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PHYT875-Research Paper

# A Trifecta of Injuries in the Triathlete

## Introduction

The sport of modern triathlon consists of swimming, biking, and running segments.[1-3] The first triathlon was held on Mission Bay in San Diego in September 1974, consisting of 6 miles of running, 5 miles of cycling, and 500 yards of swimming.[4] The first Ironman distance race was the Hawaiian Ironman Triathlon held in February 1978.[4] Triathlon made its debut as an Olympic sport at the 2000 Sydney Games, just 19 years after first being recognized by the International Olympic Committee.[5] Since it's inception in 1978, the number of individuals participating in this arduous sport has increased significantly. In 2010, USA Triathlon membership was over 150,000, and an estimated 2.3 million individuals worldwide competed in a triathlon within the year.[4,5] With its popularity steadily on the rise, it will be imperative for the clinician to be conscious of training regimens, injury mechanisms and incidence, as well as treatment and preventive options for the triathlete.

The complexity of the multisport athlete should not be overlooked. Bales and Bales state that in training for 3 different disciplines, the triathlete walks a very fine "knife's edge."[1] Athletes must balance training to maintain optimal fitness levels in 3 sports; at the same time, they need to avoid overuse injuries that might interfere with or completely inhibit their participation in training, racing, and/or finishing a triathlon.[1,2,6] Distances vary widely across the triathlon spectrum, but all require a significant amount of endurance. The sprint distance consists of .5mi swim, 15mi bike, and 3mi run. The international/Olympic distance is a .9mi swim, 24.8mi bike, and 6.2mi run. Half Ironman distance contains a 1.2mi swim, 56mi bike, and 13.1mi run. Finally, the Ironman distance requires a 2.4mi swim, 112mi bike, and 26.2mi run.[6]

**TABLE 1.** Triathlon Distances

| Type | Swimming | Biking (km) | Running (km) |
|---|---|---|---|
| Sprint | 750 m | 20 | 5 |
| Olympic | 1500 m | 40 | 10 |
| Long | 2.0 km | 80 | 20 |
| Half Ironman | 1.9 km | 90 | 21 |
| Ironman | 3.9 km | 180 | 42 |

[27]

The sacrifice in competing at such a level can be much greater than that of the individual disciplines alone, physically and mentally. The "average" triathlete spends approximately 800hrs per year doing some type of training.[7] Depending on the individual and desired race distance, weekly training schedules are also variable, ranging from 30min workouts 2-3x a week to 5-6hr workouts 7 days a week.[7-10] It has been estimated that long-course triathletes (Olympic distance or greater) train an average of 10x per week, while short-course triathletes train an average of 8x per week.[8] Part of triathlon training is becoming accustomed to changing the discipline with each workout or even within a given workout. This need to train in multiple arenas can be an asset or a hindrance in the care of a triathlete.[1,7] One asset is the ability to rebalance training volume and intensity over 3 disciplines, which can be very beneficial if the athlete has an injury that particularly affects training in 1 discipline.[1] However, the combined stresses of multisport training may hinder the healing process due to its cumulative effects.[7] Therefore, the clinician needs to be aware of the propensity for injury in this population and how each discipline may lend itself to particular injuries.

*Risk Factors and Prevalence*

Due to the physically demanding and endurance nature of a triathlon, these athletes are prone to overuse injuries.[1-3,8,11-13] An overuse injury is a gradual damaging of tissue such that the athlete often cannot remember the exact onset.[14] The damage is the result of a series of repetitive microtraumatic events that is too much for the tissue to repair before it is required to perform again—over time, this constant breakdown without a corresponding recovery and repair period can overwhelm tendon, cartilage, bone, or muscle and lead to an overuse injury.[14] Several retrospective studies have reported between 47% and 75% of triathletes experience overuse injuries.[8,15,16] In a study by Burns et al., 68% of preseason and 78% of competition season injuries had an overuse etiology.[2] Similarly, many authors have found that the majority of injuries occur during training versus competition.[2,6,7]

Although overuse injuries may be multifactorial, there are extrinsic and intrinsic risk factors that may contribute to their prevalence. Intrinsic risk factors are inherent to the athlete and consist of the internal personal factors that may lead to a sports injury.[3] For example, factors such as age, gender, triathlon experience, previous injury, or personal anatomy and biomechanics are intrinsic.[2,3,10] Extrinsic risk factors can be independent of the athlete and usually consist of external or environmental precipitants of injury.[3] Factors such as weather, training equipment, or intensities of training are extrinsic.[2,3] Of 3 prospective studies looking directly at links between these risk factors and rate of injury, the only positive associations have been previous history of injury, years of triathlon experience, and a supinated foot type.[2,8,17] Aside from these factors, it is important to note the demands of each discipline within triathlon and how this might also lead to injury.

*Swim, Bike, Run*

The swim leg is first in the triathlon. Swimming related injuries generally occur less often than in cycling or running, accounting for 1% to 12% of reported triathlon injuries.[2,8] In longer distance races, the swim is usually performed in open water and presents a unique problem of a tangle of competitors in a small area.[12] The use of wetsuits may prevent hypothermia, but interestingly they also increase buoyancy and decrease drag forces experienced when swimming[12]; thus, less effort is required to stay afloat and more energy can be used to propel one's body through the water. Due to the nature of the freestyle swim stroke, the rotator cuff muscles are at risk because of the repetitive overhead activity.[6,12] Injuries directly related to swimming usually involve the shoulder, but there may also be indirect injuries that occur in the lower extremities. These will be discussed in detail in later sections.

Next is the cycling leg of the triathlon, which is usually raced along city streets or highways sometimes. Injuries in cycling typically occur as a result of direct trauma or due to overuse.[7] While traumatic injuries are fairly rare, this is a chief concern in training when athletes have to use busy roads in order to fulfill a certain mileage for that day. Bike set-up and fit are very important to the efficiency of the cycling action and play a large role in cycling-related overuse injuries.[1,6,7,12] Bike fit has been described in detail elsewhere[18], but as it applies to particular pathologies, bike set-up will be discussed later.

The final portion of the triathlon is the running leg. The consensus among several studies is that the majority of triathlon injuries occur during running[1-3,6,7,8,10,12,15], possibly due to the high impact loads the lower extremities experience while pounding on the road. Unique to this portion is that the triathlete is now experiencing the accumulative effects of the previous 2 legs, placing him/her under a moderate amount of physical and mental stress. Consequently, this places the individual at a greater risk for sustaining fatigue-based injuries.[12]

Many injuries experienced by triathletes can develop by overuse in a single discipline or can be compounded by training effects of multiple disciplines. Swimming and cycling have been shown to have a significantly lower injury rate per 1000 training hours when compared to running.[2] In their sample of triathletes competing in the 1999 Australian triathlon season, Burns et al. found 72% of overuse injuries were attributable to running.[2] In light of the plethora of reported injuries in triathletes, this discussion will only include 3 of the most common injuries, highlighting pathomechanics, interventions, and prevention strategies for each.

**Box 1**
**Examples of injuries and illnesses in triathletes**

Nonmusculoskeletal
- Dehydration
- Hyperthermia
- Blisters
- Abrasions
- Muscle cramps
- Female athletic triad (anorexia, amenorrhea, osteoporosis)

Musculoskeletal, nonimaged
- Short-duration low back pain
- Muscle strains
- Ulnar neuropathy (cyclist's palsy)

Musculoskeletal, imaged
- Rotator cuff impingement
- Stress fractures
- Tendinosis
- Plantar fasciitis
- Radiculopathy
- Osteitis pubis
- Meniscal tear
- Iliotibial band syndrome

[24]

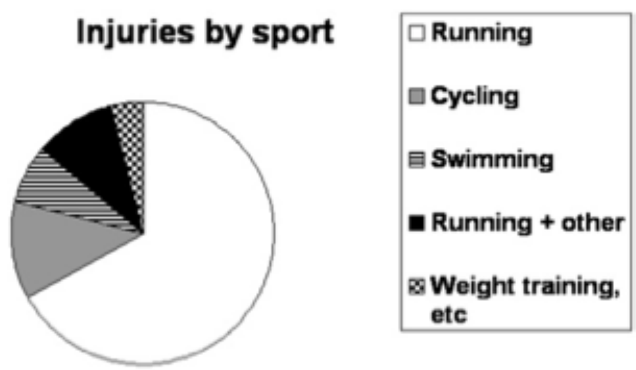



Fig. 1. Percentage of injuries in triathletes that occur from the 3 sports. [24]

<u>Rotator Cuff Tendinopathy</u>

The rotator cuff consists of 4 intrinsic shoulder muscles: supraspinatus, infraspinatus, teres minor, and subscapularis. The tendons of these 4 muscles insert and reinforce the capsule of the shoulder joint, forming a musculotendinous cuff. Inherently, this formation helps protect the glenohumeral joint and stabilize the humeral head in the small glenoid cavity.

Compositionally, the tendon components are comprised of 95% Type I collagen fibers, giving them strength and stiffness.[19] When unhealthy tendon is present, such as with tendinopathy, there is decreased collagen content, an increase in mucoid ground substance, and the collagen that is present is oriented in many different directions (versus its normal parallel orientation); all of which lead to weakness in the tendon tissue.[19]

In order to understand the mechanism of injury behind rotator cuff tendinopathy in the triathlete, it is imperative to analyze the biomechanics of the swim stroke. The freestyle stroke can be broken down into a propulsive or pull-through phase and a recovery phase.[12,20,21] When the hand enters the water in the propulsive phase, the shoulder goes through continual adduction and internal rotation.[22] In the recovery phase, the arm comes out of the water into abduction and external rotation.[22] During these 2 phases, the path of the hand in the water follows an 'S' shaped movement in order to propel the body.[12] Movements essential to the recovery phase are the body roll and the ability to repeatedly retract the scapula—these motions protect the subacromial bursa, supraspinatus tendon, and the posterior-superior labrum.[20] The supraspinatus tendon is especially vulnerable both in the recovery and propulsion phases, as the relative avascular region of the tendon becomes exposed to repetitive microtrauma as it passes rapidly under the coracoacromial arch.[12] This may lead to pain, inflammation, and weakness of the rotator cuff, which may further cause a decrease in space under the arch due to the superior migration of the humerus during the swim stroke.[21]

The best and most efficient swimmers engage and generate most of the power in their stroke by using a significant amount of core musculature from the body roll rather than limiting the stroke to the shoulder girdle.[21] Because swimming is the first leg of the triathlon, athletes may tend to reduce the effort of their legs because the bulk of the race will emphasize the strength and endurance of their lower extremities—in doing so, they may reduce the balance of proper arm and leg propulsion and create undue stress in the glenohumeral joint.[7] Additionally, this may be compounded by the constant stress of holding the torso in a fixed position on the bicycle's aerobars in the cycling leg.[23] The optimal aerodynamic position [See Figure[18] in next section] causes the humeral head to compress against the supraspinatus tendon and subacromial bursa[24], which may aggravate impingement symptoms. Furthermore, the repetitive arm swing in the running leg of the race may irritate the tendon by the constant motion and tension created by this movement.[23]

Several authors have agreed that treatment options need to begin with active rest and reduced training.[12,20,21] A close second to that is a technical stroke analysis and correction by a coach or trained professional[20], as the mechanics of the swim can have huge implications for the shoulder as mentioned above. The stability of the core and scapular function also need to be addressed, with exercises being directed toward specific dysfunctions in any of the musculature. Exercises should be aimed at maintaining proper humeral head inclination, minimizing strain on the capsule and ligaments, and maximizing the efficiency of scapulohumeral muscles by allowing an optimal length-tension relationship.[20] Modalities and soft tissue massage may also be beneficial in reducing inflammation and pain.[20]

Preventive measures need to begin with aiming all efforts toward avoiding collision of the rotator cuff and subacromial bursa with the undersurface of the anterior acromion.[20] In order to accomplish this, the triathlete's swim stroke needs to be thoroughly analyzed. The goal here is to decrease the amount of internal rotation of the arm during pull phase, improve early initiation of external rotation during recovery phase, and improve the tilt angle of the scapula.[25] Also in the recovery phase, emphasis should be placed on increasing body roll and scapular retraction;

this aims to normalize the strength and endurance of the cuff and scapular stabilizers.[25] Furthermore, multidirectional stretching of the arm and core strengthening are critical in preventing this injury. Overall, balanced strength training of the rotator cuff, improvement in core stability, and correcting scapular dysfunction are central elements in treatment and prevention.[20] However, swimming may predispose the triathlete to the next injury, Achilles tendinopathy.

Achilles Tendinopathy

The Achilles tendon is the common tendon of the triceps surae, formed by the gastrocnemius and soleus muscles, and it inserts into the calcaneal tuberosity. Because of the very high collagen content of tendon (95% Type I fibers), it does not change appreciably in length in response to tensile loading; additionally, this tissue may only undergo 10% strain prior to failure in response to tensile stress.[26] Normal tendon structure can be disrupted in response to 3 stressors: tension, compression, and frictional abrasion.[19] Due to the high repetitive nature of the endurance athlete, the triathlon participant is particularly subject to high frequency and high load stressors.

Swimming, although non-weightbearing, may predispose the individual to Achilles tendinopathy.[6,7,12] Throughout the swim cycle, the foot largely remains in a plantarflexed position in order to streamline the body; this could indirectly result in shortening of the triceps surae and Achilles tendon. This may cause a predisposition to injury of the calf, which is largely concentric in the bike leg and eccentric in the running component of triathlon.[12] During the bike and run parts of the race, the posterior calf is forced to work through a greater range of motion, especially being pushed to end range dorsiflexion in hill training. As the athletes transition to the biking portion of the race, called T1, they are often running barefoot to where their bikes are located. Immediately after being non-weightbearing in swimming, they transition into high load, high repetition cycling. This quick transition is thought to exacerbate Achilles tendinosis in triathletes.[24] Furthermore, in an abnormal cycling technique where the heel drops below the pedal in the lower portion of the pedaling stroke[18], the Achilles tendon may be placed under more repetitive tensile stress.

Initially, the presentation of this injury may be an atraumatic, sharp discomfort of insidious onset that occurs anywhere along the course of the Achilles tendon.[27] However, there are 2 main types of this diagnosis: hypoxic and mucoid. The hypoxic type involves focal thickening of the tendon—this person may have a painless lump in the tendon, with little risk for progressing to tendon rupture.[24] The focal thickening in the mucoid type is usually painful, and there is an increased risk for progressing to a rupture in this situation; as such, triathletes with this type may have to significantly modify their workout.[24]

Treatment interventions usually involve rest, use of anti-inflammatory medications, ice application, and/or a modification of cycling technique.[18] As a lower cadence and standing up out of the saddle for hills may lead to increased pain in this injury, it is recommended that one maintain a higher cadence at lower gears—this also allows for energy conservation in the quadriceps muscles for running.[7] Activity modification, in terms of decreasing training intensities and duration in running and biking, might specifically be recommended for a short period in order to remove the athlete from the offending activity. To the triathlete's advantage is the ability to cross-train. If experiencing this injury, the athlete may be able to spend more time swimming, with careful consideration paid to not overtraining and to adequately stretching the triceps surae complex. A gradual return to the offending activity should be employed, so as not to inhibit the tendon from going through the proper stages of healing.[26]

Because this injury is particularly associated with overuse and poor bike fit, special preventive measures should be taken to ensure that overtraining is not happening and proper bike fit has been established.[6,7,12,18] Deakon has written a phenomenal article on cycling related injuries and proper bicycle fitting.[18] The desired goal of the proper bike fit is an aerodynamic position that is comfortable to maintain for the duration of the cycling portion of any given triathlon distance [See Figure below].[18] The seat height, saddle position, and arm reach/aerobar height are the main components to analyze. This should be done by a professional at a bike shop that understands the demands and biomechanics necessary for the triathlete to perform optimally and avoid injury.


**FIGURE 2.** A knee flexion angle with the foot at bottom dead center of 25 degrees, a hip angle of 97 degrees, a near horizontal back position, and good arm position. [18]

Plantar Fasciitis

The deep fascia of the plantar surface of the foot is referred to as the plantar fascia. The plantar aponeurosis is the extremely thick central portion of this fascia. This aponeurosis originates from the base of the calcaneus and extends distally to the phalanges. Unique to this area of the body is the windlass mechanism—this describes the manner by which the plantar fascia supports the foot during weightbearing activities.[28] The anatomy of the foot inherently forms an arch-like truss, with the calcaneus, midtarsal joint, and medial longitudinal arch forming the arch, and the plantar fascia forming the tie-rod.[28] Thereby, the plantar fascia helps support the longitudinal arches of the foot via anatomical orientation and tensile strength.

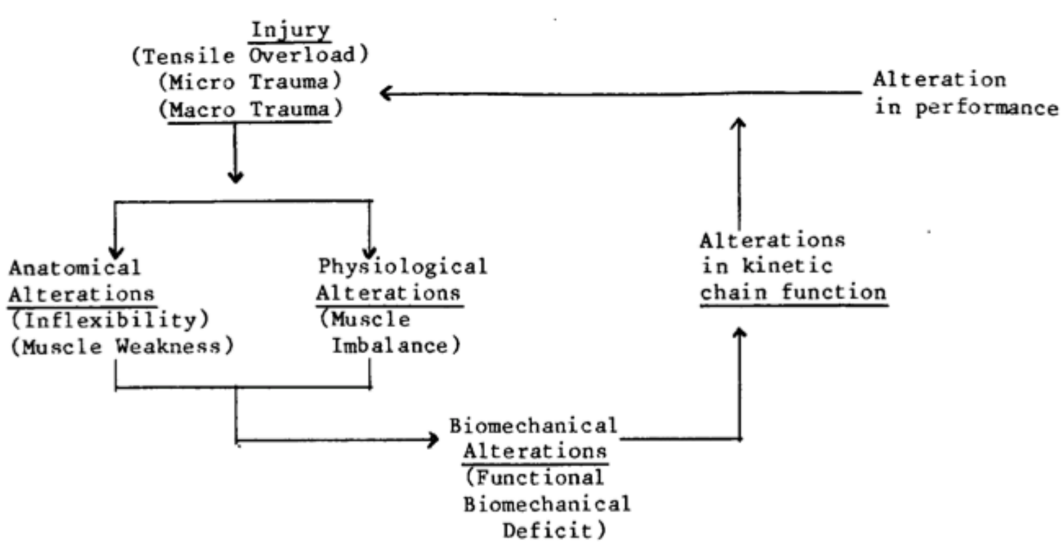
**Figure 1. The triangle shows the truss formed by the calcaneus, midtarsal joint, and metatarsals. The hypotenuse (horizontal line) represents the plantar fascia. The upward arrows depict ground reaction forces. The downward arrow depicts the body's vertical force. The orientation of the vertical and ground reaction forces would cause a collapse of the truss; however, increased plantar-fascia tension in response to these forces maintains the truss's integrity.** 28

The development of plantar fasciitis, as with the other injuries discussed in this paper, is multifactorial. Especially in the long distances run by any level of triathlete, there are tremendous demands placed on the lower extremities. For the final leg of the triathlon, athletes must face accumulating physical and mental fatigue; additionally, they must also regain their "running legs" after lower extremity exertion in the water and being fixed on the radius of bike pedals.[27] The transition from biking to running (called T2) presents a delicate situation as there is a change from concentric muscle contractions to eccentric ones, and from a lower load situation to forces up to 250% of the person's body weight with every heel strike.[29,30] Compounding the chances for pathologic development are factors such as lower limb malalignments, biomechanical imbalances, decreased calf or great toe extensibility, training techniques, environmental terrain, footwear, or running style.[31-33] Specifically, excessive pronation may cause an increase in tensile stress to the plantar fascia.[27,29,31,33] Therefore, the majority of treatment interventions are focused on controlling this motion and correcting other biomechanical issues as needed.

Treatment success is mostly dependent on reducing the stress that caused the original injury.[33] It is important to educate the athlete on a typical presentation of this diagnosis, as early recognition will be crucial in developing a treatment plan and preventing further tissue damage. As outlined by Cornwall and McPoil, the goals of conservative management are to reduce pain and inflammation, reduce tissue stress, and restore muscle strength and flexibility.[33] Ice, anti-inflammatory medications, and other modalities may be helpful in addressing the first goal. To address the second, a thorough biomechanical and footwear evaluation should be conducted. The importance of proper shoe wear cannot be overstated. Running shoes may lose between 30% and 50% of their shock absorption after about 250mi of use and should be replaced every 400 to 600mi or every 6 months.[34] The role of shoe wear or foot orthoses in treating plantar fasciitis is not to directly control foot motion, but rather to provide full contact for the foot, thus supporting and reducing tensile stress of the plantar structures.[29,33]

Preventive methods include much of the same components of a treatment program for plantar fasciitis. Given the propensity for tight calf musculature coming from the swimming and cycling legs of the race, the triathlete should be proactive about stretching both in training and competition. Increasing flexibility of the triceps surae and strengthening both intrinsic and extrinsic muscles of the foot will assist in treating and preventing this injury.[27,31,33] Due to the overuse nature of plantar fasciitis, the athlete needs to be aware of the risks of overtraining or changing environmental factors such as running surface or hill training. Additionally, to combat the drastic change in muscle contractions from biking to running, athletes should begin the run at a slower pace before building up to their desired pace[12], allowing the body time to adapt to the new demands placed on it. Finally, educating triathletes on sound shoe construction[31] and their footwear needs, based on their particular anatomy and running style[27,29], will be important steps in reducing the likelihood of sustaining an injury such as plantar fasciitis.

Conclusion

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The complexity of the multisport athlete presents a unique set of challenges to the clinician. Due to the intense nature of training and competition in the endurance athlete, there is a propensity for overtraining and sustaining overuse injuries. Pathology may begin as simple muscle or flexibility imbalances, which may lead to anatomical or biomechanical alterations; thus, a negative feedback cycle[32] is likely to develop if these imbalances are not preventively addressed [See Figure[32] above]. Three common overuse injuries have been discussed in this paper. The first step in preventing and treating any overuse injury is knowledge of the symptoms and prompt identification of overtraining effects.[1] An advantage of the triathlete is the ability to balance training and intensities over 3 different disciplines.[1,7] For example, if an overuse injury is incurred through excessive mileage in running, the option exists to cross-train in the non- and low-impact disciplines of swimming and cycling, respectively. The fundamentals of maintaining good core stability, stretching and resting appropriately, practicing efficient mechanics in each discipline, ensuring proper bike and shoe fit, and being prudent in all training components will help prevent overuse injuries for novice and experienced triathletes alike.

References:

1. Bales J, Bales K. Training on a Knife's Edge: How to Balance Triathlon Training to Prevent Overuse Injuries. Sports Med Arthrosc. 2012;20(4):214-6.
2. Burns J, Keenan AM, Redmond AC. Factors associated with triathlon-related overuse injuries. J Orthop Sports Phys Ther. 2003;33(4):177-84.
3. Gosling CM, Gabbe BJ, Forbes AB. Triathlon related musculoskeletal injuries: the status of injury prevention knowledge. J Sci Med Sport. 2008;11(4):396-406.
4. USA Triathlon. 2012. Retrieved from: [http://www.usatriathlon.org/about-multisport/history.aspx](http://www.usatriathlon.org/about-multisport/history.aspx). Accessed December 2012.
5. International Triathlon Union. ITU triathlon facts and figures. 2012. Retrieved from: [http://archive.triathlon.org/?call=TVRZMw==&sh=keep](http://archive.triathlon.org/?call=TVRZMw==&sh=keep). Accessed December 2012.
6. Strock GA, Cottrell ER, Lohman JM. Triathlon. Phys Med Rehabil Clin N Am 2006;17(3):553-64.
7. Cipriani DJ, Swartz JD, Hodgson CM. Triathlon and the multisport athlete. J Orthop Sports Phys Ther. 1998;27(1):42-50.
8. Korkia PK, Tunstall-Pedoe DS, Maffulli N. An epidemiological investigation of training and injury patterns in British triathletes. Br J Sports Med. 1994;28(3):191-6.
9. Niles R. Overtraining: The delicate balance. Triathlete. 1993;111:64-69.
10. O'Toole ML. Training for ultraendurance triathlons. Med Sci Sports Exerc. 1989;21(5):S209-13.
11. Gosling CM, Forbes AB, McGivern J, Gabbe BJ. A profile of injuries in athletes seeking treatment during a triathlon race series. Am J Sports Med. 2010;38(5):1007-14.
12. McHardy A, Pollard H, Fernandez M. Triathlon injuries: A review of the literature and discussion of potential injury mechanisms. Clinical Chiropractic. 2006;(9):129-138.
13. Shaw T, Howat P, Trainor M, Maycock B. Training patterns and sports injuries in triathletes. J Sci Med Sport. 2004;7(4):446-50.
14. Pecina M, Bojanic I. Overuse Injuries of the Musculoskeletal System. Boca Raton: CRC Press LLC; 2004.
15. Collins K, Wagner M, Peterson K, Storey M. Overuse injuries in triathletes. A study of the 1986 Seafair Triathlon. Am J Sports Med. 1989;17(5):675–680.
16. Wilk BR, Fisher KL, Rangelli D. The incidence of musculoskeletal injuries in an amateur triathlete racing club. J Orthop Sports Phys Ther. 1995;22(3):108–112.
17. Burns J, Keenan A-M, Redmond A. Foot type and overuse injury in triathletes. J Am Podiatr Med Assoc 2005;95(3):235-41.
18. Deakon RT. Chronic musculoskeletal conditions associated with the cycling segment of the triathlon; prevention and treatment with an emphasis on proper bicycle fitting. Sports Med Arthrosc. 2012;20(4):200-5.
19. Gross M. Tendon: Composition, structure, function, mechanical properties, and healing. [Voicethread]. University of North Carolina at Chapel Hill: Division of Physical Therapy; 2012.
20. Bak K. The practical management of swimmer's painful shoulder: etiology, diagnosis, and treatment. Clin J Sport Med. 2010;20(5):386-90.
21. Bales J, Bales K. Swimming overuse injuries associated with triathlon training. Sports Med Arthrosc. 2012;20(4):196-9.
22. Troup JP. The physiology and biomechanics of competitive swimming. Clin Sport Med 1999;18(2):267-85.

23. Reuter RM, Hiller WD, Ainge GR, et al. Ironman triathletes: MRI assessment of the shoulder. Skeletal Radiol. 2008;37(8):737-41.
24. Tuite MJ. Imaging of triathlon injuries. Radiol Clin North Am. 2010;48(6):1125-35.
25. Yanai T, Hay JG. Shoulder impingement in front-crawl swimming: II. Analysis of stroking technique. Med Sci Sports Exerc. 2000;32(1):30-40.
26. Gross MT. Chronic tendinitis: pathomechanics of injury, factors affecting the healing response, and treatment. J Orthop Sports Phys Ther. 1992;16(6):248-61.
27. Spiker AM, Dixit S, Cosgarea AJ. Triathlon: running injuries. Sports Med Arthrosc. 2012;20(4):206-13.
28. Bolgla LA, Malone TR. Plantar fasciitis and the windlass mechanism: a biomechanical link to clinical practice. J Athl Train. 2004;39(1):77-82.
29. Gross ML, Davlin LB, Evanski PM. Effectiveness of orthotic shoe inserts in the long-distance runner. Am J Sports Med. 1991;19(4):409-12.
30. Migliorini S. Risk factors and injury mechanism in Triathlon. J Hum Sport & Exer. 2011;6(2):i-vi.
31. Wilk BR, Fisher KL, Gutierrez W. Defective running shoes as a contributing factor in plantar fasciitis in a triathlete. J Orthop Sports Phys Ther. 2000;30(1):21-8.
32. Kibler WB, Goldberg C, Chandler TJ. Functional biomechanical deficits in running athletes with plantar fasciitis. Am J Sports Med. 1991;19(1):66-71.
33. Cornwall MW, McPoil TG. Plantar fasciitis: etiology and treatment. J Orthop Sports Phys Ther. 1999;29(12):756-60.
34. Asplund CA, Brown DL. The running shoe prescription: fit for performance. Phys Sportsmed 2005;33(1):17-24.