KNEE PAIN IN COMPETITIVE SWIMMING

Scott A. Rodeo, MD

The high volume of training involved in competitive swim training result in cumulative overload injuries. Knee pain ranks second to shoulder pain as a common complaint in competitive swimmers. Most knee pain occurs on the medial side of the knee and occurs most commonly in breaststroke swimmers; however, knee pain may occur in all strokes. This article will review the incidence, biomechanical and anatomic factors predisposing to injury, specific injury patterns, injury diagnosis, treatment, and prevention of injury to the knee in swimmers.

PREVALENCE

In a survey of the 1972 Canadian Olympic Swim Team, Kennedy and Hawkins reported that 12 out of 43 (28%) orthopedic consultations were for knee pain.[3] These authors also reported a survey of the major swimming programs in Canada, in 1978,[4] in which 261 out of 2,496 swimmers reported an orthopedic complaint, an incidence of approximately 10%. Knee pain occurred in 70 out of these 261 swimmers, or 27%. All 70 of the swimmers who reported knee pain were breaststroke swimmers. Rovere and Nichols reported a survey of 36 competitive breaststroke swimmers in 1985.[7] These authors found that 75% of swimmers surveyed reported at least three episodes of knee pain per season, and 47% of these swimmers reported weekly episodes of knee pain; the incidence of bilateral symptoms was equal to the incidence of unilateral symptoms. The data indicate that knee pain is quite common in swimmers.

BIOMECHANICAL FACTORS

Because most knee pain in swimmers occurs in breaststroke swimmers, it is instructive first to review the normal breaststroke kick. Based on underwater

From the Sports Medicine and Shoulder Service, The Hospital for Special Surgery, New York, New York

films (Fig. 1) Counsilman has described precisely the components of a properly performed whipkick.[1] The kick begins with the knees held in a fully extended position. At this time they are close to the surface of the water. The ankles are in a plantar-flexed position. Leg recovery begins with hip and knee flexion. The heels should be kept close together during this phase. Once the knees and hips are in maximum flexion, the feet begin to dorsiflex, and the heels and knees separate slightly. The hips and knees reach their maximum flexion as the toes are turned outward, with the tibia in external rotation, and the ankle dorsiflexed. The feet are then pushed outward and backward as the knees gradually extend. The ankles are maintained in dorsiflexion.

The thighs are driven upward toward the surface of the water by hip extension. As the legs continue to extend at the knees, they gradually are brought together. The knees should reach full extension when the feet are nearly together. At the termination of the kick, the ankles are in plantar flexion. This description of the normal kick will be contrasted with abnormal kicking mechanics that have been noted in swimmers with specific patterns of knee pain.

Swimming in unique in that it is a noncontact and non–weight-bearing sport. Knee pain and knee injuries in swimming generally occur because of repetitive overuse.[2] The particular kicking mechanics used in swimming result in high loads on specific structures around the knee.[6] In the breaststroke kick there are high valgus loads on the knee, as the knees go into rapid extension, in association with external rotation of the tibia (Fig. 2). This results in high tension stress on the medial side of the knee as well as compression stress in the lateral compartment. In the flutter kick there is repetitive quadriceps contraction, which may lead to knee pain because of cumulative patellofemoral overload. High patellofemoral contact stresses also are generated during push-off from the wall

Figure 1. A demonstration of breaststroke, with knees in a flexed, valgus, position, and the ankles and feet externally rotated. (Courtesy of A.B. Richardson, MD, John A. Burns School of Medicine, Honolulu, HI.)

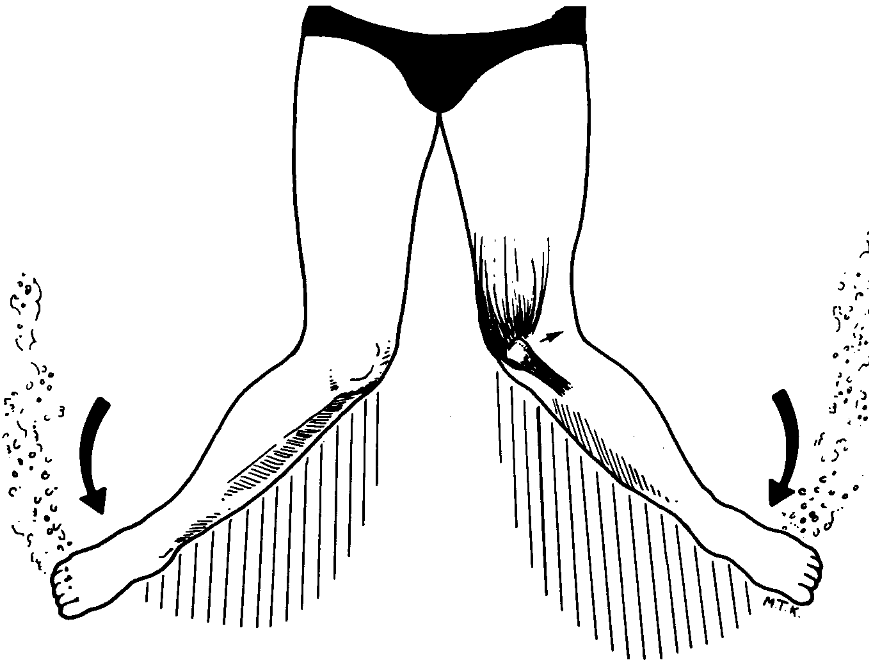

Figure 2. The breaststroke kick showing the extension of the knees and the "catch" of the water (shaded area).

because at that time there is forceful quadriceps contraction with the knee in a high degree of flexion. The resulting increase in patellofemoral contact stresses may lead to knee pain.

INTRINSIC FACTORS RELATED TO KNEE PAIN

Patellofemoral pain is common in swimmers. Several anatomic factors are related to an increased incidence of patellofemoral pain. These particular factors are common in adolescents (especially females), and thus probably play some role in overuse knee pain in adolescent swimmers. Patellofemoral pain generally is related to patellar maltracking, which may be related to abnormalities in quadriceps strength, quadriceps muscular endurance, flexibility, and muscle balance.

Patellofemoral pain also is related to patellar instability, which is often associated with patellar subluxation. Patellofemoral pain also may be related to patellar malalignment, which may be associated with lateral patellar tilt. These are conditions that commonly occur in adolescence and must be considered in the diagnosis and treatment of knee pain in swimmers. Other anatomic factors that have been related to patellofemoral pain include increased valgus alignment, and increased external tibial torsion. These two factors are both components of the normal breaststroke kick and thus may contribute to patellofemoral pain. Knee recurvatum and generalized ligamentous laxity, which often are present in swimmers, may be related to patellofemoral pain. Other anatomic factors that have been related to knee pain include patella alta, increased femoral anteversion, and hindfoot pronation.

Rovere and Nichols reported a significant decrease in internal rotation of the hips in breaststroke swimmers with knee pain.[7] In the normal breaststroke kick the hips are maintained in internal rotation with the thighs held together during the thrust phase of the kick. Thus, decrease in internal rotation of the hip may result in an improperly performed kick with resultant knee pain. Imbalances in muscle flexibility also may contribute to knee pain. In a study of 51 competitive adolescent age group swimmers, averaging 16 years old, 77% demonstrated tight hamstrings, 63% demonstrated tight calf muscles, and 56% demonstrated tight hip adductors. The relationship of these findings to knee pain was not discussed.

EXTRINSIC FACTORS RELATED TO KNEE PAIN

Rovere and Nichols reported that knee pain in breaststroke swimmers was related to the number of years of training and training volume, increased age, and caliber of swimmer.[7] These factors generally relate to increased exposure. Because most knee pain in swimmers is due to overuse, it is logical that prolonged exposure leads to an increased incidence of knee pain.

It should be pointed out that all swimming strokes (freestyle, butterfly, and backstroke) require significant bending of the knee during normal kicking (Fig. 3). Added to the stresses of multiple starts and turns, in which a partial knee squat is required, the patellofemoral joint is placed until continual, repetitive, stress.

SPECIFIC KNEE INJURIES IN SWIMMERS

Pathologic alterations in several different structures may result in knee pain in swimmers, and knee pain may be caused by abnormalities in several structures concomitantly. These will be discussed separately, but it is important to remember that several areas may be affected simultaneously. It also is important to remember that knee pain is common in adolescence (usually patellofemoral) and may not be directly related to swimming.

Kennedy et al reported that knee pain in breaststroke swimmers was due to medial collateral ligament strain.[4] These authors thought that the high valgus loads on the knee during the whipkick resulted in strain injury to the medial collateral ligament. Strain gauges on the medial collateral ligament on a cadaver knee were used during a simulated breaststroke kick to demonstrate high strains on the medial collateral ligament, especially with external rotation at the end of the kicking motion. These authors reported that tenderness may occur at either the femoral or the tibial origin of the medial collateral ligament.

An increased incidence may be related to increased hip abduction during the whipkick because the subsequent increased adduction during the propulsive phase of the kick will result in higher valgus loads on the knee. Stulberg et al reported that breaststroke swimmers with tenderness along the medial collateral ligament use a whipkick that was significantly different from that of asymptomatic swimmers.[8] These authors found that the legs were abducted widely as the hips and knees flexed during the recovery phase of the kick. The knees reached full extension while the legs were still widely abducted. The legs then

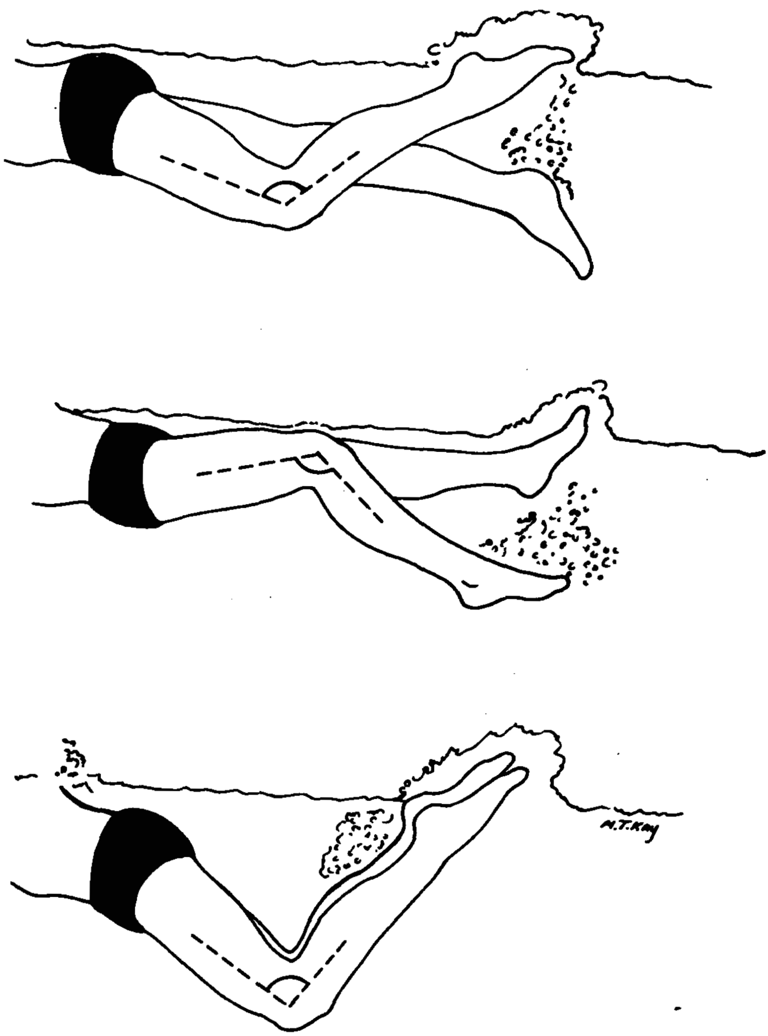

Figure 3. Knee flexion in freestyle, backstroke, and butterfly, demonstrating degree of flexion associated with the *flutter* kick.

were pulled forcefully together to complete the kick. The authors thought that this resulted in higher valgus loads on the knee and resulted in tenderness along the medial collateral ligament.

Stulberg et al studied 23 breaststroke swimmers with painful knees.[8] These authors used underwater movies of the swimmers to examine the mechanics of the kick and reported that 18 out of 23 of these swimmers had tenderness at the medial patellar facet. Five of these 18 swimmers also had tenderness along the medial collateral ligament. They found that swimmers with medial patellar facet pain had distinct abnormalities in the whipkick. These swimmers kept their hips in wide abduction as the hips and knees were flexed; there appeared to be increased hip flexion during the recovery phase. The ankles were dorsiflexed and the tibia externally rotated while the hips and knees were flexed; the legs were maintained in the position as the hips and knees extended.

This differed from swimmers with medial collateral ligament pain, who derotated and plantar-flexed the ankles as the knees went into extension. In swimmers with medial patellar facet pain the thrust phase of the kick ended with the legs in wide abduction and the knees fully extended. Unlike the swimmers with medial collateral ligament tenderness, these breaststrokers did not appear to pull their legs together at the termination of the kick. Stulberg et al felt that such abnormal kicking mechanics resulted in the patella being pulled medially, causing the medial facet to contact the intercondylar ridge.[8] These authors reported that medial patellar facet pain was not related to any other specific anatomic abnormalities, including alterations in Q-angle, tibial torsion, patellar instability, femoral anteversion, or patella alta. Arthroscopic inspection of two patients with intractable knee pain demonstrated significant chondral degeneration of the medial patellar facet. Plain radiographs from these swimmers did not reveal any distinct abnormalities. These findings are supported by Keskinen et al, who used high-speed cinematography with computerized film analysis of the breaststroke kick in breaststroke swimmers with and without knee pain.[5] These authors found that the swimmer with the most knee pain had high hip abduction angles in comparison with the control swimmers.

Keskinen et al examined nine breaststroke swimmers with knee pain, using both clinical and arthroscopic examinations.[5] These investigators found that seven out of nine of these swimmers with medial side knee pain had synovitis in the medial compartment of the knee. No other distinct abnormalities were noted. An inflamed and fibrotic medial synovial plica was postulated as a cause of medial knee pain in swimmers by Rovere and Nichols.[7] These authors found that 47% of their breaststroke swimmers with weekly knee pain had a tender and thickened medial synovial plica. Palpation of these plica produced pain similar to that experienced during the breaststroke kick in these swimmers.

Tendinitis or bursitis of the pes anserinus also may result from repetitive valgus load in the breaststroke swimmers. Pain in this region may be difficult to distinguish from pain and tenderness because of medial collateral ligament strain. Swimmers also may develop patellar tendinitis with pain at the inferior pole of the patella at the insertion of the patellar tendon. This may be caused by repetitive forceful push-off from the wall of the pool during turns.

There are several other less common causes of knee pain in swimmers. Some of these are conditions that commonly occur in adolescence and must be considered in all swimmers with knee pain. Apophyseal injuries, including Osgood-Schlatter disease and Sinding-Larsen-Johansson disease, may occur in adolescence and cause anterior knee pain. Osteochondritis dissecans is another consideration. Juvenile rheumatoid arthritis should be considered in young adolescents with persistent knee pain of unclear etiology. Meniscus pathology also must be considered. A discoid lateral meniscus must be considered in young adolescents and, in particular, those adolescents who report mechanical symptoms in the knee. Because of the compressive loads on the lateral side of the knee with the high valgus loads during the breaststroke kick, there may be pathology in the lateral compartment. Chondral injuries in the lateral compartment should be considered. Furthermore, iliotibial band tendinitis has been observed in swimmers. Lateral patellar subluxation also must be considered in breaststroke swimmers with knee pain, in particular those swimmers who report a sense of the knee giving way or clicking.

Another injury common in breaststroke swimmers includes strain injury to the hip adductors and flexors. These strain injuries usually involve the adductor magnus and brevis. Loosli and Quick surveyed two National Collegiate Athletic Association (NCAA) Division 1 Swimming Teams in 1989, and found that 10 out of 30 (30%) breaststroke swimmers and individual medley swimmers reported strain injury to the hip adductor and flexors (A. Loosli and J. Quick, personal communication, 1990). Such injuries may result in quadriceps weakness, which may contribute to patellofemoral pain.

DIAGNOSIS

A careful history and physical examination usually is adequate for the diagnosis of knee pain in swimmers. It is important to inquire about activities that the swimmer engages in outside of swimming. Young active adolescents may be involved in a variety of activities, which may figure prominently in the cause of their knee pain. It is important to determine when the symptoms occur. The swimmer should be questioned as to mechanical symptoms, which may be suggestive of internal derangement, such as a discoid lateral meniscus or lateral patellar subluxation. The swimmer also should be asked about any history of previous knee injury. Most swimmers report pain along the medial side of the knee.

Physical examination should include a thorough evaluation of the patellofemoral mechanism, signs of patellar malalignment or instability, and meniscus injury, as well as chondral and ligament injury. Overall limb alignment should be noted and the Q-angle assessed. Effusions are uncommon, but mild synovial thickening may be present. The presence of lateral patellar tilt may suggest patellofemoral compression overload as the source of pain. Evidence of patellofemoral crepitus also should be elicited. There may be tenderness to palpation over the medial patellar facet. Patellar instability is suggested by the presence of patellar subluxation and apprehension.

Tenderness usually occurs along the medial side of the knee in breaststroke swimmers with knee pain. Valgus stress testing may produce pain in association with medial collateral ligament strains. Lateral joint line tenderness as well as clicking in the knee may suggest a discoid lateral meniscus. An Ober's test will indicate tightness of the iliotibial band, which may be associated with knee pain in swimmers.

All swimmers with persistent knee pain should have standard radiographs made of the knee. Undergoing MR imaging, in advance, is rarely necessary but may be helpful in certain cases.

TREATMENT

Early recognition of knee pain and a proper diagnosis is crucial to the expedient management of this problem. Rest and activity modification represents the mainstays of treatment because these are usually overuse injuries. The swimmer may train with a different stroke or do pulling sets in which only the arms are used. A proper warm-up before intense interval training sets should be recommended. Specific stroke modifications also may be recommended. Swimmers should keep the legs together during the recovery phase of the kick and the thrust phase of the whipkick.[1, 8] Swimmers also may decrease the external rotation of the tibia during the breaststroke kick because this has been related to increased knee pain. Stretching to increase hip internal rotation may be recommended for those swimmers with inadequate hip internal rotation.[7]

Quadriceps strengthening is the mainstay of treatment for patellofemoral pain. This should be performed using closed chain exercises with avoidance of high flexion angles. Flexibility exercise of the hamstrings, hip adductors, hip flexors, and quadriceps also should be recommended.

Acute episodes of knee pain may be treated with ice and judicious use of nonsteroidal anti-inflammatory medications in addition to rest and activity modification. Modalities including ultrasound and phonophoresis may be helpful. The treating physician may consider injection of an inflamed or fibrotic synovial plica, but this should be used rarely. Steroid injections around the medial collateral ligament or pes anserinus tendons are indicated rarely, and, if considered, should be used judiciously because corticosteroids can weaken collagenous tissues.[9]

Other treatment modalities for patellofemoral knee pain include orthotics and patellar braces (worn while the swimmer is out of the water), and a counterforce strap (such as a Cho-Pat strap) that may be worn while swimming. The rationale behind this type of strap is to decrease patellofemoral contact stresses.

Surgical intervention should be a last resort and should be guided by objective findings on imaging studies and physical examination. Options include resection of a fibrotic and thickened synovial plica, arthroscopic débridement of medial patellar facet chondral lesions, lateral retinacular release, and proximal realignment for persistent patellar pain due to patellar maltracking.

For swimmers with generalized laxity and evidence of patellar instability with laxity of the patellar retinaculum, thermal shrinkage of this tissue using a radiofrequency or other heat device may be considered. This is analogous to the use of this device for treatment of capsular laxity in the shoulder. However, at this time, these techniques should be considered experimental, and careful follow-up of these patients needs to be performed.

PREVENTION

Knee pain in breaststroke swimmers may be prevented by gradually increasing the breaststroke kicking during the early season. Breaststroke swimmers should have up to 2 months off per year from breaststroke kicking. A proper warm-up should be used before intense interval training sets. Stretching may be recommended to increase hip internal rotation.[7] Lower extremity muscle strength, muscle endurance, and flexibility should be maintained. Specific stroke modifications may be suggested as noted above. Breaststroke swimmers should keep the legs together during the recovery phase of the kick and during the thrust phase of the whipkick. Stroke analysis may be performed by a coach who is experienced in breaststroke kick analysis, and underwater cameras may be used. A dry land training program, focusing on quadriceps muscle strength and endurance (especially vastus medialis obliquus), as well as hamstring flexibility, should be recommended. Such a program should be planned carefully to fit into the overall training schedule so that this program does not contribute to the overall repetitive stress on the knee.

THE INJURED ATHLETE

Swimmers may experience injuries, such as meniscus or anterior cruciate ligament tears, which occur in adolescents who engage in sports and recreational activities. Special considerations apply to returning these swimmers to a regular training program for swimming. If these swimmers are treated conservatively for these injuries, then the swimmers should go through a thorough muscle-strengthening program. The swimmers should return gradually to swimming workouts, within limits of their pain. Cybex strength testing should be used to document the strength of the injured extremity and to compare to the uninjured extremity. Once strength is at least 90% of the contralateral extremity, then return to full athletic competition may begin. In the early phase of return to swimming, the swimmer should avoid high loads on the knee, such as may occur during the breaststroke kick. Different strokes should be used and the swimmer may use pulling sets with avoidance of kicking. The swimmer should be assessed carefully for signs of pain and instability related to the underlying injury.

References

1. Councilman J: The Science of Swimming. Upper Saddle River, NJ, Prentice Hall, 1968, pp 17–123
2. Johnson J, Sim F, Scott S: Musculoskeletal injuries in competitive swimmers. Mayo Clin Proc 62:289–304, 1987
3. Kennedy J, Hawkins R: Swimmer's shoulder. The Physician and Sports Medicine 2:35–38, 1974
4. Kennedy J, Hawkins R, Krissof W: Orthopaedic manifestations of swimming. Am J Sports Med 6:309–322, 1978
5. Keskinen K, Eriksson E, Komi P: Breaststroke swimmer's knee: A biomechanical and arthroscopic study. Am J Sports Med 8:228–231, 1980
6. Richardson A: The knee in swimming: Part II. Swimming World, 1979, pp 36–37
7. Rovere G, Nichols A: Frequency, associated factors, and treatment of breaststroke's knee in competitive swimmers. Am J Sports Med 13:99–104, 1985
8. Stulberg S, Shulman K, Stuart S, et al: Breaststroke's knee: Pathology, etiology, and treatment. Am J Sports Med 8:164–171, 1980
9. Wiggins ME, Fudale PD, Barrach H, et al: Healing characteristics of a type I collagenous structure treated with corticosteroids. Am J Sports Med 22:279–288, 1994

Address reprint requests to

Scott A. Rodeo, MD
Hospital for Special Surgery
535 East 70th Street
New York, NY 10021