

BioMechanics

May 2006

Overuse injuries curb triathlon preparation efforts

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The primary goals of an endurance athlete are to arrive at the starting line healthy and injury-free, to finish the race with a great personal performance but without injury or illness, and to recover from the effects of the race. To accomplish those goals requires the athlete to optimize training in order to be in the best possible shape to meet the demands of the race. Completing an endurance event such as the Ironman Triathlon (a 2.4-mile swim, 112-mile bicycle ride, and 26.2-mile run) requires an athlete to have adequately prepared both physically and mentally for the challenge; the results may be disastrous for anyone who is underprepared.

Efficient energy use

It costs energy to just move the limbs, support the body, and maintain balance. This is the unloaded cost of movement. Movement frequency affects total efficiency; a higher running cadence (stride length and frequency) costs more energy than a low cadence. Trained athletes tend to zero in on an optimal cadence and stride length for their body type and anatomy.¹⁻⁴ The key to achieving optimal power and velocity with each stride is to find a balance between cadence and stride length.

Average stride length is 1.35 times an athlete's height.^{5,6} Studies have shown that most experienced runners naturally choose a stride length that gives them optimal efficiency.⁶⁻⁸ In most cases, efforts by the runner or a coach to change a runner's stride length tend to make it less efficient, increasing energy costs and reducing running speed.

Training has been shown to improve running efficiency.⁹⁻¹² Although beginning runners make the greatest gains in efficiency, experienced runners can make small improvements in efficiency that may give them a slight edge over competitors. Running more will, in itself, improve a beginning runner's efficiency tremendously. Stride length and frequency will naturally adjust to a more efficient pattern. Body weight will decrease to the demands of running. Neuromuscular coordination and movement biomechanics will improve.

Overuse injuries in endurance athletes

Consistently pushing the body to its limits, both physically and mentally, will inevitably result in injury. Injuries in endurance athletes are common.¹³⁻¹⁹ They can drastically alter training and will probably affect racing performance. It is imperative that an endurance athlete quickly recognize and treat these injuries in order to achieve optimal performance. For athletes and their treating practitioners, the keys to preventing and treating injuries are to recognize training errors that can lead to an injury, recognize the early signs of an injury, and address injuries as soon as possible.

Knowing and understanding errors in training that put an athlete at greater risk for injuries is an important component of designing a training program. There are several periods of training when an athlete is more vulnerable to injury: when adding training volume; when increasing training intensity; when adding new movement patterns such as swim stroke, running form, or bike position; and when returning from an injury or an absence from training. Biomechanical problems, both extrinsic and intrinsic, that may contribute to developing overuse injuries are listed in Table

1.14,18,20

Overuse injuries make up the majority of injuries in endurance athletes and they are preventable.^{14,16,19} Acute injuries are difficult to prevent but are less frequent.^{11,19,21} The best way to prevent and reduce the risk of overuse injuries is by correcting the above factors when recognized.

Common overuse injuries

Endurance training repetitively stresses muscles, tendons, and the tissues around joints and bones. This continuous stress produces repetitive microtrauma. Overuse injuries result from the body's inability to keep up with repair of the damage created by repetitive microtrauma. The body's tissue eventually breaks down, resulting in pain, inflammation, and weakness. Ignoring the pain and inflammation and continuing to train will lead to macrotrauma and disruption of the tendon or muscle. Table 2 presents guidelines to preventing overuse injuries.

The types of overuse injuries encountered in endurance sports relate to the type of repetitive motion the body encounters. In triathletes, injuries to the shoulder result from the motions of swimming while lower extremity injuries result from motions of running and cycling. Most overuse injuries^{14,15,19} can be treated successfully by adhering to practical guidelines (Table 3).

Swimmer's shoulder. The most common overuse injury²⁰ developed in swimming is rotator cuff tendinitis, better known as "swimmer's shoulder." Repetitive stress around the shoulder causes inflammation and microtrauma to the muscles and tendons surrounding the shoulder ball and socket joint called the rotator cuff. Rotator cuff tendinitis is usually caused by pool workouts that are either too much, too hard, or too frequent (that is, too many total yards per session, too many high-intensity yards, or too many sessions per week); shoulder muscle imbalances; and poor stroke form.

Symptoms include pain localized to the shoulder cuff, stiffness and difficulty raising the arm above the shoulder, weakness, and pain at night.

Such an injury may also keep the triathlete from taking a proper "aero" position on the bike (back flat, head lowered, and forearms parallel to the bicycle frame-on clip-on bars, for example-to reduce aerodynamic drag), which can diminish performance.

For most cases of swimmer's shoulder, treatment consists of rest, ice, and compression to reduce inflammation and pain; training adjustments to decrease overhead activities (such as swimming and lifting weights); and reducing the volume of swimming to allow adequate healing.

In some cases this requires the practitioner to recommend the athlete completely cease swimming for a time and avoid the aero position on the bike as much as possible. Instead, the athlete should sit upright with hands on the top bar when riding.

In severe cases, or if symptoms persist for more than two weeks, the athlete should see a sports medicine specialist for further evaluation and treatment. Often, treatment requires physical therapy to strengthen the weakened muscles and reduce pain and inflammation.

Sacroiliac joint dysfunction. The SI joint connects the back to the hips, making it a major joint in the body. A muscle or structural imbalance there can lead to irritation, termed SI joint dysfunction.^{11,14,18,19} This is a common cause of low back pain in triathletes.^{22,23} It was noted to be one of the three most common injuries to competitors in Hawaii's Ironman Triathlon.²³

Contributing factors include leg length discrepancy, tight hamstrings, gait dysfunction, and poor

bike positioning.²¹

SI joint dysfunction causes pain in the low back, above the hips. The pain is usually a dull ache but can be sharp during exercise. It may radiate to the hip or back. Athletes may describe a "catch" in their low back. The best way to treat SI joint dysfunction is to identify and correct the contributing factors, including ankle overpronation and any muscle imbalances, compensate for any leg length discrepancies, incorporate into the training protocol a program of back and leg strengthening and stretching, and adjust bicycle fit and position (the seat too high and stretching too far forward on the aerobars are common culprits).

Iliotibial band friction syndrome (ITBFS). The iliotibial band runs along the outer side of the leg from the hip to the knee. ITBFS is a condition common to both cyclists and runners and is caused by tendons in the IT band rubbing against bony prominences of the hip and knee (see "Conservative therapy stretches iliotibial band friction for recovery," April, page 41). The rubbing causes irritation, pain, and inflammation. Most commonly it causes a dull to sharp pain on the outside of the knee. The athlete may note a snapping sensation in the outer hip area. Initially, pain is usually aggravated by cycling or running up or down hills. As it progresses, the pain will occur during all training activities; it will interfere significantly with hill workouts and sprints. After long cycling or running sessions, an athlete may note pain in the groin area as the tight IT band causes increased strain on the adductor muscle. Scar tissue and adhesions develop with chronic ITBFS.

ITBFS is caused by biomechanical imbalance or overuse, repetitive running on canted roads, a leg length discrepancy, cycling with fixed cleats, low back and hamstring tightness, and IT band tightness and overuse.

Treatment includes rest, ice, massage, and stretching; identification and correction of any contributing biomechanical factors; orthoses to correct leg length discrepancies and ankle overpronation; a professional evaluation/correction of running gait and cycle position; a daily program of stretching to increase flexibility; massage therapy to stretch and loosen any adhesions or scar tissue; and a strengthening program to correct any muscle imbalances.

As the athlete recovers, appropriate training adjustments include decreasing the volume and intensity of training; avoiding hill workouts, running on canted roads, and intense bike rides; using bicycle cleats with free rotation (allowing the leg to rotate freely between the shoe cleat and pedal); and deep-water pool running, which allows the athlete to maintain aerobic conditioning without aggravating the injury.

The best way for athletes to prevent ITBFS is to incorporate a regular program of stretching and strengthening into their training program. They should also replace worn-out shoes often and avoid running on canted roads. Bicycle cleats that allow some rotation while cycling will help.

Hamstring muscle injury. A hamstring muscle strain or tear is a running or cycling injury. It usually occurs as a result of a sudden contraction during an intense session such as interval training, downhill running, or sprinting at the end of a race. The tear is usually a result of either tight hamstrings secondary to overtraining or a muscle imbalance. Muscle imbalances may exist between the hamstrings and the quadriceps and gluteus muscles. Hamstring tears usually occur at the muscle-tendon junction near the hip or knee, more rarely they will occur in the middle of the muscle.^{3,14,18,19,24}

The pain is usually sharp, localized, and sudden in onset. Muscle spasms may occur as well. Typically, the injury is persistent and often difficult to get rid of completely.

The best treatment for mild hamstring tears is one to two days of rest, application of ice and a compression wrap, gentle stretching and light massage, gradual progression back into running and

cycling, and incorporating a diligent stretching program into the training protocol.

For more severe strains, or if symptoms persist and the athlete is unable to resume running, it is a good idea for him or her to see a sports medicine specialist.

Endurance athletes should consider adjusting their training by reducing the intensity of their running and cycling sessions, using shorter strides while running, avoiding downhill runs and interval/speed workouts, and participating in deep-water running or swimming.

It is important to emphasize to the athlete that the best way to prevent a hamstring injury is to incorporate a daily stretching program into the training routine. Hamstring strengthening exercises will help balance muscles of the lower extremity.²⁵ An adequate warm-up prior to interval or speed workouts will also help prevent muscle injuries.

Anterior knee pain. This is a common complaint of many runners and cyclists.^{11,14,18,19,21} Pain is usually surrounding or underneath the knee cap, but typically not localized to one specific area.

Anterior knee pain is frequently associated with cycling or long runs. It worsens with sitting for long periods with the knee bent ("theater sign") or walking up and down stairs. Occasionally, there is swelling about the knee. It usually is gradual in onset but can begin after an acute injury to the knee. Symptoms resolve with rest and decreased activities.

The cause of anterior knee pain is multifactorial. The basis of the pain stems from biomechanical factors that cause poor tracking of the patella in the femoral groove. Factors that contribute to anterior knee pain may include tight hamstring muscles, muscle imbalances, weak quadriceps muscles, ankle overpronation, poor bike position, arthritis, and weak hip muscles.

Initial management of anterior knee pain requires rest, application of ice, and anti-inflammatory medications. To keep the problem from recurring, an athlete should identify and correct any factors contributing to the pain. This may require a careful evaluation by a sports medicine specialist to assess gait, biomechanics, and leg structure. Easy corrections include regular stretching, strengthening to better balance muscles, using orthoses, raising the bicycle seat, and a gradual return to running and cycling when symptoms improve.

Achilles tendinitis. The Achilles tendon connects the calf muscles to the heel. It is prone to microtrauma and inflammation from the repetitive motion of running. The causes are ankle overpronation, tight calf muscles, excessive hill running, overtraining, poorly cushioned shoes, a change in running surface, excessive dorsiflexion during cycling (the heel dropping below the pedal at the bottom of the pedal stroke), and progressing too rapidly with the intensity and volume of training (more than 10% per week). When the muscle and tendon are unable to keep up with the increased repetitive stress, tissue breakdown occurs.

Achilles tendinitis causes pain and tightness, localized to the ankle area. The pain worsens with walking on the ball of the foot or on the toes. If the symptoms are ignored, pain and inflammation will continue, leading to further tissue damage, which may in turn lead to a chronic tendinitis and the possibility of the tendon rupturing.^{14-16,18,19}

Achilles tendinitis treatment includes ice massage of the affected area, anti-inflammatory medication, reduction in the volume and intensity of training with a gradual increase as healing takes place, avoidance of steep hills and hard surfaces, a daily warm-up and stretch, and a water-running element included in the training program. Taping or wrapping the ankle and using a heel lift may bring temporary relief.

It is important to give this injury time to heal, typically four to six weeks but sometimes six months

or longer for complete healing.^{19,24} Racing an endurance triathlon with this condition will end disastrously for the athlete. It could result in a partial or complete rupture of the tendon.

Several preventive measures are available to athletes. For runners, a warm-up, regular stretching, good running shoes with a stable heel counter and adequate cushioning, and possibly orthoses, will help. They should also increase training volume and intensity gradually and avoid running on hills and hard surfaces, such as cement, at the beginning of training. Cyclists may need to adjust the position of the cleats or height of the seat on their bicycle.

Plantar fasciitis. The plantar fascia is a spring-like ligament that supports the arch of the foot; the ligament is stretched as it distributes the weight of the body on the foot during running. Overtraining, foot imbalances, and running on hard surfaces or in worn-out shoes can cause inflammation of the fascia called plantar fasciitis.^{14,15,18,19,24,25} Tight calf muscles are also a contributing factor.

Symptoms are gradual in onset but increase with continued running. Pain is localized to under the foot or the heel. This condition is also referred to as "painful heel syndrome." A typical complaint of plantar fasciitis is intense pain with the first step in the morning. Symptoms will gradually worsen and pain may occur with daily walking.

Plantar fasciitis is a serious running injury that can become severe enough to require several months to heal. To treat plantar fasciitis, athletes should apply ice, take anti-inflammatory medication, replace worn-out shoes with well-cushioned ones, consider using an orthosis and heel cushion, stretch the calf muscles daily, and apply cross-friction massage to the plantar fascia.

If symptoms persist, athletes should consult a sports podiatrist to help evaluate the condition and prescribe the right treatment. Night splints are often used to keep the plantar fascia stretched while the athlete is sleeping.

Training should be adjusted by reducing the running distance; light cycling and deep-water running are good alternatives. While the athlete should spend time in the water improving his or her swim stroke, wall push-offs that may aggravate the condition should be avoided.

To reduce the risk of plantar fasciitis, the athlete should be urged to stretch the calf muscles daily, wear well-cushioned shoes and replace them frequently, avoid running on hard surfaces, and use orthoses if indicated.

Stress fractures. A stress fracture is an overuse injury to the bone. Repetitive stresses that break down bone occur with endurance training. Normally, the body is able to repair the bone as it breaks down. But if the stresses are too much, the body is unable to keep up with repairs and the bone eventually is unable to repair itself. Mild pain that gradually worsens with continued activity may indicate a stress fracture.

The most common symptoms of a stress fracture are point tenderness over the bone, night pain, and pain that doesn't improve with rest. The three most common sites of a stress fracture in endurance athletes are the metatarsals, tibia, and femoral neck.^{14,15,19,25}

Factors contributing to developing stress fractures include biomechanical factors such as overpronation at the ankle and poor running form, overtraining, and improper training progression (too much, too hard, too frequent). This is the most common training error that leads to stress fractures, along with lack of flexibility and muscle imbalances.

Stress fractures can be diagnosed with an x-ray but often require a bone scan.^{14,15,19,25} Treating a stress fracture calls for complete rest from running or any other weight-bearing or

impact-loading activities. Deep-water running and swimming may continue. Progression back to running is gradual and carefully monitored.

Conclusion

Understanding the biomechanics of sports and sports movements is the key to understanding the pathophysiology of sports injuries. Most often an underlying biomechanical issue or issues contribute to an athlete's current injury. Properly assessing weaknesses, biomechanical deficiencies, and training errors will help to identify the cause of the athlete's injury. Understanding the injury's biomechanics will help practitioners to prescribe the correct treatment and make corrections in biomechanics and training.

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Table 1. Biomechanical factors that may lead to injury

Extrinsic factors

- New or different equipment; e.g., a different bicycle, pedals, aerobars, or wetsuit
- New or different shoe type, style, wear
- Change in bicycle cleats or their positioning
- Change in bicycle position
- Change in road surface; e.g., cement, canted roads

Intrinsic factors

- Muscle imbalances
 - Leg length discrepancy
 - Lower extremity alignment
 - Poor flexibility
 - Changes in technique or form; e.g., swim stroke or running form
 - A sudden change in training volume, intensity, frequency, or activity
 - Previous or untreated injury
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Table 2. Guidelines to prevent overuse injuries

Practitioners should be sure endurance athletes are told:

- To avoid over-training
- To listen to their bodies and rest when needed
- To not try to make up missed training sessions
- To address all injuries, even minor ones
- To allow your body time to recover and heal
- To include daily stretching into your program
- To include a strengthening program in your training
- To correct biomechanical problems (obtain a formal gait analysis, adjust bike to the proper position, have swim stroke evaluated/corrected, use orthoses if recommended, use correct running and cycling shoes, strengthen muscle imbalances, adhere to a regular stretching program)
- To warm up and cool down adequately with each training session
- To monitor training with a personal log
- To obtain an analysis of their training program by an expert, who can recommend: training progression of no more than 5% to 10% per week, rest days and easy days be included in training schedule, cross-training, development of an aerobic base in training protocol, periodization, balance between the disciplines

Table 3. Guidelines for overuse injury treatment

PRICE

P = Protection Protect the injured extremity

R = Rest Cross-train or deep-water run for relative rest

I = Ice Apply 20 to 30 minutes every two to three hours, first three days

C = Compression Apply an elastic wrap to reduce swelling

E = Elevation Raise extremity above the level of the heart

REST = Resume Exercise below Soreness Threshold

Reduce Volume: 25% to 30%

Reduce Intensity: 10% to 20%

Reduce Frequency: 25% to 50%

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