Gymnastic Wrist Injuries

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WEBB, B.G. and L.A. RETTIG. Gymnastic wrist injuries. Curr. Sports Med. Rep., Vol. 7, No. 5, pp. 289–295, 2008. During gymnastic activities, the wrist is exposed to many different types of stresses, including repetitive motion, high impact loading, axial compression, torsional forces, and distraction in varying degrees of ulnar or radial deviation and hyperextension. Many of these stresses are increased during upper extremity weight-bearing and predispose the wrist to high rates of injury during gymnastics. Distal radius stress injuries are the most common and most documented gymnastic wrist conditions. Other conditions include scaphoid impaction syndrome, dorsal impingement, scaphoid fractures, scaphoid stress reactions/fractures, capitate avascular necrosis, ganglia, carpal instability, triangular fibrocartilage complex tears, ulnar impaction syndrome, and lunotriquetral impingement. It is important to diagnose quickly and accurately the specific injury to initiate expeditiously the proper treatment and limit the extent of injury. In addition, a gymnast’s training regimen should also include elements of injury prevention.

INTRODUCTION

USA Gymnastics estimates that nearly 3 million recreational athletes and 85,000 competitive gymnasts participate in gymnastics each year in the United States (1). Gymnasts range from the young child involved in tumbling exercises to the elite gymnast training for competitions such as the Olympics. Elite gymnasts may initiate training as early as 4 or 5 yr of age and quickly accelerate the difficulty and intensity of their training (2). The average elite female gymnast trains 5.36 d each week and 5.04 h each day (3) and may peak at 50 h each week (2). Exposure-based injury rates for club-level female gymnasts range from 1.4–3.7 injuries per 1000 h (4). According to a prospective study on injuries in a female NCAA Division I gymnastics team, each player had 151.4 exposures, with an injury in approximately 7% of all exposures (5). Overall, there is a 25-fold higher rate of injury in the highest level of the United States Gymnastic Federation compared with the lowest level of competition (2).

The number of injuries has been shown to increase until the middle of the season, when they plateau (5). A study of elite Swedish gymnasts with an injury rate of 6.25 per 100 gymnasts per season shows that the majority of injuries affect the lower extremities and occur mostly from mounting and dismounting. Male gymnasts sustained the most severe injuries such as fractures and dislocations, and the majority of these occur in the upper extremities (6). Overall, acute injuries are 10 times more likely during competition than practice (2,7).

The upper extremities are used for weight-bearing in gymnastics, unlike most other sports. Given the high impact loads across the upper extremities, it is the second most frequently injured body region (4). The wrist is the most frequently injured site in the upper extremity of female gymnasts followed by the elbow. Male gymnasts most frequently injure the shoulder followed by the wrist in the upper extremity. The wrist is exposed to many different types of stresses including repetitive motion, high impact loading, axial compression, torsional forces, and distraction (8). Combining these forces with varying degrees of ulnar and radial deviation and hyperextension predisposes the wrist to higher rates of injury during gymnastics (9). Wrist pain among high level club and collegiate gymnasts is 46% and 79%, respectively (10,11). According to Dobyns and Gables, up to 88% of gymnasts experience wrist pain (12). Wrist pain is associated with older age, increased training hours per week, training at a higher skill level, and the initiation of training at an older age (8). Elite gymnasts have greater rate of injuries than lower level (13), and the duration of pain is often chronic lasting greater than 1 yr (14).

Factors predisposing gymnasts to wrist pain include improper equipment, incorrect techniques, previous injury, delayed skeletal maturity, and growth spurts because of the transient weakness in the physis (8). Peak growth velocity occurs in males and females at approximately 13.5 yr and
11.5 yr, respectively. Exercises especially stressful on the wrist include floor routines, pommel horse, vault, and balance beam. The wrist can be subjected to forces up to 16 times body weight during these activities (15,16).

Gabel (2) divided the extensive list of gymnastic wrist injuries into acute and chronic and osseous and soft tissue. Chronic dorsal wrist pain in young gymnasts that gets worse with weight-bearing and extension is caused most commonly by distal radial physeal stress injuries, scaphoid impaction syndrome, and dorsal impingement syndrome. More rare conditions consist of scaphoid fractures, scaphoid stress reactions, avascular necrosis of the capitate, ganglia, and carpal instability. Skeletally mature gymnasts more commonly can have tears of the triangular fibrocartilage complex, ulnar impaction syndrome, and lunotriquetral impingement (Table).

Hand injuries in gymnasts are usually traumatic and relatively uncommon. Therefore, the focus of this chapter is on wrist injuries. Caine and Nassar reviewed injury rates for the 2002-2004 USA Gymnastics National Women's Championships and identified a paucity of hand maladies (3 of 146 reported injuries) (4). Phalangeal and metacarpal physeal injuries are some of the more common hand injuries among skeletally immature gymnasts.

**DISTAL RADIUS STRESS INJURIES**

The distal radius physe is a common site for injury in gymnasts because of the significant amount of load applied during upper extremity weight-bearing. In the early 1980s, Read and Roy (17,18) described radiographic abnormalities of wrist growth plates in young gymnasts. According to DiFiori et al. (14), there have since been multiple series reporting stress injuries to the distal radius physe. The incidence rates are approximately 1.9–2.7 injuries per 100 participant seasons (3,19). The typical patient with a distal radial stress fracture is a 12- to 14-yr-old female who is participating in gymnastics greater than 35 h each week (2). Symptoms begin at the onset of the offending activity and worsen during the activity. Physical examination will show tenderness along the physe and pain with extreme dorsiflexion and axial loading. Occasional swelling may be noted just proximal to the radiocarpal joint. Grip strength is often diminished compared with the contralateral extremity. Radiographic criteria for the diagnosis of stress injuries to the distal radial physe include any of the following: widening of the growth plate especially volarly and radially, cystic changes of the metaphyseal aspect of the growth plate, a beaked distal volar and radial physe, and haziness within the growth plate (20) (Fig. 1).

The cause likely is repeated injury to the growth plate from compression, distraction, and torsion forces. The etiology of physeal injury may be from compromise of the blood supply to the metaphysis and/or epiphysis (14), which can lead to abnormal enchondral ossification (2). Prolonged intensive physical loading can even lead to arrest of the distal radius physe (14). A Madelung-like deformity, where the articular surface of the distal radius is directed volar and ulnar, has been described with premature closure of the ulnar aspect of the distal radius physe (14). Risk factors for developing distal radius physeal injuries include very soft mats leading to more dorsiflexion, twisting vault routines leading to dorsiflexion and ulnar deviation, and beam activities with locked forearms and rotational moments at the wrists (14).

There are no systematic studies describing treatment in the literature. The injury can be divided into three stages. In Stage 1, the diagnosis is made clinically before radiographic abnormalities. Gradual return to participation can begin once symptoms cease. Stage 2 demonstrates radiographic physeal changes as described previously. Return to competition is much longer, and can be up to 2–4 months (21). Clinical and radiographic reassessment should be made before return. Serial radiographs should be examined for resolving injury to the growth plate. If symptoms return, participation should be stopped, and radiographic and clinical reassessment be performed. Rehabilitation should evaluate overall limb alignment and laxity and include both strengthening and proprioception training. Bracing in the rehabilitation phase can be considered during functional return to participation. The Gibson brace with a palm pad is particularly helpful for radial stress injuries (Fig. 2). It has a palm pad that acts like an orthotic for the hand to take the pressure off the radial physe (Nassar, L., personal communication, 2008). Stage 3 has the same clinical features as Stage 2 with ulnar positive variance on radiographs. In this stage, one should worry about ulnar abutment (14,21).

There have been no studies showing correlation between magnetic resonance imaging (MRI) findings and stages of healing; therefore, MRI is not a useful prognostic tool (21).

A significant amount of research has been conducted to investigate the relationship between ulnar variance and distal radius stress injuries. Ulnar variance refers to the relative length of the ulna with respect to the radius, determined at the carpal surface. Neutral variance occurs when the bones are of equal length. It is defined as negative variance when the ulna is shorter than the radius and positive variance when the ulna is longer than the radius. Ulnar variance affects the distribution of force across the wrist. Experimental studies suggest that the load is increased.

### TABLE. Differential diagnosis of gymnastic wrist injuries.

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<tr>
<th>Anatomical Location</th>
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<td>Radial</td>
<td>Distal radius stress injuries</td>
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<td>Scaphoid impaction syndrome</td>
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<td>Scaphoid fractures</td>
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<td>Ulnar</td>
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<td>Lunotriquetral impingement</td>
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<td>Carpal instability</td>
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Figure 1. (A) Lateral and oblique radiographs of a 13-yr-old Level 9 gymnast with distal radial stress injury. Note the distal physeal widening, most pronounced volarly and radially. (B) Comparison radiographs of the asymptomatic wrist in the same gymnast with normal-appearing distal radial morphology.

across the radius as the ulnar variance becomes more negative — an increase from 80% to 96%, from ulnar neutral to −2.5 negative ulnar variance (22). As a general rule, the ulnar variance in children with open physes is usually negative. Therefore, it can be inferred that it is likely that the loading across the radius is significant in young, skeletally immature gymnasts who already have negative ulnar variances (14). There are several reports showing greater prevalence of relative and absolute positive ulnar variance in gymnasts compared with non-gymnasts in both skeletally mature and immature gymnasts (14). Over time, two conflicting longitudinal studies of ulnar variance in young gymnasts show different trends in ulnar variance. One suggests (23) increasing negative ulnar variance, and the other suggests significantly more positive variance over time (24). There is no definite evidence linking skeletally mature or immature gymnasts with positive ulnar variance with symptoms of chronic wrist pain or radiographic findings of distal radial growth plate injury (14). Young gymnasts with wrist pain and radiographic findings of distal radius physeal injury tend to have more negative ulnar variance (25). As stated previously, as a group, young gymnasts display an ulnar variance that is more positive than expected, but those with a more negative variance may be more at risk for wrist pain and distal radial physeal injury (14). If growth of the radius is affected by the repetitive loading of gymnastic training, an absolute positive ulnar variance may develop as skeletal maturity occurs.

SCAPHOID IMPACTION SYNDROME

Linscheid and Dobyns (26) described this injury as an impaction of the dorsal rim of the scaphoid against the dorsal lip of radius that is caused by forced hyperextension of the wrist. Symptoms are pain, weakness, and tenderness at the dorsal-radial aspect of the wrist aggravated with extension. Treatment of scaphoid impaction syndrome consists of rest and avoidance of hyperextension. If nonoperative modalities fail, then surgical cheilectomy of the dorsal scaphoid ridge or dorsal radial lip may be necessary (9).

DORSAL IMPINGEMENT

Primary dorsal impingement is direct or passive extension tenderness along the dorsal rim of the radius and carpus (2). It may result from dorsal capsulitis or synovitis with resultant capsular thickening (21). In chronic cases, osteophytes may form on the dorsal rim of the distal radius,
scaphoid, or lunate (21). Most cases resolve with splinting, rest, NSAIDs, and injections. Refractory cases may require wrist arthroscopy with debridement of synovitis and osteo-
physis, and posterior interosseous nerve excision. Diagnostic
lidocaine injection of the posterior interosseous nerve is
helpful in determining the source of pain and potential
benefit after excision.

VanHeest et al. (27) described extensor retinaculum im-
pingement in a retrospective series of eight wrists with this
condition and correlated it with cadaveric study. Symptoms
included dorsal wrist pain with extension and load-bearing
in pommel horse, floor, and vault. Examination showed pain
over the distal border of the extensor retinaculum. Swelling
was visible and palpable just distal to the retinaculum over
the tendons. A provocative maneuver of wrist hyperextend-
ion and resisted digital extension showed tenderness over
the distal wrist. The cadaveric wrists showed 5 of 10 had a
distinct distal border of the retinaculum that may predispose
to this impingement. Two patients were successfully treated
with steroid injections, while six wrists required surgery
consisting of partial distal resection of the extensor
retinaculum. Pathological findings from surgery included
thickening of the distal border of the extensor retinaculum,
concomitant extensor tendon synovial thickening, and a
tendon rupture in one patient.

Wilson et al. (28) described a case of extensor tendon
impingement in an elite gymnast. Significant synovitis
around the extensor digitorum communis tendons was
encountered at the time of exploration. These tendons were
compressed under a thickened extensor retinaculum of the
fourth dorsal compartment. Attritional tears of the commi-
nus tendons were noted. The patient’s symptoms resolved
following debridement along with a synovectomy and
release of deep thickened retinaculum.

SCAPHOID FRACTURES

The scaphoid is the most commonly injured carpal bone
and second to the distal radius in sports-related wrist
fractures (29). Scaphoid fractures can be a result of a stress
reaction, a fall onto an outstretched hand, or a direct blow.
Weber and Chao (30) demonstrated that greater than 95° of
hyperdorsiflexion load of the wrist in radial deviation places
the scaphoid waist at the highest risk for fracture. Early and
accurate diagnosis is crucial for appropriate treatment and
overall outcome. Nonunion may be as high as 12% in
untreated scaphoid fractures (31). Athletes who present in a
delayed fashion often report difficulty with hyperdorsiflex-
ion loading activities of the wrist. In the acute setting,
discomfort is often reproducible with deep palpation in the
anatomic snuffbox. Reduced mobility and decreased grip
may be noted on examination. Adams and Steinmann (31)
advocate an aggressive algorithm in patients with wrist
trauma to evaluate for possible scaphoid fractures because
unnecessary immobilization has been shown to be more
expensive than aggressive diagnostic imaging in several
studies. Standard anteroposterior, lateral, scaphoid view,
and oblique radiographs of the wrist should be obtained. If
radiographs are negative, then an MRI of the wrist is the
study of choice in suspected cases of an occult scaphoid
fracture (31).

Traditional treatment of stable, nondisplaced fractures
has been cast immobilization. However, if early return to
participation is desired, internal fixation may be the best
option (32). Closed treatment can result in delayed union,
nonunion, malunion, stiffness, and delayed return to play
(33). Union rates are comparable with casting with
operative stabilization of stable wrist scaphoid fractures,
approaching 95% (31,34). Prospective randomized studies
comparing acute fixation with closed treatment of stable
fracture have shown that patients treated surgically heal
faster and return to work earlier (35,36). Most authors
recommend surgically treating all displaced scaphoid frac-
tures (those that can be seen on plain radiographs) and all
proximal pole fractures. Percutaneous treatment of both
nondisplaced and displaced fractures with headless cannuli-
ated compression screws can achieve nearly perfect union
rates and return the player to action much quicker (33).

Slade et al. (37) expanded on Whipple’s technique and uses
fluoroscopic assistance with a dorsal percutaneous approach.
They locate the central axis of the scaphoid using the
fluoroscopic scaphoid ring sign, which is achieved by flexing
and pronating the wrist until the proximal and distal poles
of the scaphoid are in a straight line. Postoperatively, it is
recommended to undergo a rapid mobilization program
using a removable thumb spica splint. Unprotected activity
is allowed when bridging callus is noted. Haddad and
Goddard (38) were some of the first to report on percuta-
neous fixation of nondisplaced fractures in athletes and
showed an average healing time of 55 d in 50 patients.
Return to sport with a playing cast was allowed within 2 wk.
They recommend wearing a playing cast until healing is
documented by CT. It should be understood that because
the upper extremities are weight-bearing limbs in gymnastics,
return to play may take longer to allow full healing
to occur. A functional return to weight-bearing for gymnasts
is facilitated with use of a wrist support such as a lionspaw
splint.

SCAPHOID STRESS REACTIONS/FRACTURES

Stress fractures of the scaphoid are rare conditions, which
have been infrequently described in the literature (39–43).
Hanks et al. (39) presented a series of four such fractures
in three athletes. Two were male gymnasts, with one
having bilateral stress fractures. In addition, Engel et al.
(43) described bilateral stress fractures in a young gymnast.
The mechanism of injury is repetitive compressive loads to
the wrist in varying degrees of extension. The repeated
trauma is insufficient to create an acute fracture, but over
time can lead to stress changes. In addition, forearm muscle
fatigue can lead to increased abnormal loading of forces on
the scaphoid. Over time, a stress reaction occurs at the
scaphoid waist, and later a frank fracture can occur. Early
symptoms include chronic wrist pain without a specific
injury and tenderness over the scaphoid that is worse with
hyperextension and radial deviation. X-rays may show
sclerosis at the waist early and later a distinct fracture line.

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A physician should be alert to the possibility of a stress fracture in a high-performance gymnast who continues to load cyclically a painful wrist even in the setting of a negative radiograph. Treatment includes immobilization until radiographic healing is noted. Matzkin (41) presented a 13-yr-old in which successful treatment involved 8 wk in long arm spica cast followed by 4 wk in a short arm splint.

**AVASCULAR NECROSIS OF CAPITATE**

Avascular necrosis of the capitate has only been reported in two gymnasts (44) and was likely caused by interruption of blood flow to the head of the capitate from repetitive microtrauma. The blood flow to the head is retrograde, and any injury to the neck may lead to resorption of the head. These two athletes underwent partial resection and drilling, allowing them to resume their immediate careers. Long-term follow-up was not mentioned (21), and later failure may require intercarpal fusion procedures (2).

**GANGLIA**

Occult dorsal ganglia may result from repetitive dorsal stress from gymnastic activities, and they may cause dorsal wrist pain. The cysts can be secondary to scapholunate pathology (21). Symptoms include pain with dorsiflexion in loading conditions as they impinge dorsally (2). Point tenderness over the scapholunate ligament is usually found on physical examination (21). If immobilization, rest, and possible aspiration (2) with or without corticosteroid injection fail to resolve symptoms, excision in combination with posterior interosseous nerve resection is usually curative (21).

**CARPAL INSTABILITY**

The scapholunate interosseous ligament is one of the key ligaments in maintaining stability of the carpus. The ligament consists of dorsal, proximal, and volar segments connecting the scaphoid to the lunate. Injury to this ligament is the most common and most significant ligament injury to the wrist. The spectrum of injury ranges from dynamic scapholunate instability in which there are connecting the scaphoid to the lunate. Injury to this ligament is the most common and most significant ligament injury to the wrist. The spectrum of injury ranges from dynamic scapholunate instability in which there are no findings on standard radiographs of abnormalities to frank dissociations in which the scaphoid can dislocate and rotate into a volarly flexed position. The mechanism of injury is axial loading with wrist extension and ulnar deviation with the capitate driven between the lunate and scaphoid. Both acute falls on an outstretched hand or repetitive chronic forces on the wrist can cause this injury. History and physical may show pain on the dorsal radial wrist, loss of motion, and decreased grip strength (46). The Watson maneuver may be positive. This maneuver is performed by placing constant pressure by the examiner's thumb over the volar aspect of the distal pole of the scaphoid while the wrist is moved from extension and ulnar deviation to flexion and radial deviation. Wrist pain or a clunk may be elicited. Often these patients present after experiencing symptoms for an extended period of time because of the lower level of pain experienced chronically, or because it was initially clinically missed. Static scapholunate diastasis will present radiographically as a scapholunate distance greater than 3 mm (Terry Thomas sign). Dynamic instability may require stress views or clenched fist views. A scapholunate angle greater than 70° and cortical ring sign may be seen (45), with chronic cases possibly showing dorsal intercalated segment instability (DISI) with eventual degenerative changes throughout the carpus. MRI arthrography is an excellent imaging modality to evaluate the integrity of the ligament or bone edema. Arthroscopy is the gold standard for evaluation of the competency of the ligament and is often useful for evaluating for dynamic instability. Geissler has recently described four grades of scapholunate instability based on arthroscopic evaluation (46). During arthroscopy, debridement and/or repair can be performed (45).

Snider et al. (45) presented three case reports of gymnasts with chronic dorsal wrist pain exacerbated with axial loading. These patients all had partial scapholunate ligament tears and mild synovitis noted during arthroscopy. They hypothesized that the twisting, dismount activity in gymnastics placed maximal stress on the radial column of the wrist. They also recommend future consideration to the use of dorsiflexion limiting wrist supports to prevent these injuries.

**TRIANGULAR FIBROCARTILAGE COMPLEX (TFCC) TEARS**

Ulnar sided wrist pain is more common in skeletally mature athletes and is often caused by injury of the triangular fibrocartilage complex. It is more common in older gymnasts because of the higher frequency of ulnar positive variance and increased ulnar sided transmission of force from the repetitive weight-bearing over time. Differential diagnosis of ulnar sided wrist pain in the gymnast includes: extensor carpi ulnaris instability/tendonitis, distal radio-ulnar instability, TFCC tears, lunotriquetral tear, pisotriquetral joint dysfunction, and flexor carpi ulnaris tendonitis. The examiner must assess for other pathology when evaluating the athlete with ulnar wrist pain. Tenderness secondary to a TFCC tear is noted with deep palpation between the flexor carpi ulnaris and the ulnar styloid. Pain may be reproduced by positioning the wrist in ulnar deviation and pronation. Mandelbaum et al. (11) proposed a diagnostic and treatment algorithm initiated with a conservative treatment including rest, NSAIDs, ice, therapy, and modification of training. If symptoms persist, then a period of 4–6 wk of immobilization and cessation of gymnastic activities is begun. Persistent pain warrants work-up with an MRI arthrogram, which has been shown to correlate well with arthroscopic findings (11). In the absence of distal radial-ulnar joint instability, a cortisone injection into the ulno-carpal joint can be entertained as a treatment option in gymnasts with recalcitrant pain. Relief
of symptoms after the injection may facilitate a gradual return to participation. Arthroscopic debridement of central tears often renders good results. TFCC repair is the mainstay of treatment in peripheral tears.

ULNAR IMPACTION SYNDROME

Ulnar carpal abutment can be either developmental or acquired, such as from a previous injury to the radial growth center in a gymnast. Increased stress across the ulnocarpal joint may occur with repetitive loading of the wrist in dorsiflexion, ulnar deviation and pronation. Force transmission across the ulnocarpal joint can increase with positive ulnar variance (47). If ulnar deviation is combined with pronation, the ulnar loading can increase from 15% to 40% (2). Injuries that can occur from these forces include tearing of the TFCC, attritional tears of the lunotriquetral ligament, chondromalacia, subchondral sclerosis, and subchondral cyst formation on the lunate, triquetrum, and ulna (Fig. 3). Symptoms include tenderness over the proximal lunate and triquetrum made worse with forced ulnar deviation. Physical exam may show ulnar snuff box tenderness and passive ulnar deviation tenderness. Radiographs may show positive ulnar variance and possible cyst or sclerosis formation in the ulnar head or lunotriquetral region (2). Nonoperative treatment is attempted first with rest, NSAID, steroid injections, and modification of training. If unsuccessful, an attempt at immobilization and cessation of gymnastics for 4–6 wk can be initiated. MRI then should be ordered to evaluate the TFCC and intercarpal ligaments.

If clinical exam is concerning for intercarpal ligament tear (lunotriquetral), then MRI arthrogram should be obtained during the early stages of evaluation. In cases of recalcitrant pain, an unloading procedure of the ulna is indicated. Recent literature suggests that arthroscopic wafer resection is just as effective as ulnar shortening osteotomy in relieving pain in these patients (48).

LUNOTRIQUETRAL IMPINGEMENT

This condition is caused by impingement of the dorsal lunate and triquetral rims and is caused by repetitive wrist hyperextension and ulnar deviation. Symptoms are tenderness over the lunotriquetral joint that is worse with extension and ulnar deviation. Treatment is first rest, immobilization, and NSAID followed by surgical intervention if nonoperative measures fail (9).

CONCLUSION

We have reviewed some of the most common wrist injuries in gymnasts. The gymnast's wrist is subjected to a high level of force transmission across the radiocarpal and ulnocarpal joints as a result of the significant weight-bearing loads required of the sport. Many of these stresses are imparted during a significant period of longitudinal growth of the wrist, creating potential for physeal injury. It is important to quickly and accurately diagnose the specific injury to expediently initiate the proper treatment and limit the extent of injury. Prevention should also be an important aspect of a gymnast's training regimen. Concepts to be considered include the following: individualize the training, gradually increase training loads, reduce high loads during growth spurts, alternate loading activities, and consider the possibility of wrist orthoses.