Abstract: Osteoarthritis (OA) is prevalent in today’s population, including the athletic and recreationally active “middle-aged” population. OA is a degenerative condition of the articular/hyaline cartilage of synovial joints and commonly affects the knee joint. In general, athletic participation does not specifically influence a higher incidence of knee OA in this population; however, traumatic injury to the knee joint poses a definitive risk in developing early-onset OA. The purpose of this article is to review evidence-based nonpharmacological interventions for the conservative management of knee OA. Manual therapy, therapeutic exercise, patient education, and weight management are strongly supported in the literature for conservative treatment of knee OA. Modalities [thermal, electrical stimulation (ES), and low-level laser therapy (LLLT)] and orthotic intervention are moderately supported in the literature as indicated management strategies for knee OA. While many strongly supported conservative interventions have been published, additional research is needed to determine the most effective approach in treating knee OA.

Key Words: osteoarthritis, knee, athlete, physical therapy, rehabilitation, intervention, manual therapy, therapeutic exercise, modalities

Arthritis is the most common cause of disability among US adults with costs attributable to arthritis and other rheumatic conditions estimated at $128 billion in 2003. In 2005, approximately 27 million US adults were diagnosed with clinical osteoarthritis (OA) affecting quality of life through pain and functional limitations. The number of US adults with arthritis is projected to rise to 67 million by 2030.4

Recent research reports increased prevalence of knee OA among middle-aged athletes and former professional athletes. In a New Zealand study of 22 male ex-table tennis players, 78% of the players displayed radiologic evidence of knee OA as compared with 36% in age-matched and sex-matched controls.5 In a 2012 systematic review out of the Netherlands, between 60% and 80% of former elite soccer players developed radiologic evidence of knee OA.6 In addition, a study in the United Kingdom in 1996 suggested higher incidence of OA in female, ex-athletes (tennis players and middle-distance, long-distance runners) aged 40 to 65 compared with age-matched controls.7

The Osteoarthritis Systematic International Review and Synthesis Organization (OARSI) in 2006 presented recommendations for patients with knee OA regarding appropriate physical activity participation. They concluded the 3 highly modifiable risk factors for symptomatic knee OA are obesity, injury, and occupations involving excessive mechanical stress.8 For sports and recreational activity, OARSI suggests a correlation between activities representing risk factors for knee OA and intensity and duration of exposure. The group also states that risk of OA is associated more with history of trauma and obesity than with sport participation in general. The group recommends athletes to be informed that joint trauma is a greater risk factor than mere activity or sport participation. Additional evidence concludes that OA risk is associated with duration and intensity of exposure in higher level activities. The clinical consensus of OASIS stated patients with OA participate regularly in recreational sports as long as the activity does not cause pain, but should be encouraged to change sports that involve activities at risk for joint trauma.8

Other research groups have studied OA to compile treatment protocols and interventions for conservative management of the disease. For example, the American College of Rheumatology in 2010 to 2011, convened a Technical Expert Panel to update recommended guidelines for nonpharmacological and pharmacological management of OA of the hand, hip, and knee. The Technical Expert Panel performed extensive literature reviews and evaluated the best available evidence for specific interventions for the conservative management of hand, hip, and knee OA (Table 1).

Another scientific study group, the Osteoarthritis Research Society International (OARSI), developed guidelines for conservative management of hip and knee OA. The OARSI group first released their guidelines in 2007 with updated recommendations in 2008. Overall, they presented 23 recommended interventions for the treatment of hip and/or knee OA, based on opinion alone, research evidence or both. However, despite the group’s high ratings for a core set of pharmacologic and nonpharmacologic recommendations, OARSI admits that the consensus recommendations are not always supported by the best available evidence.10 Other recommended interventions include patient education regarding lifestyle modification, activity pacing, exercise, weight reduction, knee bracing, and appropriate footwear/orthoses/wedging devices.11

**MANUAL THERAPY**

Symptoms associated with knee OA may result from restricted soft-tissue mobility and adhesions as a result of.
TABLE 1. Nonpharmacologic Recommendations for the Management of Knee Osteoarthritis

<table>
<thead>
<tr>
<th>Recommendation</th>
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</thead>
<tbody>
<tr>
<td>We strongly recommend that patients with knee osteoarthritis (OA) should do</td>
</tr>
<tr>
<td>the following:</td>
</tr>
<tr>
<td>Participate in cardiovascular (aerobic) and/or resistance land-based exercise</td>
</tr>
<tr>
<td>Participate in aquatic exercise</td>
</tr>
<tr>
<td>Lose weight (for persons who are overweight)</td>
</tr>
<tr>
<td>We conditionally recommend that patients with knee OA should do the following</td>
</tr>
<tr>
<td>Participate in self-management programs</td>
</tr>
<tr>
<td>Receive manual therapy in combination with supervised exercise</td>
</tr>
<tr>
<td>Receive psychosocial interventions</td>
</tr>
<tr>
<td>Use medially directed patellar taping</td>
</tr>
<tr>
<td>Wear medially wedged insoles if they have lateral compartment OA</td>
</tr>
<tr>
<td>Wear laterally wedged subtalarp strapped insoles if they have medial compartment OA</td>
</tr>
<tr>
<td>Be instructed in the use of thermal agents</td>
</tr>
<tr>
<td>Receive walking aids, as needed</td>
</tr>
<tr>
<td>Participate in tai chi programs</td>
</tr>
<tr>
<td>Be treated with traditional Chinese acupuncture*</td>
</tr>
<tr>
<td>Be instructed in the use of transcutaneous electrical stimulation*</td>
</tr>
<tr>
<td>We have no recommendations regarding the following</td>
</tr>
<tr>
<td>Participation in balance exercises, either alone or in combination with</td>
</tr>
<tr>
<td>strengthening exercises</td>
</tr>
<tr>
<td>Wearing laterally wedged insoles</td>
</tr>
<tr>
<td>Receiving manual therapy alone</td>
</tr>
<tr>
<td>Wearing knee braces</td>
</tr>
<tr>
<td>Using laterally directed patellar taping</td>
</tr>
</tbody>
</table>

*These modalities are conditionally recommended only when the patient with knee OA has chronic moderate to severe pain and is a candidate for total knee replacement but either is unwilling to undergo the procedure, has comorbid medical conditions, or is taking concomitant medications that lead to a relative or absolute contraindication to surgery or a decision by the surgeon no to recommend the procedure.

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Other proposed benefits of manual therapy include mechanical alteration of tissue, neurophysiological effects, and psychological influence. Joint mobilization has been shown to induce immediate hypoalgesia in individuals with knee OA with a concurrent improvement in function. moss and colleagues demonstrated immediate reduction in pain pressure threshold after joint mobilization in patients with knee OA, further supporting hypoalgesic effects found in other studies. The positive hypoalgesic affects are believed to occur through stimulation of mechanoreceptors and activation of pain inhibitory cortical systems.

Sambanis and colleagues have demonstrated nearly 70% decreased concentration of prostaglandin PGE2 24 hours after repetitive mobilization in a healthy in vitro animal study. As an inflammatory mediator, prostaglandin PGE2 is implicated in arthritic hyperalgesia, which may sensitize peripheral nociceptors. The authors of this study have found that the hypoalgesic effects of manual therapy often improve patients’ participation in therapeutic exercise in those who are limited by pain.

Knee joint mobilization techniques focus on accessory movement of both the tibiofemoral joint and the patellofemoral joint as both articulations have been shown to be affected by soft-tissue restrictions associated with knee OA. Benefits have been reported for various amplitudes of joint mobilization. Moss and colleagues concluded that large amplitude (Maitland Grade III) anterior-posterior glide of the tibia on femur (supine, slight knee flexion) combined with pain-free oscillatory glides (Maitland Grade I, II) of the tibia improved pain levels 3 to 4 times greater than a control group not receiving joint mobilization. Performance during Sit-To-Stand and Timed Up and Go testing also showed significant improvement in the joint mobilization group.

Pollard and colleagues demonstrated that a combination of knee joint mobilization techniques decreased patients’ pain and crepitus, while also improving patients’ satisfaction, general function, and joint mobility. The first technique in the study was active knee ROM from 90 degrees of flexion (Fig. 1) through as much pain-free extension possible while a sustained inferior patella glide was applied to the superior pole of the patella (Fig. 2). The technique was performed to minimize the natural superior glide of the patella and to decrease compressive forces of the patella into the femoral trochlea. The second technique consisted of a grade IV posterior tibial mobilization while applying a tibial traction force near full knee extension (Fig. 3) (Table 2).

Connective tissue is known to lose extensibility related to the physiological aging process and is believed to occur secondary to collagen adaptation. The diminished extensibility combined with joint degeneration in patients with knee OA may cause loss of terminal knee extension and flexion ROM. Loss of full knee extension ROM has been shown to result in abnormal joint arthrokinematics with subsequent increases in patellolateral and tibiofemoral joint contact pressure. Weng and colleagues has demonstrated ROM of the arthritic knee joint as the main factor resulting in muscular weakness during isokinetic exercise. Therefore, when developing a program for an athletic or recreationally active patient with knee OA, improving knee joint ROM is a vital consideration.

The authors of this study include static and proprioceptive neuromuscular facilitation (PNF) stretching to restore muscle length of the lower extremity. In athletes...
with knee OA, joint capsule extensibility and quadriceps, hamstring, hip flexor, gastrocnemius, and soleus muscle length must be assessed because of their impact on knee function and their function when participating in athletics. Reid and McNair demonstrated a significant increase in knee extension ROM (mean, 7.7 degrees) after a 6-week stretching program focusing on the above-mentioned lower-extremity muscle groups. The stretching intervention utilized supervised and independent stretching sessions. The relevance of the study demonstrates the importance of independent stretching exercises as an effective piece of long-term knee OA management.21

Weng and colleagues compared isokinetic muscular strengthening exercise (group I), isokinetic exercise with static stretching (group II), and isokinetic exercise with PNF stretching (group III) in patients with knee OA. All groups demonstrated a significant reduction in knee pain and disability with increased peak muscle torques after treatment and at follow-up. However, only groups II and III had significant improvements in knee extension and flexion ROM, with group III demonstrating the greatest increase in ROM. Group III also demonstrated the greatest increase in muscle strength gain during 180 degrees/second angular velocity peak torque testing.20 The study results provide evidence that PNF stretching may be more effective than static stretching in the treatment of knee OA.

**THERAPEUTIC EXERCISE**

Research has reported a correlation between increased physical activity and decreased pain levels, improved function, and delayed disability. At least 30 minutes of moderate physical activity over a minimum of 5 d/wk is recommended by the Centers for Disease Control in specific regards to OA.23 Participation in regular physical activity has been shown to provide significant benefits in the treatment of knee OA, whereas failure to remain active may exacerbate impaired joint mechanics and potentially result in articular cartilage softening and matrix dysfunction, leading to accelerated cartilage degeneration.24 Also, individuals without knee OA who opt to exercise will not have increased progression of joint degeneration as a result of their increased physical activity; indeed, they can potentially expect reductions in knee pain and disability as the years progress.25

Repetitive loading of the arthritic knee joint can force compensatory movement and muscular recruitment

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**FIGURE 1.** Sustained inferior patella glide in 90-degree knee flexion.

**FIGURE 2.** Sustained inferior patella glide nearing terminal knee extension.
FIGURE 3. Caudal tibial traction coupled with posterior tibial glide.

patterns of the lower extremity. Liikavaino studied gait and muscle activation changes in subjects with knee OA to examine both level and stair walking biomechanics. The authors observed minor differences in gait kinetics during level-walking at each predetermined gait speed in patients (mean age 59 y) with knee OA as compared with healthy age-matched and sex-matched control subjects. However, patients with knee OA exhibited approximately 18% to 26% lower maximal loading rate, indicative of lighter loading of their lower extremities. The differences in force loading parameters were magnified during more demanding motor tasks such as stair descension at higher speeds. Patients with knee OA demonstrated significantly higher initial peak and maximal horizontal acceleration and decreased attenuation of the shock wave. Furthermore, these findings were supported by changes in muscular recruitment during all activity. The authors hypothesized that an overall decrease in muscle strength and power in subjects with knee OA was secondary to both vastus medialis and biceps femoris infrequent muscle activation while using different strategies to execute the same tasks.26

Lower-extremity strength disparities also were highlighted by Costa who studied 25 patients with unilateral knee OA,25 with bilateral knee OA (both with mean age 56 y) and 50 matched controls by using a Visual Analog Scale, Knee Lequesne Index, Western Ontario and McMaster University Arthritis Index (WOMAC) questionnaire, and a Cybex (Chattanooga, TN) isokinetic assessment. For the unilateral and bilateral knee OA groups, significantly lower peak torque was found for hip flexion, extension, abduction, adduction, medial rotation, and lateral rotation at all velocities on the ipsilateral side. Even in patients with unilateral knee OA, a similar decrease in peak torque was found on the contralateral hip when compared with controls, potentially suggesting why patients with knee OA have both impaired lower-extremity muscular strength and biomechanics.27

Traditionally, exercise programs for knee OA have focused on impairments associated with lower-extremity

<table>
<thead>
<tr>
<th>Impairments</th>
<th>Manual Intervention</th>
<th>Typical Delivery</th>
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</table>
| Loss of knee extension | Manual mobilization through range of motion (ROM) and knee extension at end range | Mobilizations grades III and IV to III ++ and IV ++ 2-6 bouts of 30 s/manual technique  
Clinical observation: this manual intervention may provide near-immediate decrease of symptoms and may be approached with relatively more vigor than knee flexion |
| Loss of knee flexion | Manual mobilization through ROM and knee flexion at end range | Mobilization grades of III – and IV – to III + and IV 2-6 bouts of 30 s/manual technique  
Clinical observation: pain with end-range knee flexion may be due to degenerative meniscal tears: end-range techniques should be utilized with caution |
| Loss of patellar glides | Manual mobilization of the patella in 5-10 degrees of knee flexion | Mobilization grades of IV to IV ++ 2-6 bouts of 30 s/manual technique  
Clinical observation: some patients may be intolerant of even slight compressive forces over the patella; therapist hand placement is important |
| Muscle tightness | Manual stretches at end length of muscle | Sustained manual stretches of 12-30 s duration repeated 1-3 times per manual technique  
Clinical observation: the lumbar spine should be manually stabilized and protected during all extremity stretches; particularly hip flexor stretches; many of these patients also will have arthritic changes in the spine, and symptoms can be increased without care in positioning |
| Soft-tissue tightness | Soft-tissue mobilization | Circular fingertip and palm pressure mobilization at the depth of the capsule or retinaculum for 1-3 bouts of 30 s/area  
Clinical observation: the soft-tissue work in the popliteal fossa seems to work best when performed slowly with occasional sustained positions of 10-12 s, this technique works well when combined with the manual mobilizations into knee extension |

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joint motion deficits, muscle weakness, and reduced aerobic capacity.28 Although these impairments are associated with the majority of patients with knee OA, many exercise programs inadequately focus on other aspects of ambulation and higher level activity such as turning, quick stopping, negotiating obstacles, or change in surface consistency. Fitzgerald et al29 reports that a range of 11% to 44% of patients with knee OA will experience mechanical symptoms of giving way or buckling during activities of daily living.

Similar mechanical symptoms are reported in patients with a deficient anterior cruciate ligament (ACL). Extensive research supports the application of perturbation training without nonoperative, ACL-deficient patients. The study results by Axe and Snyder-Mackler30 demonstrate a more effective return to high-level physical activity than an impairment-based standard program by exposing individuals to activities that challenge the knee to potentially destabilizing loads during therapy. Although there appears to be a correlation between the ACL-deficient knee and knee OA symptomatology, there is limited research measuring the proprioceptive decline in patients with knee OA and its subsequent effect on agility (Table 3).

Exercise prescription for individuals with knee OA has been studied regarding the frequency, intensity, and mode of resistance and strength training has been found to be beneficial for patients with knee OA. A study by Farr and colleagues looked at resistance training on overall moderate and vigorous physical activity in 171 patients with early knee OA. Patients (mean age, 55 y) participated in a resistance-training program, a self-management program, and a combined program. The resistance-training group participated in 1-hour exercise sessions that included leg press, leg curl, hip abduction and adduction, straight leg lift, incline dumbbell press, seated row, and calf raise. The self-management group was given educational classes. The groups were tested at baseline, 3 months, and 9 months and both the self-management and resistance-training groups were effective in raising moderate to vigorous physical activity levels in the short term. However, the resistance-training group proved significantly more effective in maintaining these results long term. The results by Farr and colleagues suggest that functional exercises targeting performance can be useful in managing knee OA.32 Sayers and colleagues conducted a study comparing high-speed versus slow-speed power training in 33

<table>
<thead>
<tr>
<th>TABLE 3. Evidence-based Clinical Practice Guidelines</th>
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<tbody>
<tr>
<td>Strengthening exercises</td>
</tr>
<tr>
<td>Lower-extremity strengthening vs. control, level 1 (RCT, n_345): grade A for pain getting up from floor and functional status (clinically important benefit); grade C for pain during walking, pain while climbing stairs, functional tasks, and quadriceps femoris muscle peak torque (clinical benefit); grade C for stiffness, mobility, quadriceps femoris muscle force, muscle activation, and quality of life (no benefit). Patients with a diagnosis of osteoarthritis (OA) of the knee.</td>
</tr>
<tr>
<td>Lower-extremity isometric strengthening vs. control, level 1 (RCT, n_102): grade A for pain getting down to and up from floor (clinically important benefit); grade C for pain getting down and up stairs and timed functional tasks (clinical benefit); grade C for stiffness and functional status (no benefit). Patients with a diagnosis of OA of the knee.</td>
</tr>
<tr>
<td>Isotonic resistance training vs. isometric combined with isokinetic (Kinetron) resistance training for knee, level 1 (RCT, n_32): grade C for quadriceps femoris muscle peak torque (no benefit).Patients with a primary diagnosis of OA of the knee.</td>
</tr>
<tr>
<td>Isometric combined with isokinetic (Kinetron) resistance training for knee vs. control, level 1 (RCT, n_32): grade C for muscle force (no benefit). Patients with primary diagnosis of OA of the knee.</td>
</tr>
<tr>
<td>Eccentric resistance training (Cybex) for knee vs. control, level 1 (RCT, n_32): grade C for muscle force (no benefit). Patients with primary diagnosis of OA of the knee.</td>
</tr>
<tr>
<td>Concentric resistance training for knee vs. control, level 1 (RCT, n_23): grade A for pain at rest and during activities (clinically important benefit); grade C for global functional status (no benefit). Patients with knee OA bilaterally and grade II or III OA.</td>
</tr>
<tr>
<td>Concentric-eccentric resistance training for knee vs. control, level 1 (RCT, n_23): grade A for pain at rest and during specific functional activities: 15-m walk and stair climbing/descending time (clinically important benefit). Patients with knee OA bilaterally and grade II or III OA.</td>
</tr>
<tr>
<td>Home program strengthening for knee vs. control, level 1 (RCT, n_81): grade A for pain, functional status, energy level, and ROM in flexion (clinically important benefit); grade C for physical mobility, muscle force, swelling, and exercise (no benefit). Patients with knee OA.</td>
</tr>
<tr>
<td>General lower-extremity exercise program (including muscle force, flexibility, and mobility/coordination) vs. control, level 1 (RCT, n_490): grade A for pain at night and ability on stairs (clinically important benefit); grade C for knee flexion range of motion (ROM), muscle force, knee joint position, gait, functional status, quality of life, muscle activation, stiffness, and physical activity (no benefit). Patients with OA.</td>
</tr>
<tr>
<td>Progression vs. no-progression lower-extremity strengthening exercises, level 1 (RCT, n_179): grade A for pain at rest and ROM (clinically important benefit); grade C for stiffness and functional status (no benefit). Patients with radiographic evidence of OA in the tibiofemoral compartment.</td>
</tr>
<tr>
<td>General physical activity, including fitness and aerobic exercises</td>
</tr>
<tr>
<td>Walking program vs. control, level 1 (RCT, n_1089): grade A for pain, functional status, stride length, disability transferring from bed, disability bathing, aerobic capacity, energy level, and medication use (clinically important benefit); grade C for disability in ADL (clinical benefit); grade C for walking speed, disability toileting, disability dressing, blood pressure, morning stiffness, and quality of life (no benefit). Patients with OA.</td>
</tr>
<tr>
<td>Jogging in water vs. control, level 1 (RCT, n_115): grade A for physical activity and aerobic capacity (clinically important benefit); grade C for morning stiffness, pain, grip force, trunk ROM, functional status, and exercise endurance (no benefit). Patients with current symptoms of chronic pain and stiffness in involved weight-bearing joints.</td>
</tr>
</tbody>
</table>

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participants with mean age of 67 years with knee OA. The high-speed group performed a greater number of repetitions at 40% of 1 repetition maximum on a leg press “as fast as able,” whereas the slow-speed group performed fewer repetitions at 80% of 1 repetition maximum slowly. The high-speed group improved muscle strength, power, and speed over the 12-week period. These findings are particularly relevant in effectively treating a recreationally active population performing high-speed movements.33

High-resistance training is shown to be equally effective as low-resistance training in people with knee OA. Jan et al34 looked at the effects of pain, function, muscle torque, and walk time in high-resistance versus low-resistance training over an 8-week period. The 2 groups performed isokinetic knee flexion and extension training at high-resistance (mean age, 63 y) and low-resistance (mean age, 63 y) session over 3 episode/wk. Both groups improved in all categories compared with the control group (mean age, 62 y). In another study regarding resistance training, Gur and colleagues looked at the effects of concentric versus concentric-eccentric quadriceps and hamstring strengthening on functional capacity and pain levels in patients aged 41 to 75 years old with knee OA. They determined an 8-week program of isokinetic quadriceps and hamstring strengthening performed 3 times/wk resulted in the concentric-eccentric group displaying a greater effect on functional activities, including stair ascension and descent while concentric training exhibited improvements in overall pain rating. The results of the study show that extensive training involving high number of repetitions and eccentric contractions are safe, effective, and productive in patients with knee OA.35

Isokinetic versus progressive resistance exercise (PRE) of the quadriceps and hamstrings was studied by Eiygor. Knee flexion and extension strengthening was assessed 3 times/wk in the isokinetic group (mean age, 53 y) and 5 times/wk in the PRE group (mean age, 51 y) over a 6-week period. Both modes of strengthening were found to be effective in achieving strength gains and subjective decreases in pain and function. There was no significant difference found between the 2 groups in overall reports of pain, function, or peak torque of the tested muscles.36

Consideration of the surrounding musculature of the hip and ankle joints when prescribing exercise for the patient with knee OA is also important. Both dynamic and isometric training of the entire lower extremity represent effective modes of resistance strengthening in people with knee OA. Topp and colleagues conducted a 16-week study comparing dynamic and isometric training, specific to effects on pain level and physical function. Two groups trained the same 6 lower-extremity muscle groups: ankle plantar and dorsiflexors, knee extensors and flexors, and hip extensors and flexors. The isometric group (mean age, 64 y) used maximum resistance Thera-band (The Hygienic Corporation, Akron, OH), whereas the dynamic group (mean age, 66 y) used appropriate-level resistance Thera-band to achieve the desired muscle activation. Both resistance-training groups exhibited similar, significant declines in reported knee pain and decrease in time to perform functional tasks, whereas the control group remained unchanged over the duration of the study. Only the dynamic training reduced perceived functional limitations, and the control group (mean age, 61 y) did not change their measures on any of the outcome variables over the duration of the study.37

**MODALITIES**

The trend of increased incidence of knee OA in a younger, more active population has developed a role for therapeutic modalities in the conservative management of functionally limiting impairments associated with knee OA. ES, therapeutic ultrasound (US), LLLT, and thermo-therapeutic agents such as heat and ice packs represent common noninvasive, nonpharmaceutical treatment approaches often coupled with therapeutic exercise to treat patients with articular degradation and other joint changes associated with knee OA.

ES is a commonly used treatment option to relieve pain and improve function in patients with knee OA. Three primary forms of ES were identified during this article’s literature review: interventional current (IFC), neuromuscular electrical stimulation (NMES), and transcutaneous electrical nerve stimulation (TENS).

The effectiveness of IFC treatment in patients with knee OA has been researched extensively with variable results suggesting short-term improvement in pain and function. However, as Adedoyin and colleagues comment in their paper, studies have largely failed to show benefit over controlled groups receiving an exercise program or sham treatment. In a randomized control trial (RCT) of 46 subjects with mean age of 55 years, subjects in 3 groups receiving IFC, TENS, or exercise program alone all reported improved levels of pain and function as defined by the WOMAC.38

To further highlight inconsistencies in this field of study, consider a recent RCT by Gundog and Atamaz of 60 patients with median age of 60 years and mild to moderate knee OA. Patients were treated 5 times/wk for 3 weeks consecutively with IFC treatment and compared with a sham-controlled group. The authors concluded that IFC treatment was an effective intervention in the management of knee OA, while also noting both IFC and controlled groups demonstrated significant improvements in pain and function as defined by the WOMAC.39 Related systematic reviews conducted by Hawker and Mian40 and Jamtvedt and Dahm41 support these findings, concluding that results in patients with knee OA are unclear because of low quality of evidence and a general heterogeneity of study parameters.

Less empirical data exist to support NMES as an effective therapeutic agent to improve pain or function scores in patients with knee OA. In a RCT conducted by Palmieri-Smith and Thomas, 30 women with mean age of 57 years and radiographic evidence of knee OA were provided either NMES treatment 3 times/wk for 4 weeks or no treatment over the same time period. The authors hypothesized that the group receiving NMES would demonstrate improved quadriceps activation and strength when compared with the controlled group. After a priori power analysis, the research group determined no statistically significant increase in quadriceps activation or strength in the intervention group of patients receiving NMES.42 Although patients in this study, and the IFC trials mentioned above, are slightly older than middle-aged athletes, principles of efficacy with respect to individuals with mild to moderate knee OA are expected to remain constant.

TENS represents another commonly used modality in treatment of knee OA, although efficacy with respect to functional mobility and joint stiffness is generally inconclusive. In a meta-analysis by Brosseau and Yonge, the reviewers reported a statistically significant reduction in pain levels in the treatment of patients with knee OA. As such, the authors recommended TENS as an adjunct...
therapy for the treatment of knee OA.\textsuperscript{43} Similarly, a systematic review by Jamtvedt and Dahm concluded that there is moderate evidence that TENS reduces pain when compared with a placebo intervention in treatment of knee OA.\textsuperscript{41} However, in contrast, a 2010 Cochrane review by Rutjes and Nüesch concluded that the current level of evidence to support the efficacy of TENS treatment in patients with knee OA with respect to pain and function is inadequate because of inclusion of small trials with uncertain methodology.\textsuperscript{44}

The efficacy of therapeutic US treatment in patients with knee OA has been sharply contended over the past several decades. Both nonthermal and thermal effects on localized pain, inflammation, and tissue repair remain in question. In a randomized, placebo-controlled, double blind study by Tasciglu and Kuzgun, the short-term effectiveness of therapeutic US was tested in 90 patients with moderate knee OA. The patients with a mean age of 62 were treated with either continuous, pulsed, or sham US for a duration of 5 min/session, 5 d/wk for 2 weeks. The authors reported significant improvements in pain levels, via the VAS, and functional status, via the WOMAC, across all the 3 groups. When compared with the placebo group, patients receiving pulsed US reported significantly improved scores on the VAS and WOMAC. Thus, Tasciglu and Kuzgun\textsuperscript{45} determined that pulsed US represents an effective short-term treatment approach for decreasing pain and improving function in patients with moderate knee OA.

In another Cochrane review by Rutjes and Nüesch and a systematic review of RCTs with meta-analysis by Loyola-Sanchez and colleagues therapeutic US in patients with knee OA was investigated. Both reviews report that therapeutic US may represent an efficacious treatment modality for decreasing pain and improving function in patients with moderate knee OA.\textsuperscript{41, 48} UTAS concluded that pulsed US at low intensities has a significant effect on pain reduction in patients with knee OA when compared with continuous US and sham. Despite the findings, both authors acknowledge a low quality of evidence and a large degree of heterogeneity in study parameters, ultimately conceding to the need for additional study in this field.\textsuperscript{45, 47}

Several studies have reported positive effects from LLLT including influences on fibroblast propagation, osteoblast production, and collagen synthesis as well as revascularization in wound healing. In a double blind, randomized, placebo-controlled trial by Hegedüs and Viharos, 27 patients with mean age of 42 years and mild to moderate knee OA received either LLLT or placebo LLLT. Patients received treatment twice a week over a 4-week period at a continuous wave form and dose of 6 J/point. Hegedüs and Viharos found patients treated with the active laser diode demonstrated a significant improvement in pain, knee circumference, point pressure sensitivity, and knee flexion compared with the control group. Still more impressive is that the authors report patients in the active LLLT group continued to present with improved test variables 2 months after treatment.\textsuperscript{48} Further, Jamtvedt and colleagues discussed similar findings in their systematic review, concluding that moderate-quality evidence supports the positive anti-inflammatory effects of LLLT on pain and function in patients with knee OA.\textsuperscript{41, 48}

Thermostimulation produces localized thermal effects on superficial target areas, depending on clinical indications and desired therapeutic outcomes. In a Cochrane review by Brosseau and Yonge, thermotherapeutic treatment of knee OA was discussed with respect to knee ROM, pain, strength, edema, and function. Brosseau and Yonge determined that ice massage, compared with control, had a statistically significant effect on knee ROM and function. The authors concluded that ice massage (20 min/session, 5 sessions/wk for 2 wk) represents an effective adjunct treatment in patients with knee OA demonstrating deficits associated with knee ROM and function. However, the authors do acknowledge a general heterogeneity in study parameters, citing variable methodology with respect to outcome results and test administration.\textsuperscript{45} Discrepancy in research standards is echoed in a systematic review by Jamtvedt and Dahm,\textsuperscript{41} who concluded due to small sample sizes and low quality of studies, the efficacy of thermo-therapeutic agents on pain and function in patients with knee OA is inconsistent and therefore unclear.

Ultimately, there is low-quality evidence to support the use of IFC, NMES, and thermotherapy,\textsuperscript{38–44} variable low-quality to moderate-quality evidence to support therapeutic US and TENS\textsuperscript{38, 41, 44–48} and, moderate-quality evidence to support LLLT in the treatment of patients with knee OA.\textsuperscript{41, 48} Currently, therapeutic exercise and weight reduction possess the highest quality of evidence with respect to effects on pain, inflammation, and stiffness in patients with knee OA.\textsuperscript{41} In light of these findings, further studies are needed to unequivocally substantiate the use of therapeutic modalities in treating middle-aged athletes with knee OA.

**PATIENT EDUCATION, WEIGHT MANAGEMENT, ORTHOTICS**

OARSI recommends patients with knee OA to be provided with information pertaining to treatment options and lifestyle modifications related to functional impairments and excessive joint loading.\textsuperscript{11} Arguably, the most influential risk factor associated with increased internal knee adductor moments (KAM), a clinically accepted identifier of moderate to advanced medial joint knee OA, is increased body mass. Research consistently substantiates obesity correlating significantly with both the incidence and progression of knee OA. Weight management, and ultimately weight loss, therefore represents the treatment option of choice in patients presenting with knee OA. In a study by Aaboe and Blidda, the authors found a significant reduction in knee joint loads during walking among subjects with an average body weight reduction of 13.7 kg (13.5% decrease relative to baseline) after a 16-week dietary intervention course. Aaboe and Blidda\textsuperscript{49} conclude that weight loss represents an excellent short-term approach to decreasing functional limitations associated with increased joint loading in patients with knee OA.

Alternative approaches to decrease joint loading forces in patients with knee OA include utilization of shoe wedges, knee braces, and assistive devices. Although the level of evidence supporting these intervention strategies remains variable, the biomechanical advantage gained by redistributing ground reaction forces (GRFs) during contact phase of gait is supported by experts in their respective fields.\textsuperscript{31} This biomechanical understanding of GRFs during gait reveals another rehabilitation trend found in literature; namely, that all patients with knee OA be educated on appropriate footwear as pertains to specific activity demands and impairments associated with articular changes found in with knee OA.\textsuperscript{11, 50–52} Although authors agree that footwear recommendations should be provided to all patients with knee OA,
the most effective type of shoe (ie, stability, cushioned, minimalist) remains in question.\textsuperscript{50–52} An individualized intervention approach is required when assessing middle-aged patients with knee OA, specific to activity demands, progression of disease, body composition, work/sport environment, and foot strike pattern.

A shock-absorbing insole may represent the ideal footwear choice for an obese, heel-striking patient with increased internal KAM and moderate tibiofemoral joint compartment narrowing, while a shoe designed to simulate barefoot mechanics may represent the desired footwear approach in a midfoot-strike athletic population presenting with early evidence of knee OA. The latter example describing innovative footwear is more specific to this paper and has recently been reported to significantly reduce dynamic knee loads during gait through proposed increased sensorimotor input and neuromuscular communication.\textsuperscript{50,51}

In addition to KAM-modifying and GRF-reducing wedges and supports, the importance of activity modification represents an essential educational component when treating middle-aged athletes with knee OA. As Vignon and his colleagues reported in their 2006 international systematic review, athletes should be made aware that the risk of knee OA is associated with duration and intensity of joint exposure; however, this risk is considerably less than being overweight or having a history of joint trauma. Further, middle-aged athletes with knee OA should be encouraged to engage regularly in recreational sport, provided the activity does not cause pain. No specific sport (long-distance running, tennis, soccer, field hockey, basketball, track and field, cross-country skiing, and hockey) demonstrated a significantly increased risk of knee OA when compared with others, but patients should be encouraged to change sport involving high risk of joint trauma.\textsuperscript{5}

Middle-aged athletes are encouraged to continue recreational sport as no correlation exists between practice of a regular sport and clinical or radiographic progression of knee OA.\textsuperscript{13} In addition, as highlighted earlier in this paper, the role of exercise in treating impairments associated with knee OA has been well established and coincides with improved functional outcomes. Therefore, as a preventative measure and rehabilitation staple, we recommend that the middle-aged athlete continue recreational sport—in a pain-free context—as research substantiates the association between increased physical activity and improved reports of pain, physical function, physical performance, and perceived effect in patients with knee OA.\textsuperscript{53}

CONCLUSIONS

In summary, knee OA is a prevalent condition in the middle-aged, athletic population causing significant physical impairments and functional limitations in fitness, recreational, and competitive activities. Many nonpharmacologic interventions for the management of knee OA have been researched in the past decade. Several research groups and organizations, including OASIS, OARSI, and American College of Rheumatology, have developed guidelines based upon available evidence-based information in the literature.

Conservative interventions such as manual therapy, therapeutic exercise, thermal and electromagnetic modalities, patient education, weight management, and orthotic/bracing/supports have been investigated. Overall, strong evidence exists for utilization of manual therapy techniques of joint and soft-tissue mobilization and passive and PNF stretching in the management of knee OA. Also, therapeutic exercise, including resistance (ie, closed-chain, isokinetic, and PRE) training and cardiovascular training has been suggested in many studies. Other strongly supported interventions include patient education regarding activity modification/pacing and symptom management and weight management strategies, particularly in an overweight/obese, middle-aged population.

Other nonpharmacologic management techniques for treatment of knee OA include modalities, such as ES, therapeutic US, LLLT, and thermal agents. In many instances, conflicting evidence abounds and often neither supports nor refutes the benefit provided by many of the modality interventions. Although an abundance of evidence-based research on OA has been developed, a void remains in the research within a middle-aged athletic population in the context of knee OA and conservative management.

REFERENCES


