



Management of Osteochondritis Dissecans of the Knee¹

in children and young adults ages 5 through 18 years

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Target Population

Inclusions: Children or young adults:

- with stable Osteochondritis Dissecans (OCD) of the patellofemoral or tibiofemoral joints
- ages 5 to 18
- who are skeletally immature and mature

Exclusions: Children or young adults:

- following surgical management of OCD lesion
- with an unstable OCD lesion with articular cartilage injury
- with OCD of the capitellum
- with OCD of the talus

Target Users

- Physical Therapists
- Physicians
- Other healthcare professionals
- Patients and families may find this information useful
- Coaches may find this information useful

Introduction

References in parentheses () Evidence strengths in [] (See last page for definitions)

Osteochondritis Dissecans (OCD) refers to a lesion or injury of the subchondral bone, the area of bone just beneath the articular cartilage surface, and may or may

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not involve the integrity of articular cartilage (Detterline 2008 [5], Kocher 2006 [5], Glancy 1999 [5], Cahill 1995 [5]). OCD is an idiopathic lesion and the specific etiology is not known (Detterline 2008 [5], Kocher 2006 [5], Wall 2003 [5]).

OCD of the knee is an increasingly common cause of knee pain and dysfunction among children, adolescents and young adults (Kocher 2006 [5], Local Consensus [5]). The long-term sequelae of juvenile OCD may contribute to further joint damage and premature development of osteoarthritis (Detterline 2008 [5], Kocher 2006 [5], Wall 2003 [5], Twyman 1991 [5]). This guideline was developed based on current evidence that exists on the management and treatment of OCD, subchondral bone and articular cartilage injuries. Recommendations for progression of the young individual through phases of treatment, from initial presentation to return to activity, are based on the understanding of joint biomechanics and tissue properties that contribute to the healing of the lesion and surrounding tissues (Local Consensus [5]).

Generally, studies show that juvenile OCD lesions with intact articular cartilage have the greatest healing potential without surgical intervention (Jurgensen 2002 [2a], De Smet 1997 [3a], Hughes 2003 [4a]). However, there is large variation among the non-surgical management approaches for individuals with OCD lesions (Local Consensus [5]). A comprehensive rehabilitation program and plan of care is developed on an individual basis to maximize outcomes (Local Consensus [5]). As such, early entry into physical therapy can safely address impairments while protecting the healing structures, and then appropriately advance the individual toward return to previous functional activities (Local Consensus [5]).

Successful non-operative management of a young individual with an OCD lesion necessitates adherence to a systematic and criterion-based progression of interventions that facilitates the therapeutic advancement (Local Consensus [5]). The progression of interventions from early management through return to activity is outlined in the section, "Guideline Recommendations." The rationale and key principles that guide the rehabilitation progression in this guideline are summarized in the section, "Key Principles for Clinical Decision Making."

Objectives of this guideline are to:

- guide and promote consistency in the delivery of physical therapy services
- promote long-term joint integrity and maximize healing
- minimize impairment and optimize function
- maintain and improve patient and family satisfaction

Guideline Recommendations

Overall Considerations

1. It is recommended that a thorough history and clinical examination be completed for each individual to establish an accurate differential diagnosis, and to develop an individualized and comprehensive rehabilitation plan (*Reinold 2006 [5], Wilk 2006 [5], Local Consensus [5]*).
 - See Tables 1 and 2 for recommendations regarding components of the history and clinical examination
 - Further information may be necessary for accurate differential diagnosis and establishing plan of care.
2. It is recommended that the advancement through the phases of rehabilitation rely on a criterion-based rather than a time-based progression (*Local Consensus [5]*).
3. It is recommended that all decisions be made with open communication between the healthcare team and the individual and family to ensure effective collaboration with the plan of care (*Local Consensus [5]*).
4. It is recommended that throughout the rehabilitation process, the individual and family receive instruction regarding the nature of the injury and risks of further injury (*Local Consensus [5]*).
5. It is recommended that the following precautions and red flags prompt communication with the referring physician and medical team throughout each phase of rehabilitation (*Local Consensus [5]*).
 - unchanging or increased irritability
 - persistent or recurring effusion
 - mechanical block or joint locking
 - unexpected loss of range of motion (ROM)
 - persistent pathological end feel with passive motion

Table 1: Components of physical therapy evaluation and re-assessment (*Local Consensus [5]*)

Physical Therapy Evaluation: Subjective Information	
Understanding of the mechanism of injury and the patient/family goals for therapy will serve to develop an individualized rehabilitation plan to maximize outcomes (<i>Reinold 2006 [5], Wilk 2006 [5], Local Consensus [5]</i>).	
Information from referral source	<ul style="list-style-type: none"> • Restrictions • WB status • Bracing • Information about lesion: <ul style="list-style-type: none"> ○ location ○ size, depth ○ tissues involved
History	<ul style="list-style-type: none"> • Onset and mechanism of pain/injury • PMH • Medications • Activity level • Patient/family goals
Pain	<ul style="list-style-type: none"> • Onset • Description • Location: <ul style="list-style-type: none"> ○ report ○ palpation • VAS: best, worse, current scores
Patient/family education	<ul style="list-style-type: none"> • Promote understanding of injury and nature of pathology • Promote understanding of rehabilitation progression • Promote cooperation with rehabilitation program

PMH = past medical history; VAS = visual analog scale; WB = weight-bearing

Table 2: Components of physical therapy evaluation and re-assessment (Local Consensus [5]), not all components are required or are appropriate at time of initial evaluation.

Physical Therapy Evaluation: Clinical Examination	
Assessing the mechanism of injury, including contributing factors at the knee and associated lower extremity/trunk contributions, will serve to develop an individualized rehabilitation plan to maximize outcomes (Reinold 2006 [5], Wilk 2006 [5], Local Consensus [5]).	
Observation	<ul style="list-style-type: none"> ● Trunk, pelvis, lower extremity alignment
Palpation	<ul style="list-style-type: none"> ● Assess pain (VAS)
Effusion	<ul style="list-style-type: none"> ● Girth measures
ROM	<ul style="list-style-type: none"> ● Hip/ankle screen ● Tibiofemoral: AROM, PROM ● Joint mobility: patellofemoral and tibiofemoral ● Flexibility: contributions of muscles crossing the pelvis, hip, knee and ankle
Strength	<ul style="list-style-type: none"> ● MMT: trunk (core), hip, knee, ankle ● Dynamometry: quadricep femoris and hamstring muscles (isometric or isokinetic)
Balance	<ul style="list-style-type: none"> ● Star Excursion Balance Test (Plisky 2006 [2a], Kinzey 1998 [3a]) ● Postural stability (stabilometer) ● SL balance (assess performance (time) and quality)
Functional Tests	<ul style="list-style-type: none"> ● Patient-reported outcome measures: <ul style="list-style-type: none"> ○ validated and reliable general health measure, such as PedsQL™ physical functioning component ○ validated and reliable knee specific measure, such as IKDC Subjective Knee Evaluation Form ● Gait assessment: walk, jog, run, stair negotiation ● Performance-based assessments (assess performance and quality of movement)*: <ul style="list-style-type: none"> ○ DL/SL squats, heel raises, ○ drop vertical jump assessment ○ tuck jump assessment ○ SL hop tests
Sport specific tasks	<ul style="list-style-type: none"> ● Sport specific drills*

AROM = active range of motion; DL = double limb; IKDC = International Knee Documentation Committee; MMT = manual muscle test; PedsQL™ = Pediatric Quality of Life Inventory; PROM = passive range of motion; ROM = range of motion; SL = single limb; VAS = visual analog scale, *See companion guideline, Evidence-based Care Guideline for Return to Activity

Phases of Rehabilitation

See the Appendix for a summary of the remaining recommendations. In the section that follows these recommendations “Key Principles in Clinical Decision Making” provide a rationale for these recommendations (see page 6).

Initial Phase

Interventions

- It is recommended that the following interventions be used to reach goals of the Initial Phase:
 - presence of pain and effusion:
 - cryotherapy (Singh 2001 [2a], Rice 2009 [3a], Meeusen 1986 [5], Local Consensus [5])
 - in conjunction with compression (including intermittent compression devices) and elevation (Local Consensus [5])
 - electrical stimulation (Robinson 1995 [5])
 - sensory or motor level
 - Oral analgesics, with consideration for tissue healing, may be prescribed by the referring physician (Local Consensus [5])
 - altered weight-bearing (WB) and joint loading (Behrens 1989 [4a], Vanwanseele 2002 [5], Local Consensus [5])
 - weight-shifting activities
 - gait training activities
 - joint immobilization, such as casting or bracing, may be considered on an individual basis to encourage compliance with activity restrictions (Local Consensus [5])
 - consider potential detrimental effects of immobilization on cartilage healing, see “Key Principles for Clinical Decision making, Principles of Healing”
 - impaired ROM
 - ROM activities (Behrens 1989 [4a], Wilk 2006 [5], Vanwanseele 2002 [5], Local Consensus [5]): PROM, AAROM, AROM (Table 3)
 - joint mobilizations (Local Consensus [5])
 - stretching of lower extremity musculature (Local Consensus [5])
 - impaired strength and muscle performance
 - neuromuscular electrical stimulation (NMES) of quadriceps femoris (QF) muscles (Snyder-Mackler 1995 [2a])
 - progressive resistive exercises (PRE) within WB restrictions (Ganley 2006 [5], Wilk 2006 [5], Local Consensus [5])
 - open and closed kinetic chain

- incorporate strength activities for hip and ankle musculature with a focus on QF muscles and muscles about the knee
- core muscle strengthening (*Reinold 2006 [5], Local Consensus [5]*)
- impaired neuromuscular control
 - activities to facilitate volitional lower extremity muscle activation with minimal compensations (*Local Consensus [5]*)
 - balance and proprioception activities within WB restrictions (*Reinold 2006 [5], Wilk 2006 [5], Local Consensus [5]*)

- demonstrate appropriate lower extremity volitional muscle activation with therapeutic activities

Intermediate Phase

Interventions

8. It is recommended that the following interventions be used to reach goals of the Intermediate Phase:
 - presence of pain and effusion (as necessary):
 - cryotherapy in conjunction with compression and elevation (*Singh 2001 [2a], Rice 2009 [3a], Meeusen 1986 [5], Local Consensus [5]*)
 - electrical stimulation (*Snyder-Mackler 1995 [2a], Robinson 1995 [5]*)
 - sensory or motor level
 - altered WB and joint loading
 - gait training activities (*Behrens 1989 [4a], Vanwansseele 2002 [5], Local Consensus [5]*)
 - concurrently progress joint loading and strength/neuromuscular control activities (below)
 - impaired ROM
 - ROM activities: AAROM, AROM (*Wilk 2006 [5]*) (Table 3)
 - stretch lower extremity musculature (*Local Consensus [5]*)
 - impaired strength and muscle performance
 - NMES of QF muscles (*Snyder-Mackler 1995 [2a]*)
 - progress intensity of lower extremity PRE (*Ganley 2006 [5], Wilk 2006 [5], Local Consensus [5]*)
 - open kinetic chain (OKC) and closed kinetic chain (CKC)
 - focus on QF and muscles about the knee
 - introduce functional strengthening activities (*Ganley 2006 [5], Wilk 2006 [5], Local Consensus [5]*)
 - progress activity intensity, for example progress from double limb (DL) to single limb (SL)
 - initiate and progress CKC strengthening activities in conjunction with joint loading activities (*Local Consensus [5]*).
 - progress core muscle strengthening (*Reinold 2006 [5], Local Consensus [5]*)
 - impaired neuromuscular control
 - emphasize appropriate technique during all OKC and CKC activities (*Local Consensus [5]*)

Table 3: Range of Motion definitions

AROM	Active range of motion
Joint movements performed and controlled solely by the voluntary muscular efforts of the individual without the facilitation of external forces; the individual is independent in this activity.	
AAROM	Active assistive range of motion
Joint movement performed and controlled, in large or small part, by the voluntary muscular efforts of the individual combined with the assistance of an external force (e.g., assistance from another body part, another person, or a mechanical device).	
PROM	Passive range of motion
Joint movement performed and controlled solely by the efforts of an external force without the use of voluntary muscular efforts of the individual.	

Goals

7. It is recommended that the following goals be met for advancement from Initial to Intermediate Phase (*Local Consensus [5]*):
 - pain and effusion: minimal
 - weight-bearing and joint loading (with or without assistive device):
 - maintain at least partial WB status without adverse effects
 - demonstrate normalized gait mechanics (*Perry 1992 [5]*)
 - ROM: 0° to 120°
 - joint mobility symmetrical with uninvolved
 - strength and muscle performance:
 - sufficient volitional QF muscle activation to maintain straight leg raise with negative lag sign (for at least 10 seconds)
 - Manual Muscle Test (MMT) grade, QF = 4-5
 - neuromuscular control:

- minimize compensation patterns
- promote core muscle stability
- balance training (*Reinold 2006 [5], Wilk 2006 [5], Local Consensus [5]*)
 - decrease base of support (DL to SL)
 - introduce external perturbations
 - progress planes of movement (from sagittal to incorporate coronal and transverse)
 - extend limits of stability
 - introduce anticipation strategies
 - manipulate support surface from stable to unstable
- progress functional strengthening activities (*Reinold 2006 [5], Wilk 2006 [5], Local Consensus [5]*)
- activity progressions (*Local Consensus [5]*)
 - decrease base of support (from DL to SL)
 - progress planes of movement (single plane to multiple planes)
 - manipulate support surface (from stable to unstable)
 - intensity, frequency, duration (increasing)
- impaired neuromuscular control
 - progress closed kinetic chain functional activities with focus on technique
 - initiate impact, plyometric and sport-specific activities with focus on movement technique (*Local Consensus [5]*)
 - initiate with sub-maximal effort DL activities
 - emphasize force attenuation strategies
 - with activity progression, focus on performance and power generation during take-off phase
 - progress all above activities when consistent demonstration of appropriate technique exists (*Local Consensus [5]*)
 - decrease base of support (from DL to SL)
 - progress planes of movement (incorporate lateral and rotational planes and multi-plane activities)
 - progress anticipation strategies (unanticipated movements)
 - extend limits of stability and progress perturbations
 - manipulate support surface (stable to unstable)
 - intensity, frequency, duration (increasing)

Goals

9. It is recommended that the following goals be met for advancement from Intermediate to Advanced Phase (*Local Consensus [5]*):

- pain and effusion: minimal
- weight-bearing and joint loading (without an assistive device):
 - maintain full WB status and independent ambulation without adverse effects
 - demonstrate normalized mechanics (*Perry 1992 [5]*) with independent ambulation
- ROM: full AROM, symmetrical with contralateral knee
- strength and muscle performance:
 - MMT score of 4+/5 for hip, knee, and core strength
- neuromuscular control:
 - demonstrates appropriate mechanics during all OKC and CKC activities
 - maintains SL balance on unstable surface, symmetrical with uninvolved

Advanced Phase

Interventions

10. It is recommended that the following interventions be used to reach goals of the Advanced Phase:

- presence of pain and effusion:
 - address as necessary
- altered weight-bearing and joint loading:
 - initiate jogging and return to running program (*Local Consensus [5]*)
- impaired ROM
 - continue lower extremity stretching, as necessary (*Local Consensus [5]*)
- impaired strength and muscle performance:

Goals

11. It is recommended that the following goals be met for transition from the Advanced Phase to the companion guideline, Evidence-based Care Guideline for Return to Activity (see Appendix) (*Local Consensus [5]*).

- pain and effusion: none
- weight-bearing and joint loading:

- demonstrate normalized gait and jogging mechanics
- ROM: full AROM, symmetrical with uninvolved
- strength and muscle performance:
 - Quadriceps Index (QI) ≥ 85%
 - $QI = (\text{involved force output} / \text{uninvolved force output}) * 100\%$
 - Measured with dynamometer
 - MMT = 5/5 for lower extremity and core musculature
- neuromuscular control:
 - demonstrate appropriate mechanics and force attenuation strategies with high-level impact and plyometric activities
- additional goals:
 - report International Knee Documentation Committee (IKDC) Subjective Knee Evaluation Form score ≥ 85%
 - demonstrate performance on SL hop tests within 85% of the uninvolved limb

Advancement to Return to Activity phase

Successful attainment of the goals for the Advanced Phase is used as an indication of the individual’s readiness to re-integrate into higher level activities (see Appendix). This does not suggest readiness for full, unrestricted activity participation.

12. It is recommended that progressive re-integration into activities be conducted according to the companion guideline, Evidence-based Care Guideline for Return to Activity (*Local Consensus [5]*).

Key Principles for Clinical Decision Making

Principles of Healing

- A benefit of this care guideline is consideration for the healing properties of the injured tissue to promote long term joint integrity (*Local Consensus [5]*).
- A benefit of this care guideline is facilitation of healing by promoting cartilage and bone health and avoiding potentially deleterious forces at the lesion site (*Reinold 2006 [5], Local Consensus [5]*) (Table 4).
- Protecting the involved joint during the early phases of healing is paramount for successful rehabilitation (Table 4) (*Local Consensus [5]*).
 - In some cases, joint immobilization, such as casting or bracing, may encourage compliance with activity restrictions.

- However, it is a risk that prolonged immobilization can have detrimental effects to the healing tissues, including: flattening of articular surface, non-contact area degeneration and inhibition of chondrogenesis, and intra-articular adhesions (*Behrens 1989 [4a], Vanwanseele 2002 [5], Sood 1971 [5]*)
- A side effect of prolonged immobilization is that adverse effects may persist even after the period of immobilization (*Sood 1971 [5]*)

Table 4: Principles of Healing

Rehabilitation is guided by principles that promote integrity and healing of involved tissue, surrounding articular cartilage, and bone.	
Protect healing tissues during early phases of rehabilitation	<ul style="list-style-type: none"> ● A period of protected activity will minimize stress and mitigate risk of further articular cartilage breakdown. ● Emphasize controlled joint loading and ROM for nourishment of healing tissues (<i>Buckwalter 1998 [5]</i>). <ul style="list-style-type: none"> -synovial fluid flow -stimulation of cartilage matrix production
Minimize pain and effusion	<ul style="list-style-type: none"> ● Persistent pain and effusion contributes to elevated intra-articular joint temperature associated with stimulation of proteolytic enzyme activity (<i>English 1997 [5]</i>). ● Prolonged increase in proteolytic enzyme activity may have a detrimental effect on articular cartilage healing (<i>English 1997 [5]</i>). ● Control of joint pain and effusion are a primary focus during the early phases of rehabilitation, the assessment and management of these impairments persists throughout the rehabilitation process.
Promote controlled joint loading throughout rehabilitation	<ul style="list-style-type: none"> ● A delicate balance between protecting the injured site from potentially damaging forces while exposing the healing tissues to sufficient levels of joint compression. ● Criterion-based progression of joint loading will maximize the healing and accommodation of subchondral bone, articular cartilage, and surrounding tissue to environmental demands. ● Joint compression and decompression (<i>Behrens 1989 [4a], Vanwanseele 2002 [5]</i>) <ul style="list-style-type: none"> -facilitates nourishment of articular cartilage -stimulates bone and tissue remodeling to accommodate environmental demands. ● Advancement of weight-bearing and CKC activities <ul style="list-style-type: none"> -gradual introduction of forces -controlled progression of loading

CKC = closed kinetic chain; ROM = range of motion

Patient Considerations

- For optimal rehabilitation outcomes, the specific location and size of the lesion, and the integrity of the surrounding tissues, is considered within the context of the biomechanics of the tibiofemoral or patellofemoral joints (*Reinold 2006 [5], Wilk 2006 [5], Local Consensus [5]*).
 - Rehabilitation for an individual with a lesion on a weight-bearing articular surface will necessitate a modified approach and slower progression compared to an individual with a lesion in a non-articulating location (*Wilk 2006 [5], Local Consensus [5]*)
 - Rehabilitation progression for an individual with a patellar surface lesion will be guided by the lesion location with respect to contact forces between the patella and femur during therapeutic activities (*Wilk 2006 [5], Local Consensus [5]*)
- A benefit of this care guideline is that the rehabilitation program is guided by the individual's unique characteristics and attributes within the context of their injury (*Local Consensus [5]*)
 - Physical characteristics (i.e. anatomical alignment, severity of impairments, skeletal age, body mass, injury history)
 - Psychosocial attributes (i.e. motivation, maturity level, activity level prior to injury, patient and family goals, kinesthetic awareness and environment, fear avoidance behaviors or kinesiophobic patterns)
- A benefit of this care guideline is the emphasis of patient and family education during the entire rehabilitation process. In the development of this care guideline, informal input from individuals and families suggested the importance of patient and family education for effective cooperation with the plan of care (*Local Consensus [5]*)

Impairments

- Utilizing *The Guide to Physical Therapist Practice* (*APTA 2001 [1b]*), individuals with OCD lesions may be classified into multiple practice patterns, specifically Musculoskeletal Patterns 4D/4E which specify “Impaired joint mobility, motor function, muscle performance, and ROM associated with connective tissue dysfunction/localized inflammation”.
- Within the framework of these practice patterns (*APTA 2001 [1b]*) addressing the following impairments in individuals with OCD lesions, will maximize rehabilitation outcome (*Behrens 1989 [4a], Gill 2006 [5], Vanwanseele 2002 [5], Sood 1971 [5], Local Consensus [5]*):
 - presence of pain and effusion

- impaired range of motion
- altered weight-bearing and joint loading
- impaired muscle strength and performance
- impaired neuromuscular control
- For each impairment, the rationale for progression through the rehabilitation program is provided below.
- Severity of impairments will vary among patients, individualized care will promote maximum outcomes (*Local Consensus [5]*).
- Throughout this guideline, therapeutic activity demands are adjusted according to the magnitude, direction and duration of forces and loading across the knee in order to ensure adequate of accommodation of involved tissues necessary for progression (*Local Consensus [5]*).
 - Severity and irritability of joint symptoms provide clinical markers for appropriate activity progression
- Following successful resolution of impairments a companion guideline, Evidence-based Care Guideline for Return to Activity is available for progressive re-integration into pre-injury activities (*Local Consensus [5]*).

a. Pain and Effusion Control

- The presence of pain and effusion at the knee may elicit an arthrogenic reflex that inhibits volitional quadriceps motor activity (*Rice 2009 [3a], Spencer 1984 [4a]*)
 - Cryotherapy reduces inhibition of quadriceps femoris muscle motor activity (*Rice 2009 [3a]*).
- Persistent pain and joint effusion contributes to the side effect of elevated intra-articular joint temperature and increased proteolytic enzyme activity (*Osahr 2002 [3a], Haimovici 1982 [4a]*), which may negatively affect articular cartilage healing (*English 1997 [5]*).
 - Immediate and frequent utilization of cryotherapy may address above adverse effects (*Singh 2001 [2a], Meeusen 1986 [5], Local Consensus [5]*).

b. Impaired Range of Motion

- It is a risk that prolonged immobilization may be detrimental to the health and healing of cartilage (*Gill 2006 [5], Sood 1971 [5]*).
- A benefit of this care guideline is the emphasis on early ROM which enhances nutrition and metabolic activity of articular cartilage, stimulates differentiation, and accelerates healing of articular and periarticular tissues (*Behrens 1989 [4a], Gill 2006 [5], Vanwanseele 2002 [5], Sood 1971 [5]*).

- Gradual progression of range of motion will minimize the negative side effects of pain elevation, muscle guarding, and joint inflammation (*Local Consensus [5]*). See Table 3 for ROM definitions.

c. Altered Weight-Bearing and Joint Loading

- During initial phases of rehabilitation, WB progression is guided by principles that promote the health and healing of the involved tissue, as well as the surrounding articular cartilage and bone (*Local Consensus [5]*).
- A risk of prolonged unloading of healing articular cartilage may result in proteoglycan loss and weakening of the cartilage structure (*Behrens 1989 [4a]*, *Vanwanseele 2002 [5]*, *Haapala 2000 [5]*).
- A risk of exposure of articular cartilage to excessive compressive or shear forces may result in tissue damage (*Setton 1995 [4a]*, *Radin 1991 [4a]*, *Radin 1971 [4a]*).
- Optimal joint compression and decompression forces are achieved via joint motion, muscle activation and controlled progression of WB and joint loading (*Local Consensus [5]*).
- A benefit of this care guideline is the gradual introduction of forces to the injured site and surrounding tissues, promoting a balance between protecting the injured site from potentially damaging forces while exposing the tissues to sufficient joint compression/loading
 - shown to stimulate matrix production and improve tissue mechanical properties (*Waldman 2003 [3a]*, *Buckwalter 1998 [5]*, *Buckwalter 1994 [5]*).
 - facilitate synovial fluid flow and stimulate metabolic activity for articular cartilage and bony healing (*Waldman 2003 [3a]*, *Buckwalter 1998 [5]*, *Local Consensus [5]*)
- Throughout rehabilitation, controlled WB and joint loading will facilitate nourishment of the articular cartilage and will appropriately stimulate involved tissues to accommodate to environmental and activity demands (*Behrens 1989 [4a]*, *Vanwanseele 2002 [5]*).
- Weight-bearing modifications will differ for each individual and the use of assistive devices, such as axillary crutches, may be used to limit joint loading.

- Safe progression of joint loading during ambulation requires that the patient demonstrate (*Local Consensus [5]*)
 - proper gait mechanics with appropriate accommodation of environmental demands
 - absence of adverse symptoms (i.e. increased effusion) following exposure to increased joint loading.
- Joint loading is progressed from ambulation with bilateral crutches, to ambulation with one crutch, and then to independent ambulation (*Local Consensus [5]*).
- Prior to each transition, demonstration of a correct gait pattern includes the following (*Local Consensus [5]*):
 - ability to accept weight onto involved limb according to WB status
 - a heel strike-toe off pattern
 - knee extensor control at loading and mid-stance
 - near symmetry in step length
 - sufficient knee flexion and ankle push-off at pre-swing.

d. Impaired Strength and Muscle Performance

- Individuals will benefit from muscle strengthening activities that include open and closed kinetic chain activities with consideration for the lesion size/location, joint mechanics, and activity demands (*Wilk 2006 [5]*, *Local Consensus [5]*).
- A benefit of this care guideline is the promotion of proper muscle activation, joint mechanics and technique, with minimal compensation patterns, during all strengthening activities (*Ganley 2006 [5]*, *Wilk 2006 [5]*, *Local Consensus [5]*)
 - for example, demonstration of appropriate eccentric action of the QF muscles during DL or SL squat activities
- During all phases of rehabilitation, this care guideline emphasizes QF muscle strengthening and performance activities due to (*Local Consensus [5]*):
 - Quadriceps femoris muscles largely contribute to force production and force dissipation at the knee (*Mikesky 2000 [4a]*, *Local Consensus [5]*)

- Quadriceps femoris muscle disuse atrophy and inhibition are common (*Local Consensus [5]*) in this patient population
 - Use of NMES in conjunction with therapeutic exercise improved QF muscle strength and activation deficits beyond therapeutic exercise alone (*Snyder-Mackler 1995 [2a]*)
- Individuals will benefit from a comprehensive approach that addresses strength and muscle performance deficits of the entire lower extremity (*Local Consensus [5]*).
- Hip and core muscle strengthening and stabilization activities are incorporated throughout the program due to the contribution of the hip and trunk in knee joint mechanics (*Reinold 2006 [5], Local Consensus [5]*).
- Initial activities target individual muscle groups and are progressed to challenge multiple trunk and lower extremity muscle groups simultaneously (*Local Consensus [5]*).
- Closed kinetic chain strengthening activities can be initiated and progressed in conjunction with joint loading activities (*Local Consensus [5]*).

e. Impaired Neuromuscular Control

- Neuromuscular control is defined as an interaction of the sensory and motor systems to anticipate or respond to proprioceptive and kinesthetic information in order to produce coordinated movements (*Kisner 2007 [5]*).
- Neuromuscular control is an interconnected component of human movement, and the neuromuscular re-education intervention strategies may also address other impairments discussed in this guideline. Multiple factors contribute to neuromuscular control (*Local Consensus [5]*):
 - strength
 - proprioception
 - balance
 - coordination
 - postural stability
 - core stabilization
 - dynamic stabilization
 - power generation and absorption
- Theories underlying the principles of the development/retraining of neuromuscular

control are founded in the principles of motor learning and skill acquisition. Specific factors influencing the acquisition and/or reacquisition of a skill include manipulation of:

- amount of practice
- feedback provided
- part-task and whole-task practice
- accuracy versus speed
- environment (*Fredricks 1996 [5]*)
- A benefit of this care guideline is that throughout rehabilitation, activities that challenge the neuromuscular system are manipulated according to the motor learning principles above in order to facilitate retention and transfer of training effects from controlled clinical environments, to activities of daily living, and to high-level and sports activities (*Local Consensus [5]*).
- A benefit of this care guideline is the approach and focus on plyometric and sport-specific training which has been shown to
 - stimulate proprioceptors of muscles, tendons, ligaments, and joints (*Kisner 2007 [5]*)
 - improve the reactivity of the neuromuscular system (*Kisner 2007 [5]*)
 - decrease the incidence of lower extremity injury, increase dynamic knee stability, and improve performance (*Hewett 1999 [3a]*).

Future Research Agenda

Suggestions for further research in this area include:

- Determining the prevalence and incidence of OCD lesions in children and adolescents
- Determining the etiology and risk factors associated with OCD lesions in children and adolescents
- Determining the harmful and beneficial effects of stress and loading on healing bone and articular cartilage tissues
- Determining the forces and loads borne by bony and articular cartilage tissues imposed during various therapeutic activities/exercises and activities of daily living/recreational activities
- Determining the effectiveness of current and new rehabilitation approaches to maximize outcomes and minimize risk of secondary injury for children and adolescents with OCD lesions

- Determining appropriate objective criteria for safe rehabilitation progression and readiness for return to high-level activities for children and adolescents with OCD lesions
- Determining the long-term outcomes and risk of secondary injuries for children and adolescents with OCD lesions

Appendix – Impairments through the phases of rehabilitation

Phase:	Initial	Intermediate	Advanced
<i>Impairment:</i> Pain/Effusion	Interventions: <ul style="list-style-type: none"> • Cryotherapy • Compression • Elevation • Electrical stimulation 	<ul style="list-style-type: none"> • Continue to assess, address as necessary 	<ul style="list-style-type: none"> • Continue to assess, address as necessary
<i>Impairment:</i> Impaired WB and Joint Loading	Interventions: <ul style="list-style-type: none"> • Weight-shifting activities • Gait training activities <p>Progression Criteria NWB to PWB:</p> <ul style="list-style-type: none"> • Knee ROM 0 to 120° • Straight leg raise with negative lag sign • MMT grade = 4-/5 • Minimal knee effusion • Demonstrate appropriate weight-shift onto involved LE 	Interventions: <ul style="list-style-type: none"> • Gait training activities • Progress joint loading <p>Progression Criteria PWB to FWB:</p> <ul style="list-style-type: none"> • Full knee AROM • Normalized gait mechanics • No change in pain and effusion symptoms with increased joint loading 	Interventions: <ul style="list-style-type: none"> • Initiate jogging • Return to running progression
<i>Impairment:</i> Impaired ROM	Interventions: <ul style="list-style-type: none"> • Early ROM (PROM/AAROM/AROM) • Joint mobilizations • LE muscle stretching 	Interventions: <ul style="list-style-type: none"> • Knee AAROM, AROM • Stretching of LE musculature 	Interventions: <ul style="list-style-type: none"> • Muscle flexibility: continue LE stretching activities within the full ROM
<i>Impairment:</i> Impaired Muscle Strength and Performance	Interventions: <ul style="list-style-type: none"> • Hip, knee and ankle PRE • NMES • Core strengthening activities 	Interventions: <ul style="list-style-type: none"> • OKC and CKC hip, knee and ankle PRE (progress intensity and task demands) • Functional strengthening activities (DL progressing to SL; progress intensity and task demands) • Core strengthening activities (progress task demands) 	Interventions: <ul style="list-style-type: none"> • Progress functional strengthening activities in terms of task demands and effort

Phase:	Initial	Intermediate	Advanced
<i>Impairment:</i> Impaired Neuromuscular Control	Interventions: <ul style="list-style-type: none"> • Facilitate volitional muscle activation • Balance and proprioception activities 	Interventions: <ul style="list-style-type: none"> • Technique training, minimize compensations • Progress balance and proprioception activities 	Interventions: <ul style="list-style-type: none"> • Initiate plyometric activities with focus on technique • Progress plyometric activities in terms of task demands and effort
<p>Advancement to Return to Activity phase (see companion guideline, Evidence-based Care Guideline for Return to Activity): Successful attainment of the following goals (local consensus [5]) indicates readiness to re-integrate into sport and high-level activities per the Evidence-based Care Guideline for Return to Activity. This does not suggest readiness for full, unrestricted activity participation.</p> <ul style="list-style-type: none"> • Previous goals for rehabilitation progression are achieved • Demonstrate quadriceps femoris and hamstrings muscle strength $\geq 85\%$ of the uninvolved (measured with dynamometer) • IKDC Subjective Knee Evaluation Form score ≥ 85 • Demonstrate performance on SL hop tests (Noyes 1991 [3a]) within 85% of uninvolved (Limb Symmetry Index ≥ 85) • Demonstrate appropriate mechanics during activity-specific maneuvers 			
<p>Discharge criteria:</p> <ul style="list-style-type: none"> • Successful completion of Return to Activity care guideline • If not returning to high-level or sport activities, successful attainment of above criteria for Advancement to Return to Activity 			

AAROM = active assisted range of motion; AROM = active range of motion; CKC = closed kinetic chain; DL = double limb; DVJ = drop vertical jump; IKDC = International Knee Documentation Committee; LE = lower extremity; MMT = manual muscle test; NMES = neuromuscular electrical stimulation; NWB = non weight-bearing; OKC = open kinetic chain; PRE = progressive resistive exercise; PROM = passive range of motion; PWB = partial weight-bearing; ROM = range of motion; SL = single limb; WB = weight-bearing;

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Development Process

The process by which this guideline was developed is documented in the [Guideline Development Process Manual](#); a Team Binder maintains minutes and other relevant development materials. The recommendations contained in this guideline were formulated by an interdisciplinary working group which performed systematic and critical literature reviews, using the grading scale that follows, and examined current local clinical practices.

To select evidence for critical appraisal by the group for the update of this guideline, the Pubmed, OVID (Medline, Cinahl, EmBase and Cochrane databases), and Pedro databases were searched between the

dates of January 1970 to June 2008 to generate an unrefined, “combined evidence” database using a search strategy focused on answering clinical questions relevant to OCD, joint loading, pathologies involving articular cartilage, rehabilitation. The search strategy employed a combination of Boolean searching on human-indexed thesaurus terms (MeSH headings using an OVID Medline interface) and “natural language” searching on searching on human-indexed thesaurus terms (MeSH headings using an OVID Medline interface) and “natural language” searching on words in the title, abstract, and indexing terms. The citations were reduced by: eliminating duplicates and non-English articles. The resulting abstracts were reviewed by team members to eliminate irrelevant citations. During the course of the guideline development, additional clinical questions were generated and subjected to the search process, and some relevant review articles were identified.

Note: Full tables of evidence grading system available in separate document:

- [Table of Evidence Levels of Individual Studies by Domain, Study Design, & Quality](#) (abbreviated table below)
- [Grading a Body of Evidence to Answer a Clinical Question](#)
- [Judging the Strength of a Recommendation](#) (abbreviated table below)

Table of Evidence Levels (see note above)

<i>Quality level</i>	<i>Definition</i>
1a† or 1b†	Systematic review, meta-analysis, or meta-synthesis of multiple studies
2a or 2b	Best study design for domain
3a or 3b	Fair study design for domain
4a or 4b	Weak study design for domain
5	Other: General review, expert opinion, case report, consensus report, or guideline

†a = good quality study; b = lesser quality study

Table of Recommendation Strength (see note above)

<i>Strength</i>	<i>Definition</i>
“Strongly recommended”	There is consensus that benefits clearly outweigh risks and burdens (or visa-versa for negative recommendations).
“Recommended”	There is consensus that benefits are closely balanced with risks and burdens.
No recommendation made	There is lack of consensus to direct development of a recommendation.

Dimensions: In determining the strength of a recommendation, the development group makes a considered judgment in a consensus process that incorporates critically appraised evidence, clinical experience, and other dimensions as listed below.

1. Grade of the Body of Evidence (see note above)
2. Safety / Harm
3. Health benefit to patient (*direct benefit*)
4. Burden to patient of adherence to recommendation (*cost, hassle, discomfort, pain, motivation, ability to adhere, time*)
5. Cost-effectiveness to healthcare system (*balance of cost / savings of resources, staff time, and supplies based on published studies or onsite analysis*)
6. Directness (*the extent to which the body of evidence directly answers the clinical question [population/problem, intervention, comparison, outcome]*)
7. Impact on morbidity/mortality or quality of life

Tools to assist in the effective dissemination and implementation of the guideline may be available online at <http://www.cincinnatichildrens.org/svc/alpha/h/health-policy/ev-based/default.htm>. Once the guideline has been in place for three years, the development team reconvenes to explore the continued validity of the guideline. This phase can be initiated at any point that evidence indicates a critical change is needed.

The guideline was externally appraised by three reviewers using the AGREE instrument and the results by domain are:

- Scope and Purpose 85%
- Stakeholder Involvement 75%
- Rigor of Development 89%
- Clarity and Presentation 92%
- Applicability 78%
- Editorial Independence 83%

Recommendations have been formulated by a consensus process directed by best evidence, patient and family preference and clinical expertise. During formulation of these recommendations, the team members have remained cognizant of controversies and disagreements over the management of these patients. They have tried to resolve controversial issues by consensus where possible and, when not possible, to offer optional approaches to care in the form of information that includes best supporting evidence of efficacy for alternative choices.

The guideline has been reviewed and approved by clinical experts not involved in the development process, distributed to senior management, and other parties as appropriate to their intended purposes.

The guideline was developed without external funding. All Team Members and Clinical Effectiveness support staff listed have declared whether they have any conflict of interest and none were identified.

Copies of this Evidence-based Care Guideline (EBCG) and its any available implementation tools are available online and may be distributed by any organization for the global purpose of improving child health outcomes. Website address:

<http://www.cincinnatichildrens.org/svc/alpha/h/health-policy/ev-based/default.htm> Examples of approved uses of the EBCG include the following:

- copies may be provided to anyone involved in the organization's process for developing and implementing evidence-based care guidelines;
- hyperlinks to the CCHMC website may be placed on the organization's website;
- the EBCG may be adopted or adapted for use within the organization, provided that CCHMC receives appropriate attribution on all written or electronic documents; and
- copies may be provided to patients and the clinicians who manage their care.

Notification of CCHMC at HPCEInfo@cchmc.org for any EBCG, or its companion documents, adopted, adapted, implemented or hyperlinked by the organization is appreciated.

NOTE: These recommendations result from review of literature and practices current at the time of their formulations. This guideline does not preclude using care modalities proven efficacious in studies published subsequent to the current revision of this document. This document is not intended to impose

standards of care preventing selective variances from the recommendations to meet the specific and unique requirements of individual patients. Adherence to this guideline is voluntary. The physician in light of the individual circumstances presented by the patient must make the ultimate judgment regarding the priority of any specific procedure.

For more information about this guideline, its supporting evidences and the guideline development process, contact the Division of Occupational Therapy and Physical Therapy Office at: 513-636-4651.

References

Note: When using the electronic version of this document,  indicates a hyperlink to the PubMed abstract. A hyperlink following this symbol goes to the article PDF when the user is within the CCHMC network.

1. **APTA:** Guide to Physical Therapist Practice. Second Edition. American Physical Therapy Association. *Phys Ther*, 81(1): 9-746, 2001, [1b] .
2. **Behrens, F.; Kraft, E. L.; and Oegema, T. R., Jr.:** Biochemical changes in articular cartilage after joint immobilization by casting or external fixation. *J Orthop Res*, 7(3): 335-43, 1989, [4a]  .
3. **Buckwalter, J. A.:** Articular cartilage: injuries and potential for healing. *J Orthop Sports Phys Ther*, 28(4): 192-202, 1998, [5]  .
4. **Buckwalter, J. A., and Lohmander, S.:** Operative treatment of osteoarthritis. Current practice and future development. *J Bone Joint Surg Am*, 76(9): 1405-18, 1994, [5]  .
5. **Cahill, B. R.:** Osteochondritis Dissecans of the Knee: Treatment of Juvenile and Adult Forms. *J Am Acad Orthop Surg*, 3(4): 237-247, 1995, [5]  .
6. **De Smet, A. A.; Ilahi, O. A.; and Graf, B. K.:** Untreated osteochondritis dissecans of the femoral condyles: prediction of patient outcome using radiographic and MR findings. *Skeletal Radiol*, 26(8): 463-7, 1997, [3a]  .
7. **Detterline, A. J.; Goldstein, J. L.; Rue, J. P.; and Bach, B. R., Jr.:** Evaluation and treatment of osteochondritis dissecans lesions of the knee. *J Knee Surg*, 21(2): 106-15, 2008, [5]  .
8. **English, T.:** *Orthopedic and Sports Physical Therapy*. St. Louise, MO, 1997, [5] .
9. **Fredricks, C., and Saladin, L.:** Pathophysiology of the Motor Systems Principles and Clinical Presentations. *FA Davis Co:* Philadelphia.ed. pp. 593, 1996, .
10. **Ganley, T. J.; Gaugler, B.; Kocher, M. S.; Flynn, J. M.; and Jones, K.:** Osteochondritis Dissecans of the Knee. *Operative Techniques in Sports Medicine*, 14: 147-158, 2006, [5] .
11. **Gill, T. J.; Asnis, P. D.; and Berkson, E. M.:** The treatment of articular cartilage defects using the microfracture technique. *J Orthop Sports Phys Ther*, 36(10): 728-38, 2006, [5]  .
12. **Glancy, G. L.:** Juvenile osteochondritis dissecans. *Am J Knee Surg*, 12(2): 120-4, 1999, [5]  .

13. **Haapala, J.; Arokoski, J.; Pirttimaki, J.; Lyyra, T.; Jurvelin, J.; Tammi, M.; Helminen, H. J.; and Kiviranta, I.:** Incomplete restoration of immobilization induced softening of young beagle articular cartilage after 50-week remobilization. *Int J Sports Med*, 21(1): 76-81, 2000, [5] [_____](#)  [_____](#).
14. **Haimovici, N.:** Three years experience in direct intraarticular temperature measurement. *Prog Clin Biol Res*, 107: 453-61, 1982, [4a] [_____](#)  [_____](#).
15. **Hewett, T. E.; Lindenfeld, T. N.; Riccobene, J. V.; and Noyes, F. R.:** The effect of neuromuscular training on the incidence of knee injury in female athletes. A prospective study. *Am J Sports Med*, 27(6): 699-706, 1999, [3a] [_____](#)  [_____](#).
16. **Hughes, J. A.; Cook, J. V.; Churchill, M. A.; and Warren, M. E.:** Juvenile osteochondritis dissecans: a 5-year review of the natural history using clinical and MRI evaluation. *Pediatr Radiol*, 33(6): 410-7, 2003, [4a] [_____](#)  [_____](#).
17. **Jurgensen, I.; Bachmann, G.; Schleicher, I.; and Haas, H.:** Arthroscopic versus conservative treatment of osteochondritis dissecans of the knee: value of magnetic resonance imaging in therapy planning and follow-up. *Arthroscopy*, 18(4): 378-86, 2002, [2a] [_____](#)  [_____](#).
18. **Kinzey, S. J., and Armstrong, C. W.:** The reliability of the star-excursion test in assessing dynamic balance. *J Orthop Sports Phys Ther*, 27(5): 356-60, 1998, [3a] [_____](#)  [_____](#).
19. **Kisner, C., and Colby, L. A.:** Therapeutic Exercise: Foundation and Techniques, 5th Edition. *FA Davis Co:* Philadelphia. 5th ed. pp. 926, 2007, .
20. **Kocher, M. S.; Tucker, R.; Ganley, T. J.; and Flynn, J. M.:** Management of osteochondritis dissecans of the knee: current concepts review. *Am J Sports Med*, 34(7): 1181-91, 2006, [5] [_____](#)  [_____](#).
21. **Local Consensus:** during the guideline development timeframe. ed., [5] .
22. **Meeusen, R., and Lievens, P.:** The use of cryotherapy in sports injuries. *Sports Med*, 3(6): 398-414, 1986, [5] [_____](#)  [_____](#).
23. **Mikesky, A. E.; Meyer, A.; and Thompson, K. L.:** Relationship between quadriceps strength and rate of loading during gait in women. *J Orthop Res*, 18(2): 171-5, 2000, [4a] [_____](#)  [_____](#).
24. **Osbahr, D. C.; Cawley, P. W.; and Speer, K. P.:** The effect of continuous cryotherapy on glenohumeral joint and subacromial space temperatures in the postoperative shoulder. *Arthroscopy*, 18(7): 748-54, 2002, [3a] [_____](#)  [_____](#).
25. **Perry, J.:** *Gait Analysis: Normal and Pathological Function.* Thorofare, NJ, 1992, [5] .
26. **Plisky, P. J.; Rauh, M. J.; Kaminski, T. W.; and Underwood, F. B.:** Star Excursion Balance Test as a predictor of lower extremity injury in high school basketball players. *J Orthop Sports Phys Ther*, 36(12): 911-9, 2006, [2a] [_____](#)  [_____](#).
27. **Radin, E. L.; Burr, D. B.; Caterson, B.; Fyhrie, D.; Brown, T. D.; and Boyd, R. D.:** Mechanical determinants of osteoarthritis. *Semin Arthritis Rheum*, 21(3 Suppl 2): 12-21, 1991, [4a] [_____](#)  [_____](#).
28. **Radin, E. L., and Paul, I. L.:** Response of joints to impact loading. I. In vitro wear. *Arthritis Rheum*, 14(3): 356-62, 1971, [4a] [_____](#)  [_____](#).
29. **Reinold, M. M.; Wilk, K. E.; Macrina, L. C.; Dugas, J. R.; and Cain, E. L.:** Current concepts in the rehabilitation following articular cartilage repair procedures in the knee. *J Orthop Sports Phys Ther*, 36(10): 774-94, 2006, [5] [_____](#)  [_____](#).
30. **Rice, D.; McNair, P. J.; and Dalbeth, N.:** Effects of cryotherapy on arthrogenic muscle inhibition using an experimental model of knee swelling. *Arthritis Rheum*, 61(1): 78-83, 2009, [3a] [_____](#)  [_____](#).
31. **Robinson, A., and Snyder-Mackler, L.:** *Clinical Electrophysiology: Electrotherapy and Electrophysiologic Testing.* Baltimore, 1995, [5] .
32. **Setton, L. A.; Mow, V. C.; and Howell, D. S.:** Mechanical behavior of articular cartilage in shear is altered by transection of the anterior cruciate ligament. *J Orthop Res*, 13(4): 473-82, 1995, [4a] [_____](#)  [_____](#).
33. **Singh, H.; Osbahr, D. C.; Holovac, T. F.; Cawley, P. W.; and Speer, K. P.:** The efficacy of continuous cryotherapy on the postoperative shoulder: a prospective, randomized investigation. *J Shoulder Elbow Surg*, 10(6): 522-5, 2001, [2a] [_____](#)  [_____](#).
34. **Snyder-Mackler, L.; Delitto, A.; Bailey, S. L.; and Stralka, S. W.:** Strength of the quadriceps femoris muscle and functional recovery after reconstruction of the anterior cruciate ligament. A prospective, randomized clinical trial of electrical stimulation. *J Bone Joint Surg Am*, 77(8): 1166-73, 1995, [2a] [_____](#)  [_____](#).
35. **Sood, S. C.:** A study of the effects of experimental immobilisation on rabbit articular cartilage. *J Anat*, 108(Pt 3): 497-507, 1971, [5] [_____](#)  [_____](#).
36. **Spencer, J. D.; Hayes, K. C.; and Alexander, I. J.:** Knee joint effusion and quadriceps reflex inhibition in man. *Arch Phys Med Rehabil*, 65(4): 171-7, 1984, [4a] [_____](#)  [_____](#).
37. **Twyman, R. S.; Desai, K.; and Aichroth, P. M.:** Osteochondritis dissecans of the knee. A long-term study. *J Bone Joint Surg Br*, 73(3): 461-4, 1991, [5] [_____](#)  [_____](#).
38. **Vanwanseele, B.; Lucchinetti, E.; and Stussi, E.:** The effects of immobilization on the characteristics of articular cartilage: current concepts and future directions. *Osteoarthritis Cartilage*, 10(5): 408-19, 2002, [5] [_____](#)  [_____](#).
39. **Waldman, S. D.; Spiteri, C. G.; Grynepas, M. D.; Pilliar, R. M.; Hong, J.; and Kandel, R. A.:** Effect of biomechanical conditioning on cartilaginous tissue formation in vitro. *J Bone Joint Surg Am*, 85-A Suppl 2: 101-5, 2003, [3a] [_____](#)  [_____](#).
40. **Wall, E., and Von Stein, D.:** Juvenile osteochondritis dissecans. *Orthop Clin North Am*, 34(3): 341-53, 2003, [5] [_____](#)  [_____](#).

41. **Wilk, K. E.; Briem, K.; Reinold, M. M.; Devine, K. M.; Dugas, J.; and Andrews, J. R.:** Rehabilitation of articular lesions in the athlete's knee. *J Orthop Sports Phys Ther*, 36(10): 815-27, 2006, [5] _____ ↗ _____.