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Rehabilitation Strategies for the Athletic Individual with Early Knee Osteoarthritis

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Abstract

Knee osteoarthritis (OA) is a major cause of disability in the United States. The condition has most commonly been associated with elderly sedentary individuals; however, it also can affect those who participate in regular athletic activities. The diagnosis and management of these individuals can be challenging because of both their higher level of physical activity and their overall athletic goals. Treatment requires an appropriate exercise regimen, rehabilitation program, and education of both the athlete and the coach. The focus of our article is to provide an up-to-date overview of the evaluation and management of the athletic individual who presents with symptomatic early knee OA, in particular, the nonsurgical rehabilitation treatment options available to the practitioner and the evidence to support these recommendations.

Introduction

Knee osteoarthritis (OA) is a progressive disease, traditionally associated with aging, that has a lifetime risk for an individual with nearly one in two developing symptomatic disease, with the prevalence of the disease increasing with age (2). This condition can affect the health of a significant number of individuals who participate in fitness activities, sports, and certain active occupations. For example, it was recently reported that 80% of National Football League (NFL) players with a history of knee injury had evidence of knee OA, 10 to 30 years after completing their NFL careers (13). The increased risk of knee OA in this athletic population appears to be related to increased incidence of knee injury rather than participation in fitness activities and sport. Cartilage lacks innervation and therefore athletes may be unable to perceive pain sensation at the point of damage to the cartilage, predisposing them to the development of OA with continued repetitive high-impact loading and frequent load bearing.

For the purposes of this article, we use the term “athletic individual” to describe someone who is physically active, is fit, and is involved regularly in a sport or leisure activity. From the health provider’s standpoint for the sedentary individual with early knee OA, the majority of the treatment goals and counseling are based on trying to encourage the patient to be physically active. In contrast, the goals of the athletic individual with early knee OA is

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to maintain or optimize performance without progressing symptoms of disease. This article will not focus on treating the individual with severe knee OA or ongoing severe pain related to mild to moderate knee OA.

Clinical Evaluation

The primary presenting symptom of knee OA is pain, and this varies depending on the individual. In the athletic individual, diagnosis may be delayed because pain is often regarded as a part of playing sports (30). However, in our clinical experience, athletes also can present with mild knee OA sooner likely because their level of activity and frequency of weight bearing are higher compared with individuals who are more sedentary. This is likely because in knee OA, pain is often exacerbated by weight bearing and improved with rest. Other symptoms include morning stiffness (less than 30-min duration), crepitus, bone tenderness, and decreased range of motion (ROM) (55). In an athletic individual, it is important that potential contributing causes of OA (or pain from OA) be identified, such as joint malalignment, sports participation, and prior injury, because these may be addressed during treatment and counseling. On physical examination, crepitus, effusion, and joint line tenderness may be present. Plain radiography is usually the diagnostic imaging modality of choice. A magnetic resonance imaging may be pursued, but further imaging evaluation and diagnostic assessment of the patient are not the focus of this article. The management of knee OA in the athletic individual must balance the need for short-term return to competition or leisure activities while promoting long-term fitness and health, both for the joint and the individual.

Physical Fitness and Exercise

Developing an Exercise Program — the Concept of Physical Fitness

Improving or maintaining physical fitness is one of the primary goals in the treatment for knee OA, and its incorporation in the treatment plan has been shown to decrease pain levels, improve function, and delay disability. The U.S. Centers for Disease Control and Prevention recommends at least 30 min of moderate physical activity over a minimum of 5 days per week in patients with knee OA (18). These also are the recommendations for physical activity and health of the general population (12). Esser and Bailey (6) have suggested that individuals without knee OA, who exercise regularly (swimming, biking, or running), are less likely to have progression of joint degeneration as they age, suggesting the importance of exercise on cartilage health (6). In contrast, failure to remain active has been shown to be associated with less physical function (27). Exercise therapy for the patient with knee OA regardless of the level of activity should be individualized and patient centered, taking into account the patient's age, mobility, activity level, comorbidity, and preferences. An assessment should be made of the individual's impairments, which should include strength, ROM, estimated aerobic fitness, and balance to determine his or her specific exercise prescription.

Precautions Before Exercise Prescription

Generally, exercise for knee OA is well tolerated, and there are few contraindications from a musculoskeletal perspective (in addition to regular cardiovascular precautions). Exercise can induce discomfort at the knee joint during exercise, and patients should be counseled that this may be normal and is not an indication of worsening disease. However, joint swelling and pain that lasts more than 2 hour likely suggests the need for at least temporary modification of the exercise program (38). Other potential safety considerations include appropriate footwear, warmup, and cool-down periods and a graded increase in exercise intensity or frequency. In the average patient with knee OA, the most important aspect of the treatment paradigm (or algorithm) is weight loss. Obesity has been shown to be consistently associated with increased knee adductor moment (an accepted risk factor for medial knee joint OA) (1). Weight loss is the main focus of treatment both in terms of functional improvement and pain reduction in patients initially diagnosed with knee OA. Although not usually associated with the athlete, obesity may need to be addressed in certain athletes. For example, Ode et al. (34) showed that in a cohort of collegiate football players ($n = 226$), 10% would be classified as obese (using percent body fat as an indicator of obesity rather than body mass index (BMI)). In the general population with knee OA, other strategies that decrease joint contact forces, including aerobic exercise, strength training, and improving ROM, are also used. However, in the athletic individual, these recommendations need to be tailored and more individualized because the functional goals are likely at a higher level.

Aerobic Exercise

General aerobic exercise has been advocated by nearly all international guidelines as effective in the management of patients with knee OA, although consensus statements for the athletic individual with early knee OA have not been developed (33,47). In the initial stages of diagnosis, the majority of patients are encouraged to partake in low-impact aerobic exercise, *i.e.*, walking, biking, swimming, or other aquatic exercises. Randomized clinical trials of walking exercise have shown significant short-term improvements in knee pain, functional status, and quality of life in the wider population of patients with knee OA (7,17,23). In terms of the exercise modality that should be undertaken, there are very few head-to-head comparisons of different types of aerobic exercise. Aquatic exercise appears to be most appropriate in obese patients, minimizing joint load, particularly in the early phases of treatment (50). Cycling is a low-impact aerobic activity that has been shown to have beneficial effects in decreasing pain and improving function, by both its aerobic effects, and partial unloading of the knee because this exercise is done through a large ROM. The athletic individual with patellofemoral OA, however, may have difficulty cycling and caution is needed to minimize the compressive joint forces on the patellofemoral articulation during this activity (24).

Although not a recent study, Lane et al. (25) investigated the effects of running and aging on the development of radiographic and clinical OA of the knees, hands, and lumbar spine. Five-year radiographic results compared with baseline radiographs from 35 runners and 38 nonrunners serving as control subjects (mean age, 63 years) revealed that if present at the baseline, there was radiographic progression of OA in the knees in 12% of all subjects.

Running did not appear to accelerate progression radiographic or clinical OA of the knees in runners compared with nonrunners. Although clear recommendations for the athletic individual have not been developed, at diagnosis, they should be counseled that low-impact aerobic exercise would likely be most beneficial. Although running itself has not been shown to be a risk factor for knee OA, prolonged high-impact activity in an already injured knee without appropriate rest has been shown in animal models to be associated with structural disease progression (20,26). A period of rest from high-impact activity such as running should be undertaken with the goal of slowly increasing running activity as tolerated by symptoms. This could involve a graded increase in running distance over several weeks with the athletic individual stopping running if he or she has prolonged pain. As suggested by Leech et al. (28), the identification of a dose or load response and defined individualized risk of running on both symptoms and disease progression would be ideal.

Physical Activity — Step Counts

With the advent of fitness trackers, accelerometers, and pedometers, objective measures of physical activity are available and a clearer relationship between degree of physical activity and progression of disease is being outlined. In particular, from a research perspective, this will allow objective distinctions to be made between recreationally active individuals compared with individuals who are more sedentary (39,45). When counseling the athletic individual with symptoms of knee OA, the goals are typically not only to manage symptoms but also to maintain or improve athletic performance. As stated above, walking is the most common form of exercise for adults and has been shown to be effective in improving pain and functional limitations in individuals with symptomatic knee OA. Studies in sedentary populations have shown that the goal of 10,000 steps a day can be effective in increasing physical activity and improving health-related outcomes such as BMI and blood pressure (21). The most recent guidelines from the American College of Sports Medicine recommend at least 7,000 steps a day to develop and maintain cardiorespiratory, and musculoskeletal and neuromotor fitness (12). It was found in a recent study by White et al. (52) that 10,000 steps a day did not translate into meeting physical activity guidelines, suggesting a disparity between the number of steps that are thought to be needed per day and the recommended time-intensity guidelines to achieve health benefits. Therefore, activity monitors must be used with caution, and considering the level of intensity during walking must be taken into account.

The majority of studies have investigated the effect of daily step counts and symptom progression in individuals who are more sedentary whose goals are to increase physical activity generally. The athletic individual's goals are to maintain activity. With this in mind, we would advise a protocol similar to that advocated by White et al. (53), for patients with mild radiographic knee OA, which involves starting a patient at 6,000 steps per day, with this being the threshold below which patients were more likely to have incident functional limitation. In their nonathletic population, they found that an increase in the step count of 1,000 steps was associated with 16% and 18% reduction of incident functional limitations by performance-based and self-reported measures, respectively. We would therefore advise increasing step count goals by 1,000 steps per day or every other day (starting at 6,000 steps) with pain exacerbation being a major factor in the reduction of this regimen. Further

research is required in this area in a specific athletic population. In developing exercise protocols for the athletic individual, recommendations regarding step count and physical activity should consider the patient's level of ability and overall goals rather than concern regarding structural progression of disease seen on imaging alone.

Resistance Training

As part of developing a resistance exercise program, resistance load, number of repetitions, movement velocity, and frequency of sessions will need to be addressed. An evaluation of an individual's strength and total knee should be performed. The applications of resistance can be applied through body weight, free weights, machines, or bands. When developing a strengthening regimen, the quadriceps, hip abductors, hip extensors, hamstrings, and calf muscles are important for weight-bearing functional activities. The recommendations for the general population are the performance of exercises 3 days per week, 2 to 3 sets per exercise at 8 to 15 repetitions per set. There are a paucity of studies that have examined resistance training specifically for the athletic individual with knee OA.

Farr et al. (9) investigated the effect of resistance training on moderate and vigorous physical activities in 171 patients with early knee OA (mean age, 55 years old). Resistance training sessions were performed three times a week for 1 hour, and each session included a leg press, leg curl, hip abduction, adduction, straight leg lift, incline dumbbell press, seated row, and calf raise. This exercise regimen was followed for 3 months. The exercise group was compared with a self-management group who were only given educational classes. At both 3 and 9 months, the resistance training group had improvement in functional status and symptoms related to knee OA. At 9 months, the resistance training group also had maintained improvement in terms of their level of physical activity as measured from accelerometer logs.

In knee OA patients, high-resistance training has been shown to be equally effective as low-resistance training. Jan et al. (19) investigated the effects of pain, function, muscle torque, and walk time in a high-resistance versus low-resistance exercise program during an 8-wk period in patients with mild knee OA. The two groups performed isokinetic knee flexion and extension training at high resistance (60% of one-repetition maximum (1RM)) and low resistance (10% of 1RM) over three episodes per week. Both groups improved in all categories compared with a control group that did not perform any resistance exercise. Gur et al. (14) investigated the effect of concentric versus concentric–eccentric quadriceps and hamstring strengthening performed 3 times per week for 8 wk in patients with mild to moderate bilateral knee OA. These treatment groups were compared with a nonexercise group. They found that at 8 wk, both intervention groups had significant improvement in pain and functional activities, including ascending and descending stairs and walking pace, whereas concentric training led to improvement in pain. This study highlighted that training involving a higher number of repetitions and eccentric contractions are safe and effective in these patients.

In terms of velocity of resistance training, Sayers et al. (43) conducted a study comparing a high-speed versus low-speed training in 33 participants with knee OA (mean age, 67 years).

They found that the high-speed group performed a greater number of repetitions at 40% of 1RM on a leg press as fast as possible, whereas the low-speed group performed fewer repetitions at 80% of 1RM slowly. The high-speed group had higher improved muscle strength, power, and speed over a 12-month period together with improved Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) scores. These findings are particularly important to the athletic population who performs high-speed movements regularly.

Eyigor et al. (8) reported the effect of isokinetic versus progressive resistance exercise (PRE) of the quadriceps and hamstrings. Knee flexion and extension strengthening was performed 3 times per week in the isokinetic group and 5 times per week in the PRE over a 6-wk period. Both strengthening programs were effective in promoting gains in strength with subjective improvement in pain and function. When developing strength training regimens for the athletic individual with knee OA, it also is important to consider the musculature surrounding the hip and ankle joints. Both isometric and dynamic resistance training of the entire lower extremity are effective methods in patients with knee OA. Topp et al. (46) undertook a 16-wk study in which they examined the effect of isometric and dynamic training of the entire lower extremity on pain and physical function. Both groups trained six lower extremity muscle groups: ankle plantar and dorsiflexors, knee extensors and flexors, and hip extensors and flexors. The isometric group used maximum resistance whereas the dynamic group used appropriate resistance (Thera-band) to achieve the desired muscle activation. Both resistance training groups reported significant decreases in knee pain and improved ability to perform functional tasks, whereas the control group remained unchanged over the study duration. Only dynamic training reduced patient functional limitations. To date, there are minimal studies that have investigated athletic individuals in these parameters.

Although not investigated in the athletic individual, it has been shown that in OA, there is an inability to fully activate the quadriceps muscle, a process that is known as arthrogenic muscle inhibition (AMI) (35,41). Changes in the discharge of sensory receptors around the osteoarthritic knee joint have been postulated to lead to AMI. There are a number of factors that may change afferent discharge, including inflammation, effusion, laxity of the joint, and damage to articular sensory receptors (41). The abnormal output from the knee joint afferents may change the excitability of spinal reflex pathways, decreasing quadriceps α -motoneuron excitability and therefore preventing optimal activation of the muscle. Therapeutic modalities such as cryotherapy (36,56) and neuromuscular electrical stimulation (11) have shown promise in treating AMI, as well as isolated quadriceps weakness. For example, it has been shown that repeated applications of ice may lead to improved quadriceps activation in subjects with chronic OA (56). In this study, subjects received ice massage to 4 standard acupoints for a total of 20 min per session, 5 sessions per week for 2 wk. At 2 wk, maximum quadriceps strength was found to improve by 22% compared with the sham treatment group's improvements of 7%.

For the athletic individual, a potential resistance training regimen could be similar to that advocated by Vincent and Vincent (49) for patients with mild knee OA. This initially starts with a 2 days per week resistance training regimen with rate of perceived exertion (RPE) of

13 to 15 with an encouragement of full knee during the exercise. The athletic individual could be progressed to RPE of 15 to 16 over 6 to 8 wk. The frequency should be increased up to 3 d-wk⁻¹ with at least 24 h between sessions. Maintenance of this regimen should be continued 2 to 3 d-wk⁻¹ with adjustment of the resistance load to keep the RPE at 15 to 16. The individualized load and volume of resistance training should be tailored to the athletic individual, with the goal of not exacerbating sustained pain during the activity.

Joint Loading Strategies

In knee OA, loading of the joint repetitively can cause compensatory movement and abnormal muscular recruitment patterns of the lower extremity. In the athletic individual, the frequency of joint loading is higher than sedentary individuals such that these changes in gait mechanics may be more apparent. It has been shown that at a predetermined gait speed in patients with knee OA, there are significant differences in gait kinematics when compared with healthy age-matched subjects without knee OA (29). In the athletic individual, a major focus during training is on higher-level activities associated with performance. These activities include stopping abruptly, turning, and negotiating obstacles and different surface terrains. Fitzgerald et al. (10) reported that a range of 11% to 44% of patients with knee OA with varying levels of activity will experience mechanical symptoms of joint instability or buckling during performance of activities of daily living. Similar mechanical symptoms have been reported in individuals who have had an anterior cruciate ligament (ACL) rupture. Perturbation training for ACL-deficient patients has been shown to be of functional benefit for active individuals. A group investigated the addition of perturbation and agility training techniques to therapy for individuals with knee OA (15). In their study, the subjects with knee OA were assigned randomly to either an exercise-only group or an exercise and perturbation training group. The perturbation training group had an exercise program that was designed to enhance forward, backward, and side balance. They found that both groups had an improvement in their WOMAC score and knee pain, but no significant improvements in any outcome measures at 1 year.

The modification of gait, with and without the use of real-time feedback, has shown some promise in modifying variables associated with tibiofemoral OA and patellofemoral OA as well as progression of OA. Although decreasing walking speed reduces ground reaction forces that contribute to knee joint load, reduced cadence (which is the number of steps per minute) may be detrimental to the patellofemoral articulation. A study in runners who exhibited higher vertical loading rates showed that decreased cadence is associated with the highest potential patellofemoral (PF) articulation stress (54). An effective strategy for decreasing forces that lead to PF articulation stress appears to be to increase cadence by 7.5%. In this particular study, the increase in running cadence was implemented over 8 retraining sessions.

ROM

Restricted soft tissue mobility and adhesions as a result of persistent inflammation of both intra- and periarticular tissues can contribute to patient symptoms. The resultant adhesions can lead to changes in the biomechanical forces on articular surfaces restricting joint

movement leading to further symptoms (4,5). It has been hypothesized that manual therapy can counteract some of the physiological changes by reducing the adhesions and improving ROM. One goal is to cease the inflammatory cycle associated with progressive disease. In addition, loss of full extension in particular has been shown to lead to abnormal joint biomechanics with changes in joint contact forces at both the tibiofemoral and the patellofemoral articulations. The loss in ROM of the osteoarthritic knee is a primary factor that leads to muscular weakness during isokinetic exercise (31).

The goals of manual therapy include improved joint mobility and ROM, by reducing soft tissue contracture and therefore improving function. Deyle et al. (5) have reported 20% to 40% pain relief in patients that underwent 2 to 3 clinical treatments of manual therapy and exercise for 6 to 7 wk compared with a control group who underwent subtherapeutic ultrasound treatments. The rapid reduction in symptoms suggests that changes within the periarticular connective and muscular tissues can potentially affect the joint. Mobilization of the osteoarthritic knee joint has been shown to cause an immediate pain reduction with associated improvement in function (32).

The knee joint mobilization techniques commonly focus on both the tibiofemoral and the patellofemoral articulations as both have been proven to be affected by soft tissue restrictions associated with knee OA. Pollard et al. (37) showed that a combination of knee joint mobilization techniques decreased pain and improved function. In this study, the first technique used was active knee ROM from 90° of flexion, through as much pain-free extension while a sustained inferior patella glide was applied to the superior pole of the patella. This technique was performed to minimize the tendency of the patella to glide superiorly and also reduces compressive forces of the patella within the femoral trochlea. The second technique they used was a posterior tibial mobilization together with the application of a tibial traction force near to full extension.

In an athletic individual with knee OA, the extensibility of the joint capsule and hip flexor, quadriceps, hamstrings, gastrocnemius, and soleus muscle length should be assessed because they impact knee function. A recent 6-wk study that incorporated a stretching program focusing on the aforementioned musculature resulted in a significant increase in knee extension ROM (40). The intervention incorporated in this study used both supervised and independent stretching sessions. Another study (42) examined the efficacy of a therapeutic program with mechanical diagnosis and therapy (MDT) in 180 subjects with knee OA in a randomized controlled trial. Subjects who were randomized to an exercise intervention group, in which they were classified as having knee derangements (MDT derangement), received MDT directional exercises, and patients classified as nonresponders (MDT nonresponders) received evidence-based exercises. These subgroups were compared with a control group of subjects with knee OA who did not receive an exercise intervention. At 3 months, both intervention groups had significantly improved Knee Injury and Osteoarthritis Outcome Score pain and function scores compared with controls.

On the basis of the aforementioned studies, stretching of the joint capsule and associated soft tissue through both active ROM and manual therapy should be performed regularly as part of the rehabilitation program. In the athletic individual with knee OA, this speaks of the

importance of stretching during warm-up and cool-down phases of exercise to minimize stiffness that likely will exacerbate symptoms and decrease athletic performance.

Athletic Taping and Footwear

Although not specifically examined in an athletic population, therapeutic taping of the knee also has been shown to improve pain scores in some patients with knee OA by improving joint alignment of the patellofemoral articulation and unloading the soft tissues (51). A double-blind randomized study investigated the use of therapeutic tape applied to the knee to promote medial glide and improve anteroposterior tilt of the patella (16). In the study, tape also was applied to either the pes anserine bursa or the infrapatellar fat pad to reduce short-term swelling. At 6 wk, 73% of participants reported improvement in pain compared with 10% of those who did not use the tape. A systematic review and meta-analysis of the efficacy of patella taping for patellofemoral OA showed that taping exerting a medially directed force on the patella significantly resulted in improvement in the subject's pain compared with no taping. However, a more recent study compared kinesiotaping to sham taping for knee OA and did not find any significant difference between groups in terms of change in symptoms (22).

All patients with knee OA regardless of the level of activity should be educated on the appropriate footwear as it pertains to the demands of the specific activity they undertake and how certain footwear may affect articular cartilage and joint-related changes based on physical examination, gait evaluation, and radiographic findings. The most effective type of shoe has not been determined, although an individualized approach that incorporates activity assessment and body habitus may be beneficial. For example, in an obese individual who heel strikes and has moderate medial tibiofemoral joint narrowing, a shock-absorbing insole may be beneficial. In contrast, a runner with a midfoot strike who has evidence of early OA on radiographs could benefit more from a shoe that simulates barefoot mechanics, although controversy regarding this remains. This type of shoe has been shown to significantly reduce dynamic knee loads during walking/running by potentially increasing sensorimotor input and neuromuscular control (44). Of note, it was found in a recent investigation by Davis et al. (3) that higher impact loading at the knee was associated with increased risk of medically diagnosed injuries.

Counseling the Patient

The active individual with knee OA should be reassured that regular physical activity can be continued provided it does not cause a prolonged increase in pain beyond 2 h after the activity has been completed (45,48). There may be a concern that physical activity may potentiate further structural degeneration within their knee joint, but there is minimal evidence for this. Exercise (both aerobic and resistance) has consistently been shown to be the most cost-effective, functionally efficacious nonpharmaceutical treatment for knee OA. During the consultation, the health provider should perform a sports-specific assessment of the individual with knee OA. An assessment should then be made of the patient's current level of physical activity and exercise practices including the amount of aerobic exercise, resistance training, and leisure activities. This also should include an evaluation of their

specific activity goals, the amount of exercise they engage in during a typical week, and specifics regarding their particular workout regimen (*e.g.*, number of repetitions, amount of free weights, use of plyometrics, etc.). An individualized exercise regimen that optimizes physical fitness without prolonged symptom generation should be developed. Although not the focus of this article, medications such as nonsteroidal anti-inflammatory medications may be required to treat pain during physical activity in the early stages of rehabilitation. The goal should be for the active individual not to remain on these medications in the long term. The entire kinetic chain also should be assessed, and the athletic individual with knee OA should be involved in a resistance exercise program that involves entire lower extremity strengthening, not just the quadriceps. They should start by adhering to the minimum recommendations for exercise for the general population with one set of repetitions per body part and progress from there. Modifications of this program may be required should symptoms be exacerbated or the amount be too little. As part of their physical therapy regimen, the ROM of the lower extremities also must be assessed and treated with manual therapy techniques and active ROM exercises. Taping may be useful to assist the athletic individual in their performance of a sporting activity, by providing more optimal joint alignment, and assessment of their shoe wear also may be beneficial. To date, a specific running protocol in patients with symptomatic knee OA has not been developed. Typical recommendations have suggested starting rehabilitation programs with low-impact activities such as walking with eventual slow progression to running. Objective measures of physical activity such as pedometers provide a means of measuring step count with some also allowing assessment of pace. The health provider can use these to slowly increase physical activity (both the volume and the high vs low impact) through a graduated progression with the goal of not exacerbating patient symptoms during these activities. Finally, before return to the patient's sport, a conditioning program and on-field sports-specific assessment should be performed to optimize his or her performance.

Conclusion

Knee OA represents a constellation of structural changes that lead to pain and functional impairment. There are several risk factors that are associated with disease development, although in the active individual, prior joint injury or blunt trauma during sporting activity appears to be a more frequent cause. The diagnosis and treatment of knee OA in the athletic individual are often challenging because of his or her higher exercise goals and need for an expedited return to play. Exercise remains the recommended initial treatment for knee OA in all populations, including the athlete, and an in-depth assessment of his or her sporting activity and workout regimen must be undertaken before development of a treatment plan. It is pivotal in managing the athlete with OA that his or her treatment regimen is specific to him or her, taking into account his or her expectations and eventual functional needs.

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