsiflex.

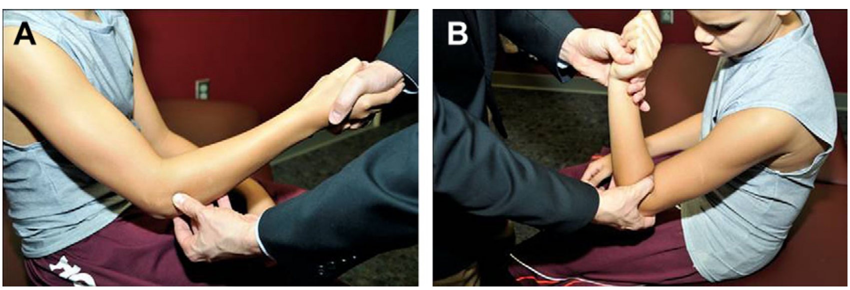

Fig. 7. Motion testing and radial head dysfunction. (*A*) With the elbow flexed to 90°, pronation and supination are tested and compared with the opposite side while monitoring the radial head. (*B*) HVLA maneuver for a subluxed radial head. The forearm is placed in pronation. With the thumb on the dorsal aspect of the radial head, the elbow is flexed to the barrier. At the barrier, a quick short thrust is performed to reposition the radial head. (*Courtesy of* Quinton Nottingham, PhD.)

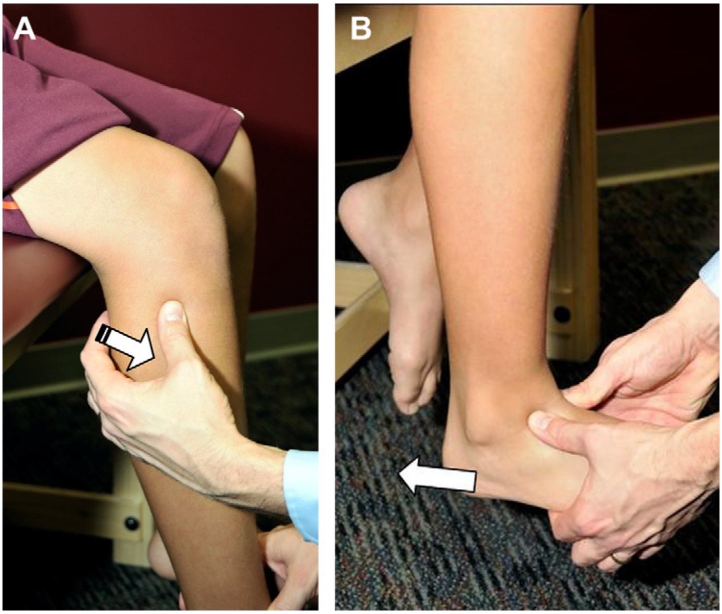

Fig. 8. Evaluation and mobilization of lower-extremity dysfunctions. (*A*) Motion of the fibular head. Mobility is assessed by gentle anterolateral/posteromedial excursion of the fibular head. Motion deficits may occur after inversion-type ankle sprains. (*B*) The swing test. The foot is held parallel to the floor and the knee gently flexed. At the motion barrier, when the ankle cannot dorsiflex further, plantar-ward pressure is felt; loss of ankle dorsiflexion after inversion injury is common. The muscle energy treatment is performed by placing the foot at the barrier; the patient gently plantarflexes 3 to 5 seconds against the physician's resistance. On relaxation, the foot is kept parallel to the floor and the knee moved into further flexion, engaging the new barrier. The process is performed 3 times. (*Courtesy of* Quinton Nottingham, PhD.)

Motion deficits at the talus and fibula are detected using the swing test and fibular motion test. Fibular head motion is assessed by grasping the fibula and pulling in the anterolateral/posteromedial plane and comparing to the unaffected side (**Fig. 8**A). Talar motion can be assessed using the swing test (see **Fig. 8**B). The swing test is performed by monitoring the motion of the talus and flexing the knee while keeping the foot parallel to the floor. At the talar barrier, the talus cannot move further into the mortise and the foot dips toward the floor; the angle of knee flexion is typically less than the unaffected side.

Treatment techniques should generally not be used in the acute injury period. In the acute period, management should consist of PRICE (*p*rotection, *r*est, *i*ce, *c*ompression, and *e*levation). After initial edema and pain is reduced, osteopathic techniques can be used to address motion restrictions attributed to specific fibular or talar dysfunctions.[47] If the talus is unable to glide or rotate into dorsiflexion (a positive swing test), muscle energy or high-velocity techniques may be appropriate. In the muscle energy technique, the ankle is moved into dorsiflexion in the same posture as the swing test. At this barrier, an athlete gently attempts plantar flexion for 3 to 5 seconds while a physician resists. As in all muscle energy techniques, physicians should not allow the foot to actually move. After a brief (1-second) relaxation period, the physician passively flexes the knee to the new barrier, maintaining the foot parallel to the floor (further into dorsiflexion). The technique is generally repeated for 2 additional cycles.

After treatment, motion is reassessed and the athlete may report that the ankle feels loose. In the author's practice, these patients are still given standard treatments and referred for therapy to restore strength and balance directed by an athletic trainer or physical therapist.

Fibular restrictions can also be treated with muscle energy techniques. For an anterior lateral maleolus, the ankle is placed into dorsiflexion and eversion to the barrier (see **Fig. 8**B). The patient gently plantar flexes and inverts the ankle against resistance for 3 to 5 seconds. After a brief relaxation period, the ankle is moved further into dorsiflexion and eversion with gentle pressure on the anterior aspect of the lateral maleolus. Gentle pressure is usually exerted on the posteromedial aspect of the fibular head proximally. After 3 cycles, motion is reassessed.

With the exception of anecdotal reports of success for manipulation in pediatric ankle sprains, most published studies for manipulation efficacy for lower-extremity injury involve young adult and adult populations. In an emergency department study of 18 patients with acute ankle sprains, the group treated with manipulation had improved immediate range of motion and decreased edema (evidence level B).[48] A sham-manipulation, single-blind study looked at load distribution via a force platform before and after manipulation in patients (ages 18 and above) with grade II ankle sprains. Manipulation leads to significant redistribution of load on the injured foot.[48] A recent review of manipulation techniques for lower-extremity conditions found modest support for the manual treatments in inversion ankle injury when combined with exercise or multimodal therapy (evidence level B).[49] Although there is sparse anecdotal support for manipulation in pediatric ankle sprains, available evidence modestly supports its use in young adults when used with standard treatments and physical therapy (evidence level B).

CUBOID SYNDROME

Cuboid subluxation or syndrome refers to pain on the lateral, dorsal, or often plantar aspect of the foot over the cuboid thought to be due to ligamentous injury and loss of joint congruity of the calcaneocuboid joint.[50] The subject has recently had a thorough literature review.[50] The disorder is commonly seen after ankle inversion injury but is also seen as a result of overuse in dance.[51] Diagnosis is usually clinical, with direct palpation of the cuboid eliciting pain. Radiography is unhelpful unless there is true fracture; ultrasound may reveal joint effusion and ligamentous injury as well as allowing for dynamic motion testing.[50] Treatment of the disorder involves restoring joint motion. There are several manipulative techniques, including HVLA and LVLA, to restore joint congruity. In a case series, 7 young athletes diagnosed and treated with mobilization and physiotherapy were able to return to activity without limitation after 1 or 2 visits.[52] Manipulation is beneficial for cuboid subluxation (evidence level B).

SUMMARY

The use of manipulation for a variety of athletic injuries remains an alternative treatment. Conditions, such as nursemaids' elbow or cuboid syndrome, that clearly resolve after appropriate restoration of function by manipulation should suggest the validity of looking more closely at underlying biomechanics to understand dysfunction and injury. As part of standard examination, motion deficits and asymmetry should be actively sought. When identified, mobilizations may be of benefit. They need not be the traditional HVLA variety; results can be achieved using muscle energy, strain-counterstrain, or soft tissue techniques to restore motion. Although manipulation may seem to offer an instant "cure," it is best used as part of a comprehensive rehabilitation approach that begins with thorough evaluation to identify contraindications and progresses to physical therapy for muscle reconditioning and retraining to offer the greatest chance for long-term resolution of symptoms.

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