Athletic Performance Management; Special Populations: Triathlete

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History of the Triathlon

- Triathlons can be found dating back to the 1970's in the states. What started as a group of friends training together in their different disciplines soon turned into a friendly competition as to who was the "best" athlete.
- What started as a friendly competition has blossomed into a huge calling to all athletes daring to explore their physical and mental will power testing the human body's capacities.

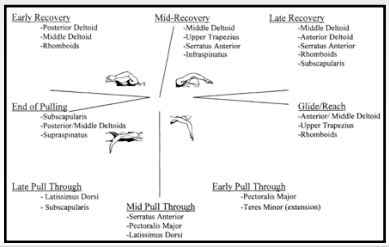
Disciplines of the Event

Discipline	Sprint	Olympic	Half-Ironman	Ironman
Swim	0.5 mile	0.93 mile	1.2 miles	2.4 miles
Bike	13 miles	24.8 miles	56 miles	112 miles
Run	3.2 miles	6.2 miles	13.1 miles	26.2 miles

Biomechanics of the Swim

- Freestyle propulsion primarily due to drag forces based on Newton's 3rd law of motion
- Freestyle stroke: equal body rotation and balance, early catch, early exit, straight-through pull arm stroke
- Normal catch (glide)
  - Forward hand enters the water; upper traps elevate and rhomboid retracts scapula. Serratus Anterior protracts, rotates the scapula up (highly active from this point through the pull)
  - Just after the catch, pec major fires and adducts and extends the humerus, while the internal rotation is balanced by the antagonistic external rotation of teres minor
- Mid pull-through
  - Lats fire in with the subscapularis until beginning of recovery
- Recovery
  - Deltoid and supraspinatus are the prime movers in this phase

Biomechanics of the Swim



The swim continued…

- Patho-biomechanics that may attribute to shoulder pain;
  - Hand entry crossing midline→ mechanical anterior impingement (biceps, supraspinatus) thumb down entry exacerbates the stresses on biceps attachment of labrum
  - Cross over pull through → crossover entry → increase time in the impingement position
  - Asymmetric body roll or unilateral breathing may increase impingement by causing compensatory crossover pull through on side with less roll or non-breathing side
  - Improper head position, forward sloping shoulders, scapular instabilities→ implicated in arm, shoulder, upper back and neck pain which may or may not associated with neurologic signs and symptoms
  - Muscle imbalances between serratus anterior (weak) and rhomboids (increased) during pull→ increase anterior impingement

Biomechanics of the Bike

- Biggest factor: proper bike fitting
  - Without proper fitting for the bike, a variety of injuries and problems can occur
  - Best advice is proper fitting and gear for the cycling part of the event
- Seat height
  - At the bottom foot stroke, the knee should be flexed between 30° -35°
  - During down stroke, ITB is pulled anteriorly
  - During upstroke, ITB is pulled posteriorly
- Click in pedals
  - Are the pedals free floating or stable in one position?
  - Some prefer floating foot pedals to prevent fixation of the foot during the ride
    - Floating pedals provide less tension on foot, ankle, knee, and hip

Bike Biomechanics

- Lower body considerations:
  - Setting an optimal bike seat height can minimize energy use while maximizing power output
  - Measure from greater trochanter to floor with feet slightly spread apart. Take into consideration length of cleats and any orthotics being used
- Upper body considerations:
  - Arms should be flexed 9-18°
  - Forearms titled up 8-17°
  - Optimal upper body position is 20° horizontally with lumbar and thoracic spine flat

Bike Biomechanics of the Hip

- The pelvis position dictates spine, hip, knee, and ankle requirements
- The more the pelvis is anteriorly rotated, the less the spine must flex, but the more stretched the gluts and hamstrings are stretched
  - This increases the quads output during the downstroke increasing power; especially with climbing
- Some riders benefit with a 10-15 degree inclination of the seat allowing a decrease in low back pain

Bike Biomechanics: Seat Position

Seat too high

- Decreases power due to LE muscles working beyond maximal length-tension ratio
- Increases stress on hamstrings, gastrocs, and posterior knee capsule
- Excessive hip extension leads to loss of pelvic stability
- Rocking pelvis leads to fatiguing adductors, gluts, and the spine

Seat too low

- Increases knee flexion
- Increases patellofemoral and suprapatellar bursal loading
- Sub-optimal length-tension ratio of hamstrings, gluts, and gastrocs

Bike Biomechanics: Seat Positioning

Seat too far forward

- Increases patellofemoral compression force
- Increased knee flexion and hip extension making LE muscles at sub-optimal length-tension ratio

Seat too far back

- Hamstrings and glutes are over lengthened causing a decrease in force production

Bike

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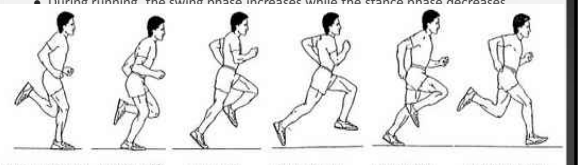
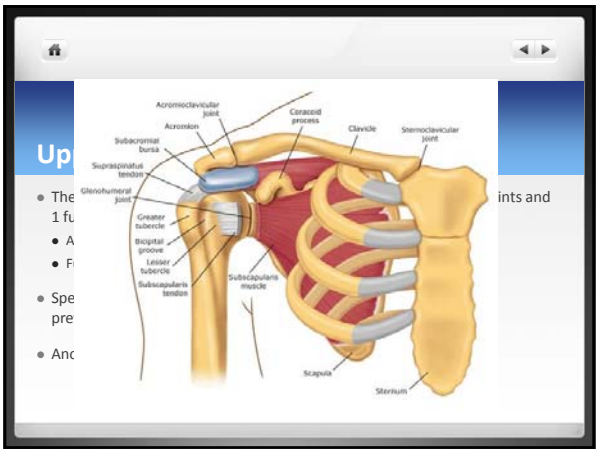
Biomechanics of Running

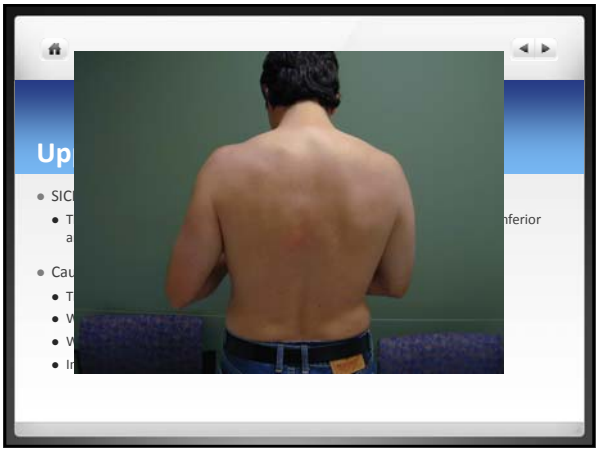
- A typical gait consists of a stance phase of 60% and swing phase of 40%
- During running, the swing phase increases while the stance phase decreases

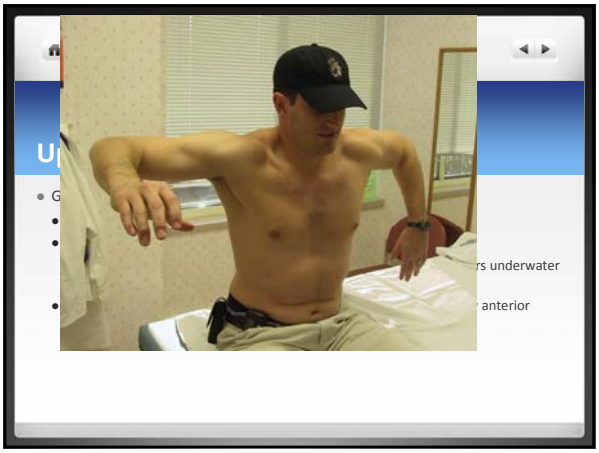


Biomechanics of the Run

- Gait Considerations
  - During normal gait, the most tension on the ITB is found during heel strike and the stance phase
  - Following the bike ride, the hip flexors may be inhibited altering normal hip flexion and extension
  - Adductors and abductors of the hip altered firing patterns following the swim and ride
  - Different orthotics specific for the run are sometime utilized


Acromioclavicular joint
Coracoid process
Acromion
Clavicle
Sternoclavicular joint
Subacromial bursa
Supraspinatus tendon
Glenohumeral joint
Greater tubercle
Bicipital groove
Lesser tubercle
Subscapularis tendon
Subscapularis muscle
Scapula
Sternum





Upper Extremity Injuries: Shoulder

- Rotator Cuff Syndrome
- Commonly associated with GH instability
- Common in overhead athletes and swimmers due to repetitive motions
- MC muscles problems with supraspinatus and infraspinatus
- Commonly see tight posterior capsule

Upper Extremity Injuries: Shoulder

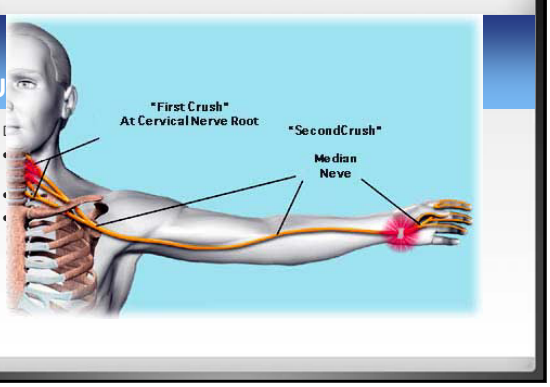
- Signs and Symptoms
  - Feeling/fear of slipping or instability
  - Pain discomfort with abduction and external rotation
  - Numbness or paresthesia of lateral arm, sometimes down to 4th and 5th digits
  - Shoulder appears inferior and internally rotated compared to non involved shoulder
  - Weakness with abduction, external rotation

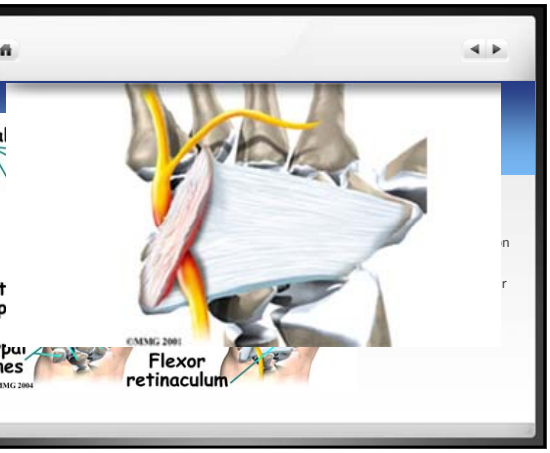
Upper Extremity Injuries: Shoulder

- Clinical Findings
  - (+) Exams include: anterior apprehension, load and shift, relocation test
  - May also see associated poor scapular positioning and functioning
  - History of trauma, overhead athlete, previous shoulder injuries

Upper Extremity injuries: Elbow

- Cubital Tunnel
  - Ulnar neuropathy due to the exposure of the ulnar nerve passing through the cubital tunnel.
  - May occur to due direct pressure on nerve on handle bars
  - Can also be due to extended periods of elbow flexion or in combination with arm flexion and elbow flexion
  - Numbness from elbow down arm into 4th and 5th digits





Upper Extremity Injuries: Wrist

- De Quervain's tenosynovitis occurs with inflammation of abductor pollicis longus and extensor pollicis brevis tendons at the runnel near the radial styloid process.
- Signs and symptoms:
  - Local tenderness
  - Swelling
  - crepitus

Tests:

Finkelstein's test

Lower Extremity Injuries: Hip

- **Femoral Acetabular Impingement (FAI)**
  - Conflict occurring between the anterior femoral head-neck junction and the adjacent anterosuperior labrum and acetabular rim; this can be due to an abnormality between proximal femur, acetabulum or both
  - Two types of FAI:
    - CAM
    - Pincer

Lower Extremity Injuries: Hip

- CAM
  - Abnormality of femoral head/neck offset
  - With flexion, adduction, and internal rotation of abnormal femoral head→ rotates into acetabular rim→ shear stress on articular cartilage.
  - Cartilage damage occurs first; labral injuries tend to be detachments
  - MC in young active males
- Pincer
  - Any abnormality of acetabular rim; can be due to retroversion or global over coverage
  - Results primarily in labral tears and bony proliferation
  - Chronicity → focal chondral injury→ cyst formation from labral tear or ossification of acetabular rim
  - May result in chondral injury in the 'counter-coup' region of the posteroinferior acetabulum
  - Occurs more in female and older age groups

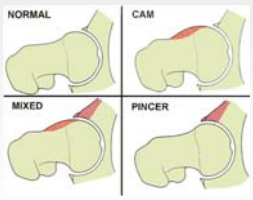
Lower Extremity Injuries: Hip

Patient Presentation:

Most frequent present complaint was pain, with 85% having moderate or marked pain

- Anterior groin
- Lateral trochanteric
- Deep posterior buttock

ADL limitations: heavy work , walking for >15 minutes , rising from sitting, light to moderate work , getting in and out of a car



Philippon et al. AOSSM 2006

Lower Extremity Injuries: Hip

(+) Findings:

- FABER's + for pain in impingement patients
- Anterior impingement will have pain with hip flexion and internal rotation
- Posterior impingement will have pain with hip extension and external rotation

Lower Extremity Injuries: Knee

- **Iliotibial Band Syndrome**
  - Condition that occurs when the ITB rubs against the lateral femoral epicondyle resulting in inflammation
  - Friction occurs at approximately 30° of knee flexion
  - 2nd most common injury among runners (1st is PFPS)
  - Very common in long distance runners and cyclists
  - Etiology: many suggested but not limited to: Leg-length differences, increased forefoot varus, downhill running, and increased Q-angles
  - In runners, posterior aspect impinges over lateral condyle, just after foot strike in gait cycle
  - In cyclist- ITB pulled anteriorly on downstroke and posteriorly on upstroke

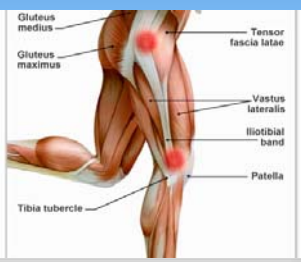
ITBS

Patient Presentation

- Pain in lateral aspect of knee
- Pain over greater trochanter
- Pain increased with physical activity: running hills most intense at heel-strike, cycling
- Lateral knee pain when walking up or down stairs/hills

Findings:

- Walking with affected side extended
- Point tenderness 2-4 cm above lateral joint line and at Gerdy's tubercle

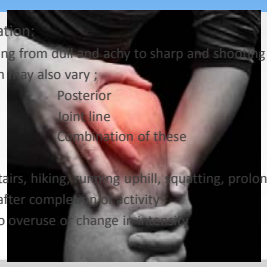


Lower Extremity Injuries: Knee

- **Patellar Femoral Pain Syndrome (PFPS)**
  - Retropatellar or peripatellar pain resulting from physical and biochemical changes in the patellofemoral joint
  - Often lack of objective findings although have subjective complaints
  - Can have short or chronic/recurrent duration
  - Etiology is multifactorial resulting from a combination of intrinsic and extrinsic factors

PFPS

- Patient Presentation:
  - Knee pain varying from dull and achy to sharp and shooting
  - Location of pain may also vary :
    - Anterior
    - Retropatellar
    - Peripatellar
    - Global
    - Posterior
    - Joint line
    - Combination of these
  - Pain climbing stairs, hiking, running uphill, squatting, prolonged sitting
  - Pain often felt after completion of activity
  - Often related to overuse or change in intensity



Lower Extremity Injuries: Knee

- Other genetic factors affecting vector forces:
  - Tibial Torsion
  - Genu Valgum/ Varum
  - Femoral anteversion
  - Wide pelvic girdle
  - Pes planus
  - Muscle tightness

Lower Extremity Injuries: Ankle/Foot

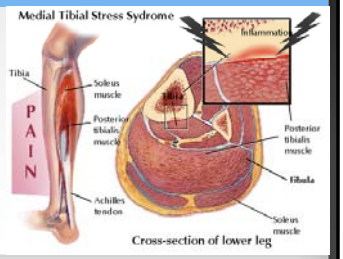
- **Medial Tibial Stress**
  - Aka medial tibial traction periostitis
  - Fasciitis and periostitis occurring along the medial aspect of the lower leg.
  - Inflammation due to tensile forces secondary to eccentric contraction of the muscles of the deep posterior and superficial posterior compartments
  - Forces exerted on fascial-periosteal attachment of the tibial crest where a stress reaction occurs
  - Factors that may contribute to the increased stress and traction:
    - Excessive pronation (flat feet)- due to eccentric loads on soleus resisting pronation
    - Training errors
    - Shoe design
    - Surface type
    - Muscle dysfunction
    - Fatigue
    - Decreased flexibility

Lower Extremity Injuries: Ankle/Foot

Patient Presentation:

Diffuse pain along the medial border of the tibia (junction between the lower 1/3 and upper 2/3rds of tibia), usually decreases with warm up

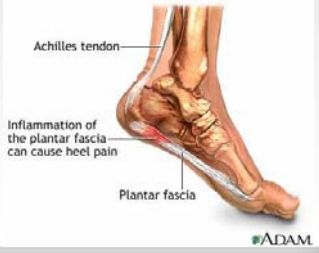
More focal pain, think possible stress fracture



Lower Extremity Injuries: Ankle/Foot

Plantar Fasciitis

Overuse condition of plantar fascia at its attachment to the calcaneus due to collagen disarray in the absence of inflammatory cells resembling that of tendinosis

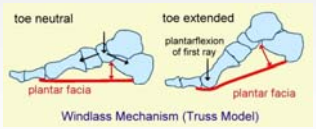


Windlass Mechanism

Windlass Mechanism

Windlass is a hauling or lifting device consisting of a rope wound around a cylinder that is turned by a crank. The rope is analogous to the plantar fascia and the cylinder is analogous to the MTP joints. In a normal foot contraction of the extrinsic plantar flexor muscles raises the calcaneus, therefore transferring body weight forward over the metatarsal heads, resulting in hyperextension of the MTP joints, stretches the PF within the medial longitudinal arch→ this increased tension from the stretch strengthens the midfoot and forefoot. Contraction of the intrinsic muscles provides additional reinforcement to arch.

Demonstrated best on tip toes, because of its attachments, on the proximal phalanges, hyperextension of MTP joints increases tension throughout the medial longitudinal arch, as the heel and most of the foot is raised, body weight shifts anteriorly toward the medial metatarsal heads, where fat pads, sesamoid bones and rigidity of the second ray provide suitable base of support for the action of plantar flexor muscles.



Windlass Mechanism (Truss Model)

Lower Extremity Injuries: Ankle/Foot

Causes of Plantar Fasciitis:

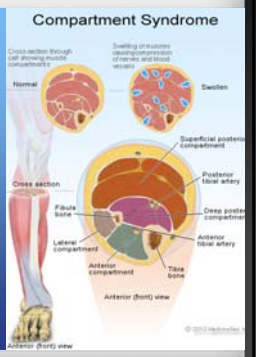
- Pes planus: places increase stress on origin of PF at calcaneus; as the PF attempts to maintain a stable arch during propulsive phase of gait, loss of windlass effect
- Pes cavus: excessive strain on heel area because the foot lacks ability to evert in order to absorb the shock and adapt to the ground
- Results from activities requiring maximal plantarflexion of ankle and simultaneous dorsiflexion of MTP joints.
- Associated with tight myofascial structures especially calf, hamstrings and gluteal regions

- Patient Presentation
  - Gradual onset of pain felt medial aspect of heel
  - Worse in the morning, decreases with activity, often ache post activity
  - As condition becomes more severe, pain may be present when weight bearing and worsen with activity
- (+) Findings:
  - Tenderness along medial tuberosity of calcaneus
  - Tight PF, painful when stretched

Lower Extremity Injuries: Compartment Syndrome

Defined as increased pressure within a closed fibro-osseous space, causing reduced blood flow and reduced tissue perfusion leading to ischemic pain; possible permanent damage to tissues of the compartment

May be acute or chronic (exertional)



Compartment Syndromes

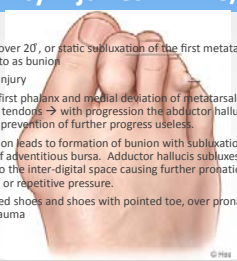
- Deep Posterior Compartment Syndrome:
  - Contains flexor hallucis longus, flexor digitorum longus, and tibialis posterior
  - AROM, PROM and RROM may exacerbate pain
  - Patient may describe a feeling of tightness or bursting sensation
  - Pain increases with exercise
  - Distal symptoms; radiating symptoms on plantar aspect of foot (tibial nerve compression)
  - Small herniations sometimes seen on medial or anterior borders of tibia after exercise
  - Mild tenderness along medial aspect of tibia; less obvious palpable tightness
- Anterior Compartment Syndrome
  - Contains tibialis anterior, extensor digitorum longus, peroneal tertius and deep peroneal nerve
  - Pain during exertion felt just lateral to anterior border of the shin and paresthesia may present in the first web space
- Lateral Compartment Syndrome
  - Contains peroneal longus/brevis tendons and superficial peroneal nerve
  - Pain is palpated just anterior to the fibula and paresthesia may occur tot the dorsum of the foot

Lower Extremity Injuries: Ankle/Foot

- **Peroneal (common fibularis) Neuropathy:**
  - Peroneal nerve is the most commonly injured nerve in LE; most commonly as it wraps around the fibular neck.
  - Most frequently reported after exertion as leg pain and weakness.
  - Burning sensation or pins/needles in anterolateral leg
  - Sensory deficits possible on dorsum of foot; paresthesia without motor deficit is common
  - May be confused with anterior compartment syndrome → lack of swelling and tenderness over anterior compartment and focal pain around fibular neck may be sufficient enough to eliminate a compartment syndrome from differential diagnoses
  - MOI: Repetitive trauma
  - NCV will show decreased amplitude of common fibular nerve

Lower Extremity Injuries: Ankle/Foot

- **Hallux Valgus**
- Lateral deviation of the toe over 20˚, or static subluxation of the first metatarsalphalangeal joint (MTPJ); commonly referred to as bunion
- Rarely results from athletic injury
- The lateral deviation of the first phalanx and medial deviation of metatarsal displace the sesamoid and also the flexor and extensor tendons → with progression the abductor hallucis tendon is subluxed inferior to the MTPJ making prevention of further progress useless.
- Advancement of this condition leads to formation of bunion with subluxation and rotation of first phalanx and development of adventitious bursa. Adductor hallucis subluxes toward the second toe and the lateral sesamoid into the inter-digital space causing further pronation. Bursa becomes inflamed with direct trauma or repetitive pressure.
- Commonly due to high heeled shoes and shoes with pointed toe, over pronation, arthritis, Achilles tendinosis, previous MTP trauma



Core Considerations: Cervical Spine

- The cervical spine can be stressed during all aspects of a triathlon
- During the swim, the head is constantly rotating and extending
- During the bike, the aerodynamic position can increase stress on neck extensors
- During the run, most core muscles are fatigued and are vulnerable to injury

Core Considerations: Cervical Spine

- Anterior head carriage will increase the stress of accessory breathing muscles and stress deep neck flexors
- Without proper cervical positioning, radicular symptoms may occur along with muscle spasms or strains of the facet joints
- To help neck pain, strengthening the scapula retractors with an anterior pelvic tilt will decrease neck pain with biking

Core Considerations: Thoracic Spine

- The thoracic spine is stressed most during the swim due to the constant scapulothoracic rhythm
- Without proper scapular placement, the thoracic spine can become taxed and make movements more difficult
- Poor cervical posture stresses breathing biomechanics and the ribs are not able to function at optimal performance

Core Considerations: Thoracic Spine

- Increased kyphosis in the thoracic spine may eventually lead to decreased in the lungs capacity to fully expand limiting the maximal cardiovascular output
- An increased kyphotic thoracic spine can also lead to limited extension in the thoracic region and weaken the back extensors
  - Special care should be focused to back extensors to help maintain proper thoracic positioning and function

Core Considerations: Lumbopelvic Region

- Common fault patterns in the lumbopelvic region during a triathlon includes:
  - Hypertonic; hip flexors, adductor magnus, rectus abdominus, quadratus lumborum, hamstrings
  - Fatigued; erector spinae, gluts, adductors
  - Hypotonic; transverse abdominus, gluteus maximus and medius.

Core Considerations: Lumbopelvic Region

- Because the swim, bike, and run are all biomechanically different, each event causes new challenges to the core. The body must be able to stabilize its core to prevent alterations of normal biomechanics thus resulting in injury.
- A weak, or unbalanced core can lead to hip, knee, ankle, foot, and spine injuries. The emphasis of endurance strength of the core is crucial to competing and completing a triathlon.

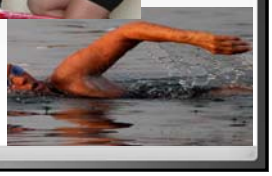
Treatment Interventions

- **Shoulder Active/Passive Care Approach**
  - Active/Passive Care Upper Quarter
  - Active/Passive Care Lower Quarter
  - Soft Tissue Approach
  - Taping
  - Sports Specific Rehabilitation and Training

Active/Passive Care Upper Quarter

Passively restore GH ROM, scapular ROM both individually and together

MRT to the hypertonic, over-used or over-developed areas of the cervical, thoracic and shoulder complex.



Active/Passive Care Upper Quarter

In the tri-athlete hypertonic areas of the thorax more than likely include:

- Pectoralis major/minor
- Subscapularis
- Latissimus Dorsi
- Levator Scapulae
- Upper Trapezius
- Sternocleidomastoid.

As for the upper extremity muscles include:

- Brachialis
- Common wrist flexors
- Pronator teres
- Pronator Quadratus
- Intrinsic hand musculature

Active/Passive Care Upper Quarter

Hypotonic musculature for cyclist more than likely includes:

- Deep neck flexors
- Erector spinae
- Infraspinatus
- Teres minor
- Middle and Lower Trapezius.

Active/Passive Care Lower Quarter

Hypertonic Musculature of lower Extremity:

- Hip flexor group
  - Psoas
  - Tensor Fascia Latae
  - Rectus Femoris
  - Sartorius
- Rectus Abdominis
- Adductor Magnus
- Tibialis Anterior
- Gastrocnemius
- Soleus

Hypotonic Musculature:

- Gluteus Maximus
- Gluteus Medius

Soft Tissue Approach

- **MRT hypertonic musculature (MRT, Trigger Point, Cross Friction, ART)**
  - C/S
  - Shoulders
  - Elbow/Wrist
  - Hip
  - Knee
  - Foot/Ankle

Soft Tissue Approach

- **Dry Needling** – Trigger point therapy, muscle pain, or muscular stimulation ONLY
  - Doctor of Chiropractic (Alabama, Colorado, Connecticut, Delaware, Florida, Illinois, Maryland, New Hampshire, New Mexico, North Carolina, Rhode Island, South Carolina, Texas, Utah, Virginia, and West Virginia)
  - Physical Therapists (Virginia, Maryland, Ohio, Colorado, Georgia, New Mexico, Kentucky, Louisiana, and North Carolina)

Soft Tissue Approach

- **Instrument Assisted Soft Tissue Mobilization**
  - Gua sha
  - Graston
  - Many other tools

- **Joint mobilization**
  - Active – Mulligan's Mobilization
  - Active assisted movement
  - Passive – Capsular mobility

Soft Tissue Approach

- **Muscle Activation/ Facilitation of Hypotonic (under used) musculature**
  - Isometric contraction / movements
  - Proprioceptive neuromuscular facilitation (PNF)
    - PIR
    - Reciprocal Inhibition (Hypertonic (over used) musculature)
    - Contract relax

Taping

- **Kinesio / Proprioceptive Taping**
  - Postural C/S, T/S, Shoulders
  - Carpal Tunnel
  - Hip/ Thigh Strain
  - IT Band
  - Patellar Femoral Pain Syndrome
    - Tracking Squat Tests
  - Achilles Tendonosus

Taping

- **McConnell Taping/ Tim Brown Tab Taping**
  - Carpal Tunnel
  - Tunnel of Guyon
  - PFPS/ Tracking/ Tilting
  - ITB
  - X- tape ankle stability

Taping

- **Low-Dye Taping**
  - Hard and soft checks
  - Plantar fascosus (Elasticon)
  - Ankle

Sports Specific Rehabilitation and Training

- **Core activation: the muscular corset**
  - Global muscles: large torque producing muscles
    - Rectus abdominus
    - External oblique
    - Lumbar iliocostalis
  - Local muscles: attach directly to lumbar spine providing segmental stability
    - Lumbar mutifidus
    - Psoas major
    - Quadratus lumborum
    - Transversus abdominis
    - diaphragm

Rehabilitation

- The first phase of exercises should include neuromotor control to improve kinesthetic sense, coordination and control.
- Second phase of exercises should be aimed at restoring the muscles capacity to meet the demands of control; ie, strength and endurance.

Stability

- **Cervical spine:**
  - Chin tucks
  - Abdominal breathing to decrease overactive accessory muscles

Stability

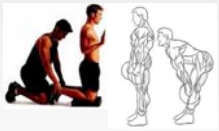
- **Thoracic spine/ shoulders:**
  - Mobility as well as stability
  - Check flexibility with wall angels
  - Exercises:
    - Bruggers
    - Scapular setting
    - "T", "Y", "W" standing, ball, prone
    - Low rows

Stability

- **Lumbar Spine:**
  - Abdominal bracing
  - Pelvic tilting
  - Dead bug and progressions
  - Bird dog and progressions
  - Superman
  - Planks, side planks, plank rolls

Stability

- **Lower Extremity; Hip complex:**
  - Can be combined with lumbar spine exercises
  - Clam shells
  - Glute bridges with progression
  - Hamstring curls with progression
  - Romanian dead lifts (RDL's)
  - Russian hamstring strengthening



Stability

- **Knee Complex:**
  - Single leg squats (also utilized with hip stability)
  - Quad setting (Pillow pushes)
  - Terminal extension
  - Heel slides

Stability

- **Foot/Ankle:**
  - Mobility and flexibility are most important here
  - ABC's
  - Peanut butter spreads
  - Towel curls with toes
  - Balance progression
    - Double leg, single leg, eyes closed, stable ground, unstable ground

Resources:

- Brunker, Khan. Clinical Sports Medicine. McGraw Hill 2009
- http://www.fitnessvenues.com/uk/biomechanics-of-cycling
- http://www.bbclasses.com.au/files/8.pdf
- http://www.beginnertriathlete.com/history.htm
- Notes from Dr. Joseph Horrigan, Dr. William Moreau, Dr. Joel Dekanich
- Hyde T, Gengenbach M. Conservative Management of Sports Injuries, 2nd Ed. Jones and Barlett Publishers 2007.
- Neumann D. Kinesiology of the Musculoskeletal System. Foundations of Physical Rehabilitation. Mosby 2002.
- Philippon M. 14th Annual Meeting of Sports Medicine and Science in Figure Skating, Cleaveland OH 2009.
- Manaster BJ, Zakel S. Imaging of Femoral Acetabular Impingement System. Clinical Sports Medicine. 25 (2006) 635-657

Resources cont…

- Johnson J et al. Swimming Biomechanics and Injury Prevention. New stroke techniques and medical considerations. The Physician and Sportsmedicine vol. 31(1) Jan.2003
- http://emedicine.medscape.com/article/90286-overview
- http://www.orthosupersite.com/view.aspx?rid=63710
- http://www.mendmyknee.com/knee-and-patella-injuries/itbs-knee-pain-iliotibial-band-syndrome.php
- http://newsletter.ultimatetennis.com/2010/12/knees-patellofemoral-pain-syndrome/
- http://www.ncbi.nlm.nih.gov/pubmedhealth/PMH0004438/
- http://www.pt.ntu.edu.tw/hmchai/kines04/kinlower/Foot.files/Windlass.jpg
- http://www.medterms.com/script/main/art.asp?articlekey=11930
- http://www.multiplesclerosisconnect.com/health-center/documents/zm5058?section=zm5058-sec