

Clinical Commentary/Current Concept Review

Rehabilitation of Capitellar Osteochondritis Dissecans (OCD) Lesions in Gymnasts: A Review of Current Concepts and Treatment

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Keywords: capitellum, gymnastics, osteochondral lesion, rehabilitation

<https://doi.org/10.26603/001c.155474>

International Journal of Sports Physical Therapy

Vol. 21, Issue 2, 2026

Capitellar osteochondral dissecans (OCD) is a prevalent condition in competitive gymnasts. While evidence-based guidelines for management of OCD are available in baseball players, this is not the case for gymnasts. OCD can be managed surgically with an Osteochondral Autograft Transfer System (OATS) procedure followed by rehabilitation or conservatively with rehabilitation alone. A comprehensive approach to rehabilitation of OCD, integrating a criterion-based progression, may optimize return to sport success. The purpose of this clinical commentary is to review the literature and summarize current concepts in rehabilitation following both surgical intervention and conservative management of OCD in gymnasts.

Level of Evidence Level 5

INTRODUCTION

Gymnastics is a sport that challenges young children, adolescents, and adults to not only demonstrate high levels of strength, metabolic capacity, and power, but also coordination, balance, and flexibility. Due to the unique biomechanics of the sport, large physical demands are required of a gymnast's body. Unlike many other sports, gymnastics requires that typically non-weight-bearing (NWB) joints such as the shoulder, elbow, and wrist, function as weight-bearing (WB) joints to perform skills such as handstands, back handsprings (BHS), and more. This repetitive overload has contributed to a high incidence of osteochondritis dissecans of the capitellum in young gymnasts. Capitellar osteochondritis dissecans (OCD) at an early age may negatively impact a gymnast, resulting in less time in practice and competition due to injury, a shorter overall career, and worst of all persistent pain after retirement from gymnastics. Currently, there are no published evidence-based rehabilitation protocols for gymnasts following surgical management of OCD and non-surgical management of OCD.

The purpose of this clinical commentary is to review the literature and summarize current concepts in rehabilitation following both surgical intervention and conservative management of OCD in gymnasts. Special attention will be placed on rehabilitation following the Capitellar Osteochondral Autologous Transfer System (OATS) procedure

due to its increased utilization and superior outcomes as compared to OCD fragment fixation and loose body removal.¹⁻⁴ The authors developed this protocol using clinical expertise and best evidence available for intended use by all healthcare providers involved in a gymnast's care: orthopedic and sports medicine physicians, physical therapists, and athletic trainers. Gymnastics coaches may also benefit from published information on this topic. Provided in the appendix is a protocol for non-operative management of OCD in gymnasts.

CURRENT CONCEPTS- CAPITELLAR OCD IN GYMNASTS

OCD is a necrotic osteochondral lesion that occurs on the capitellum. Symptoms include pain and/or mechanical deficits of the elbow such as decreased range of motion (ROM), catching, locking, and buckling under load.^{1,5} The precise pathophysiology is not widely understood, but it has been hypothesized that repetitive upper extremity (UE) weight bearing activities in gymnastics cause microtrauma to the capitellum and the associated articular cartilage, which limits capitellar blood supply, and negatively affects remodeling of potential osteochondral lesions.

Unlike the lower extremity (LE), the UE was not designed for WB, which may contribute to high joint reaction forces at the wrist, elbow, and shoulder. If the radiocapitellar joint

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is compared to a similar hinge joint in the lower body, the tibiofemoral joint, it does not have a meniscus, a fibrocartilaginous cushion between the joint surfaces that serves to increase the joint surface area and mitigates LE compressive forces. The articular cartilage and subchondral bone of the radiocapitellar joint thus sustains greater and direct compressive forces. The radial head is also stiffer in comparison to the lateral capitellar wall, which increases the propensity for the capitellum to fail with repetitive high-load compressive forces.⁶ Although the elbow joint consists of the radiocapitellar joint and the humeroulnar joint, weight is not equally distributed between both joints during compressive loading. Biomechanical studies have shown that during a BHS in gymnastics, 60-80% of axial compressive forces are sustained at the radiocapitellar joint.^{2,7} Injuries occur when the body is incapable of withstanding the force or workload placed upon it, and these biomechanical differences at the radiocapitellar joint may explain why microtrauma is likely to occur and create osteochondral lesions at the capitellum.

The location of the osteochondral lesion on the capitellum is determined by the specific demands of the sport in which an athlete participates, and the lesion is unique to where and how most compressive forces are sustained at the joint surface. Baseball players have a high incidence of OCD, specifically at the anterolateral aspect of the capitellum, whereas OCD in gymnasts occur on the posterior aspect.^{8,9} The forces exerted on the radiocapitellar joint during vaulting, tumbling, and other closed chain compression-based gymnastics skills occur with the elbow in extension, in contrast to the open chain throwing motion in baseball athletes where the elbow is loaded in both flexion during arm cocking and extension during the follow-through. The forces that must be managed by gymnasts are posterior and compressive/axial, while those sustained by throwers are anterior and shearing. Therefore, although gymnasts and overhead throwing athletes present with similar symptoms, the difference in location of the lesion warrants attention in order to optimize management in a sport-specific approach.

OCD in gymnasts typically occurs between the ages of eleven to eighteen and has increased prevalence in females.⁹ As gymnasts start training as early as five years old, they have potential to perform advanced skills before reaching skeletal maturity. Advanced skills occur at a higher velocity and have greater vertical displacement, which equates to higher joint compression forces. Fundamental skills that are taught at an early age include handstands, round-offs, and the BHS, all of which have significant closed chain UE demands. The radiocapitellar joint withstands 2.7 times bodyweight (BW) during a BHS.¹⁰ Round-offs and BHS are seen on three of the four competitive events for females and males have additional foundational elements such as circles and loops on the pommel horse (Refer to [Figure 1](#)) and swing handstands on the parallel bars. Gymnasts progress to more advanced tumbling passes (double back flips, twisting elements), high-level vaults (Yurchenko: round off to spring board, BHS to vault, back flip off vault), and one arm high-force skills (blind



Figure 1. Pommel horse

change/change of direction swinging on bars). If foundational skills produce almost three times BW to be transmitted through the radiocapitellar joint, one can only imagine how much force is put on it during more advanced skills. Regarding sex differences in presentation, there is little evidence regarding why incidence is higher in females, but the most likely factor is greater UE strength in males which may serve as protective to the repetitive microtrauma that occurs in gymnastics.

Workload management is an important factor to consider regarding incidence of OCD. Gymnasts typically practice two to four hours a day, four to six days per week, for a total of 10-20+ hours per week. In baseball, pitch count is widely accepted as a technique to monitor workload. It is the opinion of the authors that gymnastics coaches may not be aware that setting daily or weekly limits for specific skills may be beneficial and generally do not know how to integrate workload monitoring into practice. Coaches can limit the degree of joint forces of gymnasts by varying practice surfaces from firm to soft and providing spotting assistance for advanced skills. The author's viewpoint is that traditionally gymnastics strength training programs during practice include only bodyweight exercises, but coaches are beginning to add exercises that use resistance bands, dumbbells, and barbells to optimize strength, power, and agility to decrease the degree of joint forces gymnasts sustain during sport.

Early specialization in sport and year-round training has been documented in gymnastics and other sports, and both are thought to contribute to overuse injuries.¹¹⁻¹⁴ From the author's perspective, it is common for gymnasts to continue training despite feeling pain in the body. Pain is the body's natural protective response and in the case of OCD, it is an indicator that microtrauma is occurring at the joint surface. Therefore, an open honest line of communication between coaching staff, gymnast, parent/guardian, and medical team is important to help the gymnast reach his or her goals and not exercise through pain.

GENERAL PRINCIPLES OF REHABILITATION PROGRAMS

For optimal recovery following athletic injury, rehabilitation commonly follows a stepwise progression from acute to subacute to advanced, to strength and conditioning, and finally to return to sport (RTS). Typically, each phase lasts four to six weeks, but precise timing is more dependent on patient demographics (age and skill level), injury specifics (surgical vs. nonsurgical, site of injury, tissue quality, concomitant lesions, and severity), and psychosocial factors (pain and readiness to RTS). Regardless of injury, all gymnasts must demonstrate adequate tissue healing and reach objective criteria at each stage to ensure proper tissue remodeling, full restoration of joint motion and muscle strength, and adequate functional capacity to sequentially progress through rehabilitation and safely return to participation in all aspects of gymnastics.

OATS REHABILITATION PROTOCOL FOR GYMNASTS: AN EXAMPLE

The following rehabilitation protocol for utilization after the OATS procedure follows the principles of rehabilitation described above. The protocol can be referenced in [Table 1](#). It is important to note that this surgical protocol is designed for the OATS procedure and should not be used following drilling or microfracture procedures. A protocol for non-operative management of OCD can be found in Appendix A.

PHASE 1: ACUTE PHASE/MAXIMUM PROTECTION (WEEKS 1-4)

The primary goal during the acute phase of rehabilitation is to protect the OATS graft and surrounding affected tissue. Focus is on pain management, protecting the healing articular cartilage, restoring full elbow and wrist ROM, reducing swelling, reversing reflexive neuromuscular inhibition of musculature crossing the elbow joint, and limiting muscle atrophy.

Phase 1 of rehabilitation in the clinic begins one-week post-operative. With the post-surgical dressing intact, gentle elbow passive ROM (PROM) is performed to tolerance through a pain-free ROM. Active ROM (AROM) and gentle gripping exercises to tolerance are allowed at the wrist and hand for swelling management and to limit atrophy or contracture associated with immobilization. At seven days post-operative, the post-surgical dressing is removed, the incision is inspected, and gauze pads with elastic bandages are used to cover the incision site. Clinicians utilize elevation and effleurage massage for swelling management and modalities for pain management such as ice. Education is vital for proper home management including elevation of the limb above heart level throughout the day, adherence to precautions to protect the graft, importance of distal AROM, and pain management with ice.

During the first week of rehabilitation, elbow PROM exercises with the wrist in a neutral position are prioritized.

PROM of the elbow with contralateral UE assist is encouraged thirty times hourly to a feeling of mild resistance without excessive pain to prevent motion deficits and promote articular cartilage healing.¹⁵ Home sessions are focused on maintaining motion, during clinic visits the goal is to progressively improve in ROM as evidenced by AROM and PROM measurements.

At week two of rehabilitation, more time is spent on ROM, a gentle overpressure program is started, and proximal and distal soft tissue deficits are addressed. The duration of PROM and active assisted ROM (AAROM) at home is increased to five to ten minutes every hour and the goal by week 4 is to attain full elbow extension. A light overpressure program with a low load prolonged duration (LLPD) stretch can be added if extension is limited. During a LLPD stretch, a gymnast is supine with elbow extension and neutral forearm, forearm supported on the table, and the wrist off the edge of the table with an elastic band tied from the wrist to a heavy weight on the floor. The pull exerted by the band should be pain-free, comfortable enough to tolerate a fifteen minute duration, and a moist heat pack can be applied across the anterior elbow joint to facilitate muscle relaxation. The low load over fifteen minutes induces collagen deformation, otherwise known as creep, as compared to static stretching of the musculature that is focused on short-term neuromodulation of the tissues.^{16,17} Literature has suggested four bouts of fifteen-minute LLPD sessions throughout the day for significant improvements in elbow extension.^{16,17} It is the opinion of the authors that adding petrissage, instrument assisted soft tissue mobilization (IASTM), and cupping to the soft tissue surrounding the elbow joint and at the shoulder/periscapular area is beneficial to prevent excessive muscular stiffness and loss of ROM throughout the UE. Attention should be paid to the flexor pronator mass (FPM), biceps, and brachialis as limitations in flexibility may limit full elbow and wrist extension in WB, which is essential for many skills in gymnastics.

At week three of rehabilitation, elbow PROM is progressed to AAROM, gripping activities are progressed, distal isotonic exercises are added for the wrist joint, and shoulder AROM is introduced. Grip and wrist strengthening including wrist extension, flexion, supination, and pronation start at 1 pound (lb) and progressively increase weekly. To maintain mobility needed for handstands, round-offs, and BHS, shoulder AROM is added.

At week four of rehabilitation, shoulder and periscapular isotonic exercises are added with the Thrower's Ten program, starting with no weight and increasing 1lb every one to two weeks as tolerated.¹⁸ Exercises should all be performed in open chain, submaximal, and include no direct loading of the biceps and triceps. Starting proximal strengthening at four weeks post-operative is safe for the healing graft and beneficial to limit significant loss of strength that may hinder future return to sport progression. The Thrower's Ten program is designed for baseball players but is appropriate for gymnasts after OCD postoperative as it addresses all of the major muscle groups involved in gymnastics.¹⁸ If excessive gripping is increasing symptoms during exercises due to grasping dumbbells, the

dumbbells can be replaced with cuff weights applied above the wrist.

To progress to Phase 2 of rehabilitation, a gymnast must demonstrate full elbow extension PROM, weekly improvements in elbow flexion PROM and AAROM, and no discomfort of activities of daily living such as dressing and bathing.

PHASE 2: SUBACUTE PHASE/MODERATE PROTECTION (WEEKS 4-8)

The primary goals during the subacute phase of rehabilitation are to continue protecting the graft, promote articular cartilage healing, gain full elbow and shoulder AROM, and return to baseline level of shoulder strength and functional capacity of the upper extremity.

At week 5 and 6 of rehabilitation, the focus is ensuring adequate elbow PROM and addressing any elbow extension deficits. The goal is to achieve within five degrees of extension of the non-surgical side.

During week 7 and 8 of rehabilitation, elbow AROM, shoulder stretching, gentle elbow traction forces, and concentric manual resisted exercises at the wrist and elbow are added. Elbow flexion AROM is introduced in the anti-gravity position (sidelying) and then progressed to sitting or standing to work against gravity. Stretching the shoulder and soft tissue care of the latissimus and teres major to optimize shoulder flexion is essential as limitations in overhead motion can significantly limit basic gymnastics skills. The Thrower's Ten program continues to be performed daily in the home exercise program as the load of the exercises are below the physiological dosage to overload tissues but may require a day of rest between sessions. In the clinic, wrist and shoulder exercises can be challenged by manual resistance by the therapist on the concentric portion of the exercise to further increase the demand as seen in [Figure 2](#) with manually resisted supination and in [Figure 3](#) with manually resisted ulnar deviation. Wrist exercises include flexion, extension, supination, and pronation as well as finger gripping while shoulder exercises include sidelying external rotation, sidelying rowing, and sidelying scapular plane abduction. Additionally, core exercises that do not require UE WB, such as supine alternating arm and legs, v-sit ups, and prone lumbar extension are added for neuromuscular re-education of the core musculature.

To progress to Phase 3 of rehabilitation, a gymnast must demonstrate no adverse reactions to strengthening, full elbow flexion extension PROM and AROM, MMTS of 4+/5 of the shoulder and wrist musculature, and no discomfort with activities of daily living such as carrying a school backpack.

PHASE 3: INTERMEDIATE PHASE/MINIMAL PROTECTION (WEEKS 8-12)

The primary goals during the intermediate phase of rehabilitation are to progress UE strengthening. Mobility training can be decreased to two to three times per day and manually resisted shoulder and wrist exercises can be progressed to adding resistance on the eccentric portion of the exercise. A light dumbbell can be added to bicep curls



Figure 2. Manual resisted supination



Figure 3. Manual resisted ulnar deviations

and triceps extensions, following a similar progression as shoulder strengthening progressing 1lb per week. The clinic program is focused on building strength with compound movements including horizontal pushing and pulling exercises, where the weight is pushed away or pulled towards the body perpendicular to the trunk, and vertical pushing and pulling exercises, where the weight is pushed away or pulled toward the body parallel to the trunk. Exercises such as floor press, cable rows and angled pull downs, and half kneeling overhead dumbbell presses can be initiated with light weight between ten and twelve weeks with a frequency of one to two times per week for each movement. As loading increases over the course of four weeks, clinicians are encouraged to utilize more traditional strength and conditioning sets, repetitions (reps) and volume schemes by transitioning to two to three sets of ten reps with a lighter weight to three to four sets of six to eight reps with a heavier weight. As load increases and progressive overload occurs, optimizing recovery with 24-48 hours between strength training sessions is recommended.

Addressing limitations in soft tissue mobility of the UE is important to maintain the large ROM needed at the wrist,



Figure 4. Forearm stretching in elbow extension

elbow, and shoulder for participation in gymnastics. The latissimus dorsi and teres minor are commonly overdeveloped in gymnasts, so caution needs to be taken with UE pulling exercises and programming must include static stretching and eccentric exercises. Forearm muscle soft mobilization techniques should be followed by manual stretching of the wrist and fingers into full extension over the edge of the treatment table, while maintaining full elbow extension and supination, as pictured in [Figure 4](#). The goal is 100 degrees or greater of wrist extension with full elbow extension and supination to allow adequate mobility for full WB on the hands in closed chain activities.

To progress to Phase 4 of rehabilitation, a gymnast must demonstrate no adverse reactions to isolated elbow or compound UE strengthening, full elbow flexion extension PROM and AROM, and UE musculature graded at 5/5.

PHASE 4: ADVANCED/STRENGTH & CONDITIONING PHASE (WEEKS 12-28)

The primary goals during the Advanced/Strength and Conditioning phase are to build strength and power throughout the kinetic chain and to start an UE WB/traction progression. The axial WB and traction progression begins at 12 weeks pending proper bony integration shown on imaging and MD clearance. To gently introduce the radiocapitellar joint to compression forces, partial UE WB begins in a quadruped position, which is equivalent to 19% BW.¹⁹ Quadruped exercises start with multidirectional rocking with the palms flat or on top of dumbbells in a neutral wrist position. This can be progressed to variations of the bird dog exercise with alternating UE reaching at 32% BW and reciprocal arm and leg reaching at 34% BW.¹⁹ As seen in [Figure 5](#), the therapist can provide manual perturbations to challenge the stability of the surgical UE in single arm quadruped. Manual perturbations can be applied at the trunk and either UE to vary the dynamic challenge in single arm WB. Quadruped is progressed to a tall plank with UE on a 36-inch box. The box height decreases until the patient is



Figure 5. Single-arm quadruped with contralateral UE manual perturbation

able to demonstrate twenty pain-free alternating shoulder taps in a tall plank position.

It is the opinion of the authors that a strength symmetry index of at least 90% (using dynamometer testing and analysis of total lbs lifted during strength training) should be achieved between operative and non-operative UEs prior to starting higher level exercises such as push-ups, pull-ups, multidirectional plank walks, feet elevated rows, and handstand progressions. Emphasis is placed on single arm loading in the horizontal and vertical position. A handstand progression can begin with elevation of the legs in a tuck position on a box and progress to wall handstand taps as seen in [Figure 6](#). Push-ups can be started with hands elevated on a 11-inch box and progressed to the horizontal position. Traction forces can be introduced to the radiocapitellar joint with prolonged hanging on a bar and progressed to pull-ups. Traction forces are progressed from a supported hanging from a bar to a full hang, and then band assisted chin-ups and pull-up to prepare the joint for large UE traction forces sustained during uneven bars and parallel bars. If symptoms are provoked with the elbow in full extension and full supination, WB and traction exercises can be performed in a neutral grip position with WB on dumbbells and pull-ups in neutral grip. Additional traction and WB exercises are described in [Table 1](#), Weeks 12-26. When progressing exercises during this phase, traction exercises will be progressed faster than compression exercises as traction forces are not an inherent threat to the OATS graft. It is important to note that with adding and progressing UE WB and traction exercises, symptoms such as pain or swelling should not be present during, after, and the day following exercise.

By weeks 24-28, UE strength training is predominantly bilateral, plyometric movements are added, and vertical movements become more gymnastics specific such as handstands and rope climbs. The end of this strength and conditioning phase focuses on optimizing UE strength, speed, power, and endurance to improve the gymnastics-related capacity of the UE. Medicine ball slams and reverse throws can be utilized to mimic the UE demands of gymnastics



Figure 6. Wall handstand taps

skills that will be introduced in the next phase of rehabilitation. With progressing WB over the span of four months, there must be a strong foundation to reintroduce supra-physiological axial loading forces seen in gymnastics.^{10,20} The most physically challenging tests in this phase include handstands, pull-ups, and plyometric pushups, all of which are essential gymnastics skills.

To advance to Phase 5, gymnasts must continue to meet the listed requirements to progress to Phase 4, perform pain-free beginner to advanced traction and compressive forces, and show significant progress within the advanced strengthening phase. Symmetrical objective measures for strength with handheld dynamometry (shoulder, elbow, wrist, and grip) are recommended. Power measures include plyometric push-up (flight time using jump mat), weight/speed during velocity-based power exercises, and distance/force for medicine ball explosive throwing exercises (chest pass, overhead throw, standing slam).

A NOTE ON INITIATION OF UPPER EXTREMITY WEIGHT BEARING

The importance of proper UE WB progressions in rehabilitation of OCD cannot be overstated. Due to the pathophysiology of OCD associated with repetitive compressive stress to the radiocapitellar joint and a lack of evidence on UE WB recommendations following OATS in athletes, heightened caution must be taken when progressing WB. Guidelines can be based on the talocrural and tibiofemoral joints, but a conservative approach is most appropriate as the radiocapitellar joint is not typically a WB joint. Osteochondral dissecans is commonly found in ankles and knees of youth athletes and following OATS procedures partial WB begins at 6-10 weeks for ankles and 3-6 weeks for knees and full WB occurs by 6-12 weeks in ankles and 6-8 weeks in knees.^{3,21-24} A recent review article of elbow injuries in gymnasts, proposes that post-operative UE WB begins at 12 weeks. This is in line with current surgical guidance related to post-operative protocols. Sufficient rationale for this timeline is not clearly stated, but it is the opinion of the authors that the risks outweigh the benefits for starting WB earlier than 12 weeks.

Following an OATS procedure, WB is important to promote cartilage healing but only when dosed appropriately

during the rehabilitation process. The OATS graft implanted is intended to replace the OCD lesion as it is a healthy osteochondral fragment with viable cells. These cells respond well to mechanical stress and promote cartilage adaptations (osseointegration, revascularization, etc.), but both under-dosage and over-dosage of load can negatively impact cartilage health. Excessive early axial loading (i.e., 0-6 weeks during acute healing) can contribute to graft nonunion and/or necrosis and absence of load leads to tissue atrophy while significant delays in axial loading (20+ weeks) may result in failure to restore a fully integrated graft site with a robust tolerance for load.^{25,26}

In the absence of high-quality evidence for OCD in gymnasts, the authors conclude that controlled partial WB is the best way to initiate a WB progression for proper osteochondral integration of the OATS graft into the natural capitellum. Inappropriate WB progression can contribute to graft protrusion into the radiocapitellar space. When referencing distal humerus fracture literature, bony fragments heal in 6 to 8 weeks, thus it is hypothesized that a healthy OATS graft with an uncomplicated recovery will be adequately integrated within the capitellum by this same timeframe.^{27,28} However, to ensure bony integration and decrease the risk for failure in a pediatric population, four additional weeks are recommended. It is important to note that this recommendation is based on extrapolation of the best available scientific principles and clinical experience instead of empirical data. Future research is needed to confirm or deny the presented UE WB recommendations following an OATS procedure.

In the event an adverse reaction occurs following initiation of UE WB such as increased pain, swelling, or mechanical symptoms, WB should be delayed two to four additional weeks. If radiographic imaging reveals concerns for delayed healing of the graft, the surgeon states there were post-operative complications, or other setbacks occur during Phases 1-3, initiation of WB should also be delayed, and progression should be made on an individualized basis.

PHASE 5: RETURN TO RETURN TO SPORT (WEEKS 28-32)

The primary goals during the return to sport phase are to gradually return to gymnastics specific movements to facilitate safe RTS. Advanced progressions of compression and traction forces are prescribed and an interval return to gymnastic program is initiated (refer to [Table 2](#)). The interval return to gymnastics program includes safe progressions to gymnastics. Factors that are progressed include landing surface, force per skill, and repetitions per skill. By manipulating these variables, progressive overload to the radiocapitellar joint can occur for safe return to full gymnastics participation. The clinician must be knowledgeable regarding the variety of gymnastics equipment (tumbletrak, rod floor, strap bar, etc.), safety equipment (mats, low vs. high beam), level of coaching assistance (spotting), the gymnast's skill profile, and a typical frequency, duration, and structure of a gymnastics practice.

The return to sport phase is designed to rebuild the athlete's chronic workload and increase overall fitness level,

with the end goal of returning to a full training schedule. A strength and conditioning program is necessary three times per week with 24 hours of rest between bouts to promote recovery and time to monitor symptoms. Each case is unique but typically return to sport programs progress every two to four weeks for a total of eight to 16 weeks to return to prior level of training. As gymnastics is a highly individualized sport that can range from the recreational to elite level, the gymnast's age, skill level, and goals must be taken into consideration when creating a return to sport program.

CONSIDERATIONS FOR PROTOCOL ADAPTATIONS

A protocol is a framework that provides an evidence-based progression to return to sport, but each gymnast is unique so special considerations may alter this protocol. Factors include but are not limited to surgical technique, injury location, acuity, concomitant lesions, tissue quality, age, sex, skill level, and compliance to rehab program. In order to make a customized program for a gymnast following an OATS procedure, the authors recommend use of this evidence-based framework and emphasize the need for further research to fill in the gaps of knowledge on management of osteochondral lesions of the radiocapitellar joint in gymnasts.

ADDITIONAL CONSIDERATIONS

While research supports that the OATS procedure has the highest return to sport rate of all operative OCD treatments it is important to include that alternative treatments do exist.¹⁻⁴ Accordingly, a brief note on rehabilitation following microfracture/drilling is included. A protocol for non-operative OCD rehabilitation is located in the Appendix.

MICROFRACTURE/DRILLING PROTOCOL

A microfracture (drilling) procedure is an alternative technique to address a radiocapitellar lesion. A microfracture procedure does not implant a mature graft but instead attempts to stimulate the body to regenerate cartilage via bone marrow tenting, by drilling small holes into the bone. Rehabilitation after microfracture procedures limit excessive and/or aggressive ROM in the early phases and a WB progression as early as four months in uncomplicated cases. Practitioners may utilize the principles in and adjust this OATS rehabilitation protocol for microfracture/drilling, as long as these precautions are considered and the protocol is modified accordingly.

NON-OPERATIVE PROTOCOL (APPENDIX A)

In non-operative cases, delay of an UE WB progression to a minimum of six months is imperative. The OCD lesion must be given adequate time to heal prior to loading the radiocapitellar joint as the native OCD lesion is not well-adapted to repetitive load. Six months of rest from sports participation and weightlifting is recommended and then a strength and conditioning program can be initiated. If

symptoms persist for six months after treatment, a surgical consult is recommended.

CONCLUSION

This clinical commentary provides a comprehensive review of the current concepts and treatment of OCD in gymnasts. This evidence-based protocol can assist clinicians in post-operative rehabilitation to facilitate a safe and effective return to gymnastics. It is intended for reference by all providers involved in the rehabilitation process including, but not limited to surgeons, physicians, physical therapists, athletic trainers, and health professionals.

ACKNOWLEDGEMENTS

The authors would like to thank the staff at Champion Physical Therapy & Performance.

Submitted: August 13, 2025 CST. Accepted: December 12, 2025 CST. Published: February 01, 2026 CST.

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Table 1. OATS rehabilitation protocol for gymnasts

Phase 1: Acute Phase / Maximum Protection (Weeks 1-4)	
Goals	• Restore full elbow and wrist ROM • Decrease pain and swelling • Promote healing of articular cartilage • Prevent muscle atrophy
Days 1-5	• Begin gentle PROM of elbow to tolerance in bulky dressing • Effleurage massage for swelling management • Light soft tissue work to biceps, brachioradialis, FPM for tone reduction (avoid bandages or incisions) • Remove bulky dressing and replace with gauze pads & elastic bandages • Immediate post-op wrist and hand ROM, gripping exercises ◦ Putty/ball squeeze grip strengthening ◦ Wrist flexor stretching ◦ Wrist extensor stretching • Elevate hand/extremity to reduce swelling • Continue light elbow PROM exercises (3-4x/day)
Days 5-7	• PROM & AAROM elbow extension & flexion to tolerance (patient encouraged to perform on own every 1-2 hours) • Continue effleurage massage and soft tissue work as above • Begin wrist AROM exercises over edge of table ◦ Wrist curls ◦ Reverse wrist curls ◦ Neutral wrist curls (radial/ulnar deviation) ◦ Pronation/supination
Week 2-4	• Emphasis on elbow ROM, with goal of full passive extension by week 4 • Continue soft tissue work ◦ Biceps, triceps, wrist flexors and extensors ◦ Latissimus dorsi, teres major, pec major/minor and posterior RTC to increase shoulder flexibility • Begin light overpressure program into elbow extension if lacking by week 4 • Perform elbow PROM, progressing to AAROM, frequently during the day to promote articular cartilage healing (5-10 minutes every hour of the day) • Begin shoulder AROM program week 3 with elbow in available ROM or within restrictions if prescribed by the physician (in brace at home if needed for protection) • Progress wrist AROM exercises with 1lb weights • Thrower's Ten Program week 4 (can use ankle weights around wrist if concern for symptoms with gripping; excluding exercises that directly load the biceps or triceps)
Objective Criteria to Progress	• Full elbow extension ROM (within 5 degrees of non-surgical side) • No discomfort with ADL's • Minimal pain
Phase 2: Subacute Phase / Moderate Protection (Weeks 5-8)	
Goals	• Protect and promote articular cartilage healing • Restore/maintain full elbow flexion and extension PROM by week 6 • Restore shoulder ROM and strength
Week 5-6	• Continue to emphasize elbow ROM with goal of full flexion by week 6 • Continue all exercises above • If lacking full extension, continue LLPD stretching • Initiate sidelying AROM elbow flexion and extension in available ROM
Week 7-8	• Continue PROM & AAROM elbow exercises to promote articular cartilage healing (5-10 minutes every hour of the day) • Initiate antigravity AROM elbow flexion and extension in available ROM • Continue Thrower's Ten Program and scapular strength program ◦ Side-lying dumbbell ER, prone horizontal abduction at 90 and 120 degrees elevation, prone ER at 90 degrees of abduction, standing full can, resistance band external and internal rotation at 0 and 90 degrees shoulder elevation • Stretching & ROM program for shoulder with emphasis on restoring shoulder flexion ROM • Core strengthening program • Continue to maintain precautions regarding axial loading of the elbow • Initiate gentle traction forces ◦ Light elbow joint distraction mobilizations
Objective Criteria to	• No adverse events through the strengthening program

Progress	• Full/pain-free AROM and MMT 4+/5 strength of entire UE • No discomfort with ADL's
Phase 3: Intermediate Phase / Minimal Protection (Weeks 9-12)	
Goals	• Continue to promote articular cartilage healing • Protect elbow against excessive loading • Gradually progress UE strength and hypertrophy
Week 8-10	• Continue AROM elbow exercises to promote articular cartilage healing (2-3x/day) • Initiate light resistance for biceps and triceps: elbow flexion and extension with 1lb weights, progressing 1lb/week • Continue Thrower's Ten Program and shoulder PRE: emphasizing scapular and posterior RTC strengthening progressing 1lb/week • Continue stretching & ROM program for shoulder, emphasis on overhead shoulder elevation • Core strengthening program
Week 10-12	• Continue daily elbow ROM and flexibility program • Progress weight on Thrower's Ten Program • Shoulder ROM & stretching • Initiate light compound single arm horizontal pushing and pulling exercises ◦ Supine floor press, banded rows, angled band pull downs, overhead single arm dumbbell press • Core strengthening program • Running, agility drills, etc.
Objective Criteria to Progress	• Maintain same criteria from Phase 2 • Full/pain-free basic therapeutic exercise participation and MMT 5/5 strength of entire UE • Pain-free initiation of traction and compressive forces
Phase 4: Advanced / Strength and Conditioning Phase(Weeks 13-26)	
Goals	• Develop higher level fitness requirements for gymnastics-specific progressions • Begin gymnastics-specific conditioning • Rebuild general workload capacity and aerobic conditioning • Restore handstand, pull-up, and plyometric push-up
Weeks 12-14	• Continue elbow ROM program daily • Progress weights in Thrower's Ten Program • Shoulder ROM & stretching • Core strengthening program • Initiate WB per MD and clinical/imaging clearance ◦ Quadruped WB in neutral grip (on DB) with MD clearance ◦ Anterior/posterior, lateral, clockwise and counterclockwise circles on DB ◦ Angled box shoulder taps and weight shifting with caution to avoid excessive wrist extension in elbow extended position (progressing from 36 in to 12 in until tall plank position reached for 20 reps of shoulder taps) • Initiate traction force exercises using band assisted hanging • Continue wrist and finger eccentric manual strengthening drills
Weeks 14-16	• Continue elbow ROM program daily • Progress weights in Thrower's Ten Program • Shoulder ROM & stretching • Core strengthening program • Progress WB exercises over 2 weeks to full pronation and wrist/finger extension position ◦ Tripod to bird dog ◦ Push-up progressions starting on 24 in box/angled table • Progress traction force exercises ◦ Initiate full BW hanging progression ◦ Box/band assisted pull-ups with 25-50% BW in neutral grip (unload using leg assistance on box/bench, band, or partner spot) ◦ Progress to heavier manual eccentric flexor/pronator wrist and finger exercises ◦ Light suitcase/farmer carries with dumbbells or kettlebells • Initiate 90-90 dumbbell or kettlebell carries in the scapular plane
Weeks 16-18	• Continue Thrower's Ten Program • Continue stretching & flexibility exercises of elbow and shoulder • Progress WB exercises ◦ 12 in box push-ups, progress to floor push-ups ◦ Linear and lateral quadruped crawling ◦ 2-handed rubber medicine ball chest and overhead plyometrics

	• Initiate vertical WB progression ◦ Yoga push-ups (downward dog), progress to handstand shoulder taps with legs tucked on box • Progress traction force exercises ◦ Progress pull ups to use 25% BW or full BW ◦ Progress suitcase/farmer carry weight and duration ◦ Progress to heavy eccentric flexor/pronator wrist and finger exercises • Single arm cable or band pull downs at 120 degrees shoulder elevation
Weeks 18-22	• Continue Thrower's Ten Program • Continue stretching & flexibility exercises of elbow and shoulder • Progress WB ◦ Plyometric push-ups with hands on 24 in box/bench ◦ Initiate single hand medicine ball plyometric drills ▪ One-hand throws ▪ One-hand wall dribbles • Progress vertical WB ◦ Shoulder taps in pike handstand on box ◦ Handstand push-up added to top of yoga push-up on floor • Medicine ball slams and reverse throws • Progress loaded carries to overhead waiters walk (90 degrees scaption, 90 degrees elbow flexion) using DB or KB
Weeks 22-26	• Continue heavy manual eccentric forearm and elbow exercises • Progress WB ◦ Plyometric push-ups with feet on 12 in box • Progress vertical WB ◦ Handstand shoulder taps with 1ft elevated ◦ Handstand push-ups in tuck position on box • Progress traction forces ◦ Weighted pull-ups in various grips • BW rope climbs (start with using legs, progress to no legs) • Progress WB ◦ Plyometric push-ups on floor • Progress vertical WB ◦ Wall facing handstand holds ◦ Handstand push-ups in pike position on box ◦ Consider advanced loaded carries (Turkish Get-Ups) • Progress traction forces ◦ Single arm hanging, weighted rope climbs with advanced athletes • Advanced UE strength and conditioning program • Single arm horizontal pushing and pulling, single arm vertical pushing and pulling, advanced RTC strengthening
Objective Criteria to Progress	• Maintain same criteria from Phase 2 • All exercises are pain-free • Objective increases in UE strength, speed, power, and endurance
Phase 5: Return to Sport (Weeks 27 and beyond)	
Goals	• Gradual return to activity/sport via interval gymnastics program • Prepare patient for safe & successful return to sport
Weeks 26-28	• Progress vertical WB ◦ Handstand walks, wall walk-ups, lateral and anterior handstand walking • Progress traction forces ◦ Initiate strap bar/metal bar without heavy gripping if available in gym • Stage 1 of "interval return to gymnastics program" (Table 2) • Progress surface, force per skill, and total volume • Most gymnasts return to modified training at 6-7 months depending on the size and grade of initial lesion
Weeks 28-30	• Stage 2 of "interval return to gymnastics program" (Table 2) • Progress surface, force per skill, and total volume • Continue maintenance care of shoulder flexibility, shoulder strength, wrist flexibility
Week 32-34	• Stage 3 of "interval return to gymnastics program" (Table 2) • Once return to sport utilize maintenance care of rotator cuff and scapular program • Continue maintenance care of shoulder flexibility, shoulder strength, wrist flexibility

	• Progress surface, force per skill, and total volume
Week 34+	• Stage 4 of "interval return to gymnastics program (Table 2) • Most gymnasts on accelerated protocol return to competitive training at 8-9 months

Abbreviation: ROM (range of motion), PROM (passive range of motion), FPM (flexor pronator mass), AAROM (active assisted range of motion), AROM (active range of motion), LLPD (low load prolonged duration), MMT (manual muscle test), ER (external rotation), PRE (progressive resisted exercise), lb (pound), in (inches), ft (feet), reps (repetitions), BW (body-weight), dumbbell (DB), kettlebell (KB)

Table 2. Interval return to gymnastics program

Recommendation: Training should include 2-3 events/day for 3 days/week with 24 hours in between loading. The athlete should continue to follow by the recommendation of no more than 7 repetitions per skill set, per day. Home program/strength program should be done on non-loading days. Objective criteria to progress from each stage: • 2 weeks of pain-free training within each stage • General soreness resolving in <48 hours • No increase in swelling	
Stage 1	
Guidelines	• Floor ◦ Basic tumbling on soft surfaces (trampoline and Tumbl Trak) • Bars ◦ Basic swings on strap bar or low bar, drills on floor bar ◦ Initiate low bar or floor bar drills on two arms • Vault ◦ Basic vaulting drills and soft impact table entries • For male gymnasts, swings and static strength only ◦ No ring strength or heavy compression elements ◦ No above bar parallel bar work; only under bar work • For female gymnasts, non-impact beam skills only. ◦ No BHS based skills on hard beam ◦ No round off base
Stage 2	
Guidelines	• Floor ◦ Basic tumbling on medium surfaces (rod strip or semi-firm trampoline) • Bars (uneven and parallel) ◦ Advanced tumbling on soft surface (trampoline and Tumbl Trak) ◦ Kip cast handstands, giants, basic dismounts on bars ◦ Advanced one arm pirouetting skills on floor bar ◦ Progress to basic above bar compression skills and dismounts on parallel bars, and continue to advanced under bar work • Vault ◦ Basic vaulting skills on hard surface ◦ Table flipping elements on vault table ◦ Advanced vaulting skills with flipping on softer surface vault table • For male gymnasts, swings and static strength only ◦ Initiate basic ring strength holds with spot, initiate giant swings to handstand using straps or spot, initiate basic handstands and above ring holds ◦ Initiate basic press handstands, swing handstands, pirouettes, swing to basic dismounts • For female gymnasts, non-impact beam skills only. ◦ Initiate back walk overs, front walk overs on hard beam ◦ Initiate BHS on soft surface line, or beam with pad covering ◦ Initiate round off based skills, to basic dismounts if applicable
Stage 3	
Guidelines	• Floor ◦ Basic tumbling on hard surface ◦ Advanced tumbling on medium surface (Rod strip or semi-firm trampoline) • Bars ◦ Advanced one-arm pirouetting skills on bars ◦ Initiate release moves without regrasp, advanced dismounts to pit of soft surface • Vault ◦ Advanced vaulting skills with flipping ◦ Advanced twisting vaulting skills with flipping on softer surface • For male gymnasts, swings and static strength only ◦ Continue ring sequences and start giant swings if applicable. Progress all dismounts ◦ Initiate basic one arm parallel bars such as Stutz, Diamadov, Healy, etc. Progress all dismounts • For female gymnasts, non-impact beam skills only. ◦ Initiate back and front handsprings on hard surfaces in low volumes

	Progress round offs to dismounts
Stage 4	
Guidelines	- Floor - Advanced tumbling on hard surface - Bars - Advanced skills, releases with hand grasp, dismounts to semi-firm surfaces - Vault - Advanced vaulting skills with twisting - For male gymnasts advance ring, high bar parallel bar strength, giants, and dismounts to semi-firm surfaces - For female gymnasts, advance beam series and dismounts

Abbreviation: BHS (back handspring)



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SUPPLEMENTARY MATERIALS

Appendix

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