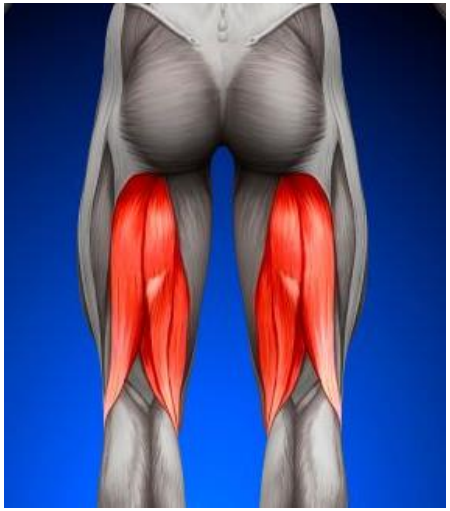
Hamstring Injuries: Rehabilitation and Running Enhancement Training



CSCCa National Conference
Kansas City, MO
May 10 2019

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Hamstring Injury Presentation Objectives

- The content of this presentation will include:
  - The Running Gait Cycle
  - Sports Rehabilitation and Strength and Conditioning components
  - ACL Reconstructions utilizing hamstring autografts
  - ACL bracing on hamstring activity
  - Hamstring injuries
  - Rehabilitation and performance enhancement training options for hamstring injuries

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Athletic Performance

- Speed is conferred predominately by an enhanced ability to generate and transmit muscular force to the ground." Weyland J Appl Physiol 2000
- The fastest athletes spend the least amount of time on the ground (0.7 – 0.9 sec seconds at sprinting speed
  - ***The main determinant of achieving maximum sprint speed was in reducing the contact time during the stance phase!*** Mann 1998

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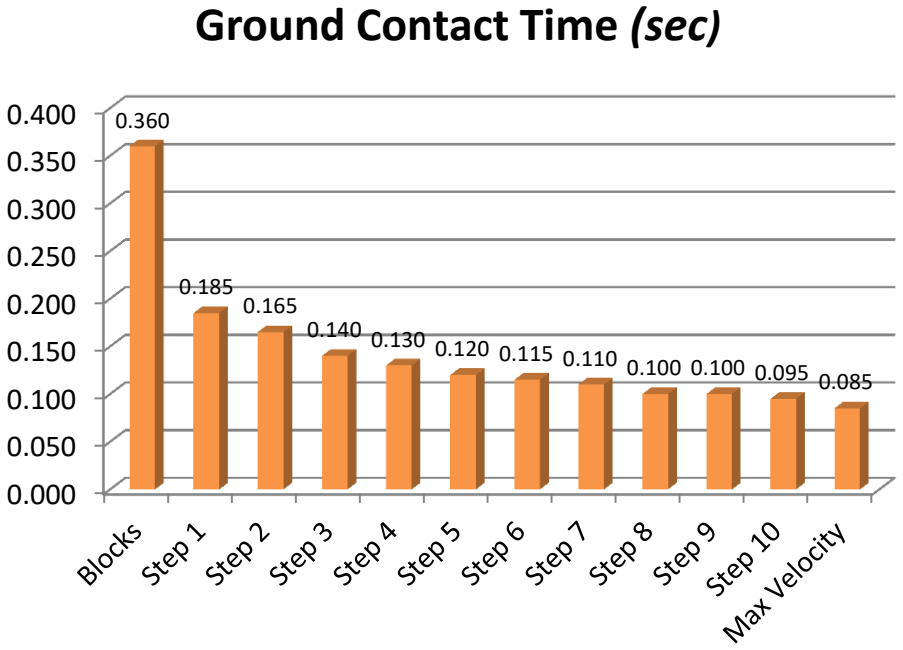
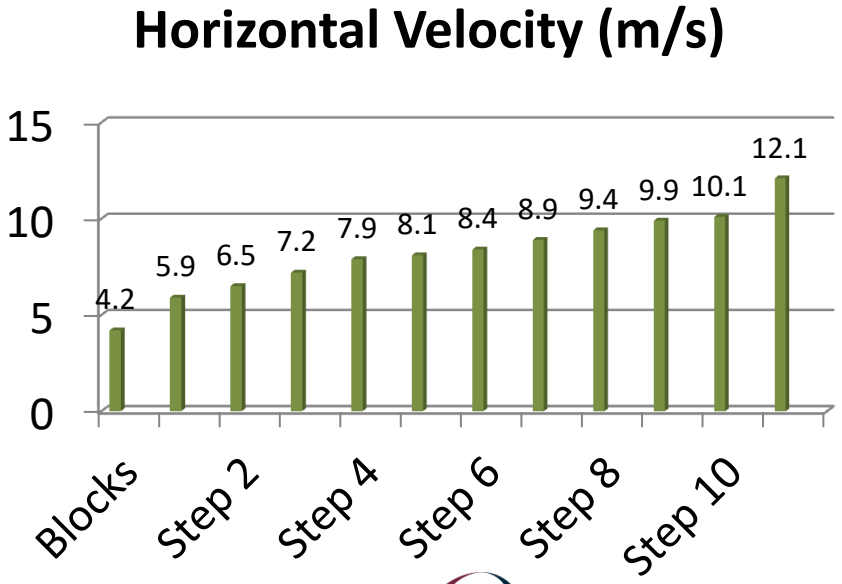
GCT and Horizontal Velocity



Ralph Mann 2007

By the 8th step GCT 0.1 sec and velocity is at 9.4 m/s



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Sir Isaac Newton's Laws of Motion

- The third law of motion states for every action (force) in nature there is an equal and opposite reaction

Sir Isaac Newton
(1642-1727)

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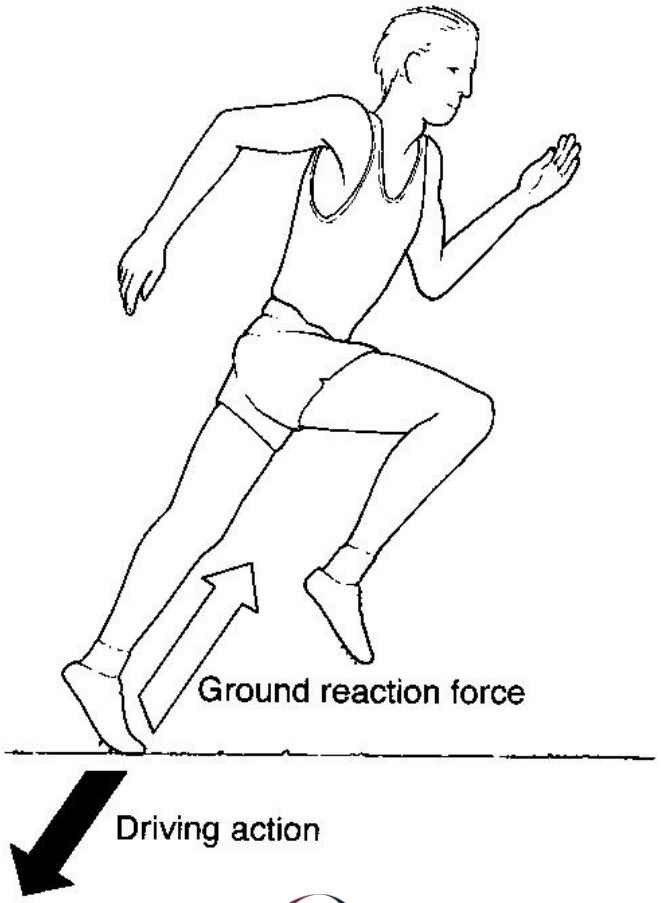
Athletic Performance After ACL and Hamstring Injury

- The athlete needs to reacquire their previous level of physical ability to react to the ground surface area
  - Acceleration
  - Deceleration
  - Change of Direction (COD)



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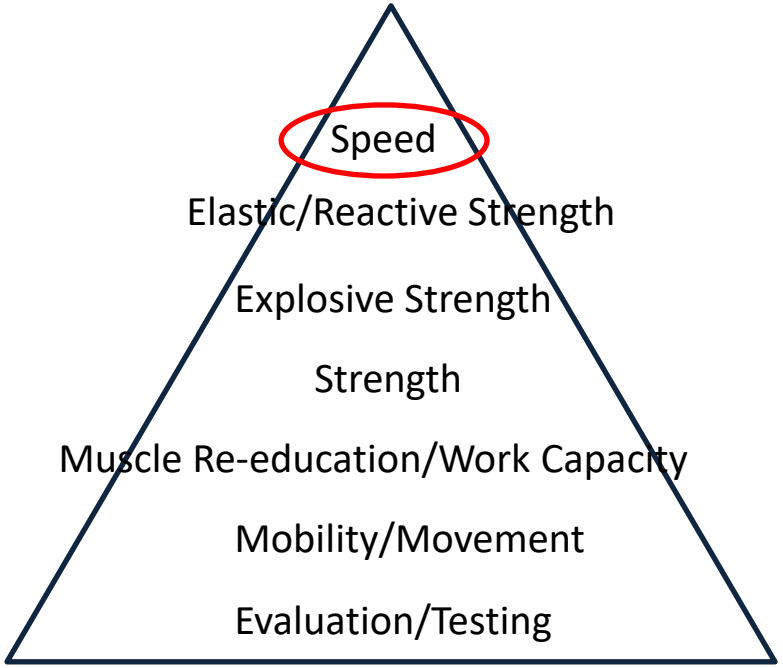
The Hierarchy of Athletic Development

Hall of Fame S&C Coach Al Vermeil's Heirarchy of Athletic Development

Vermeil's Hierarchy of Athletic Development

Each physical quality is dependent upon it's predecessor



Rehabilitation Modified

Panariello et al Oper Tech Sports Med 2016

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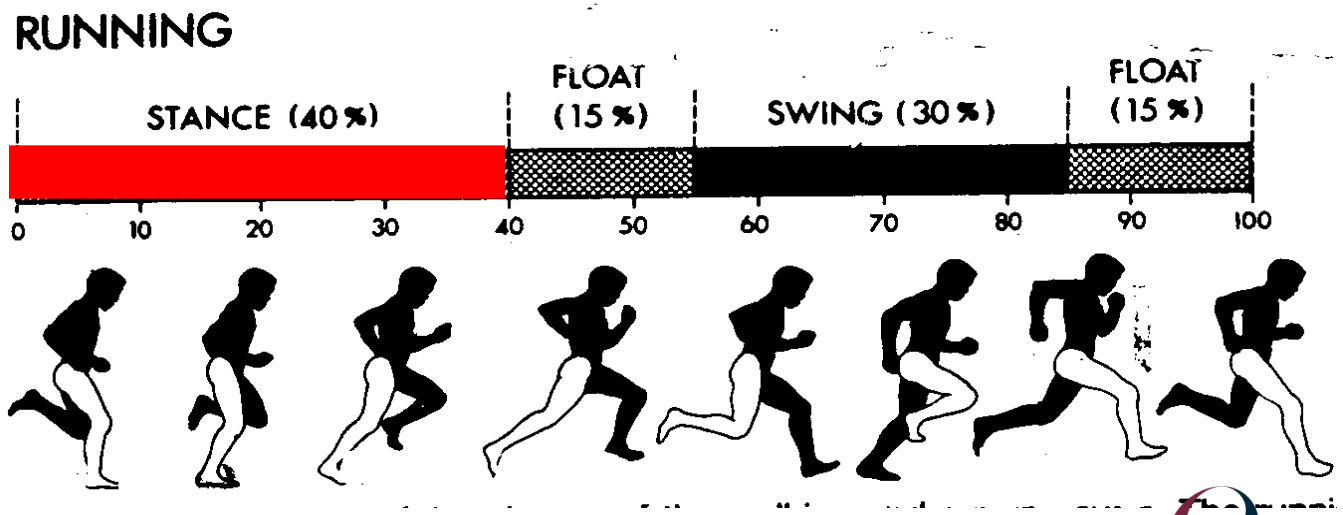
The Running Gait Cycle

- Stance Phase – 40% of the cycle
- Swing Phase – 30% of the cycle
- Float Phase – 30 % of the cycle
- The majority of the Running cycle is spent with the leg off the ground, therefore we must take advantage of the limited time spent on the ground



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The Running Gait Cycle: Stance Phase

- Most important phase of the running cycle
  - Foot and leg bear weight
  - Application of force into the ground surface area
- Traditionally divided into 3 phases
  - Initial Contact
  - Midstance
  - Propulsion

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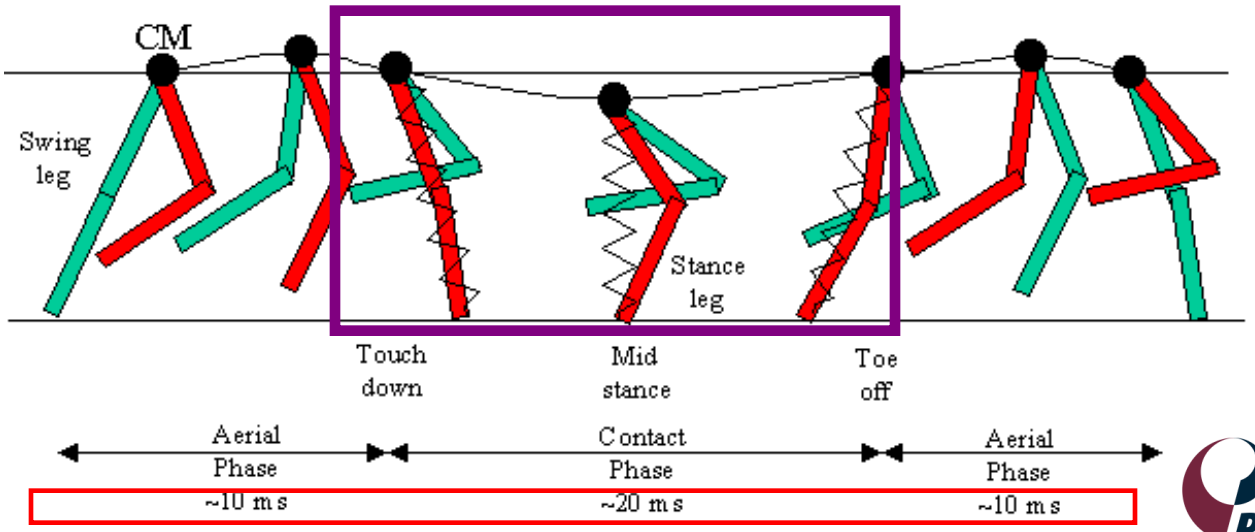
The Running Stance Phase

- Initial Contact
  - When initial contact is made with the ground (heel) and ends when the forefoot makes contact to begin midstance
- Midstance
  - Foot and leg provide a stable support for the body weight to pass over. The opposite extremity is in swing phase
- Propulsion
  - Begins as the heel lifts off the ground to toe off. Ground reaction forces are applied to the ground surface area.



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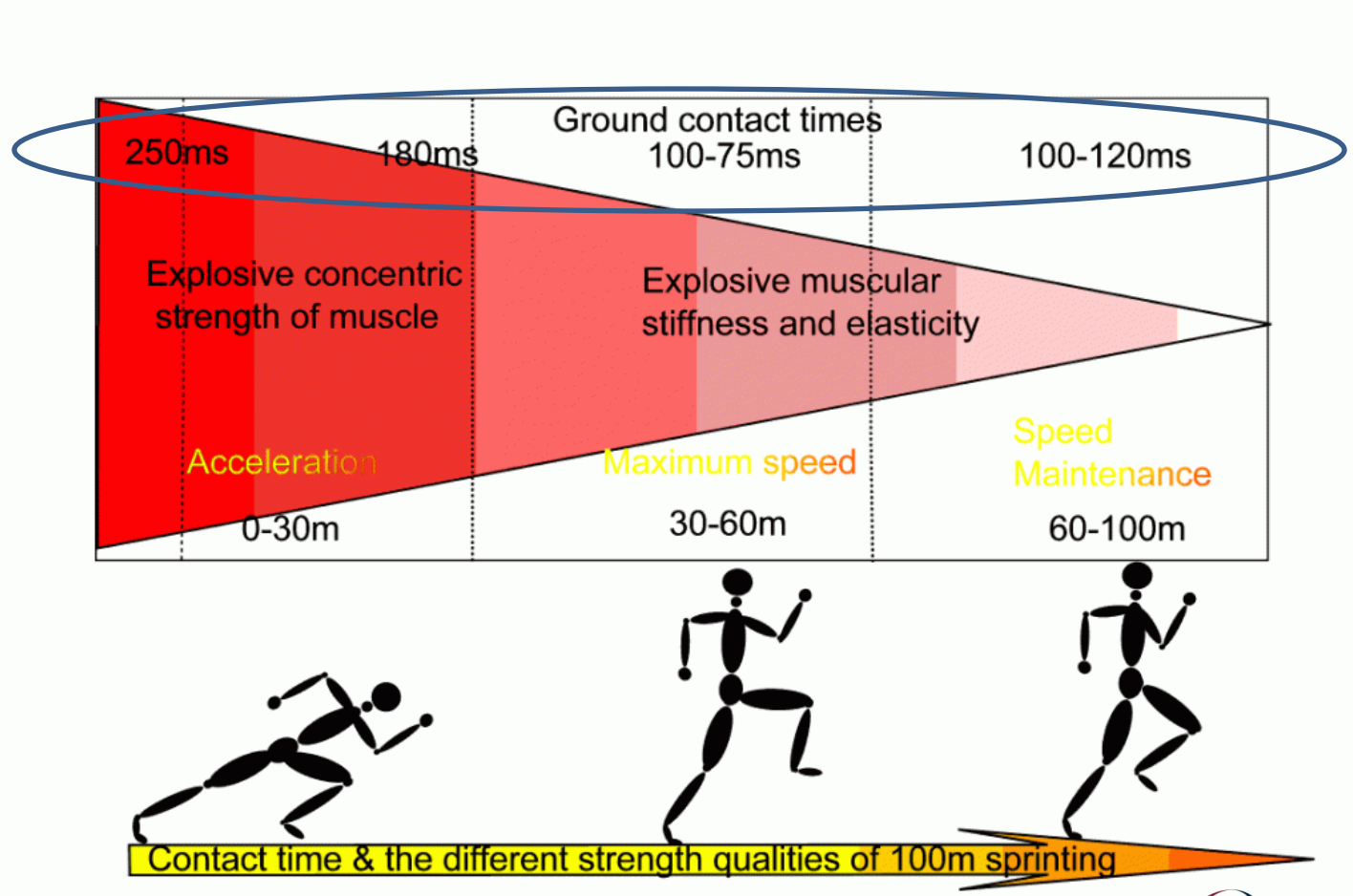
Strength Qualities and the Ground Contact Times During Sprinting



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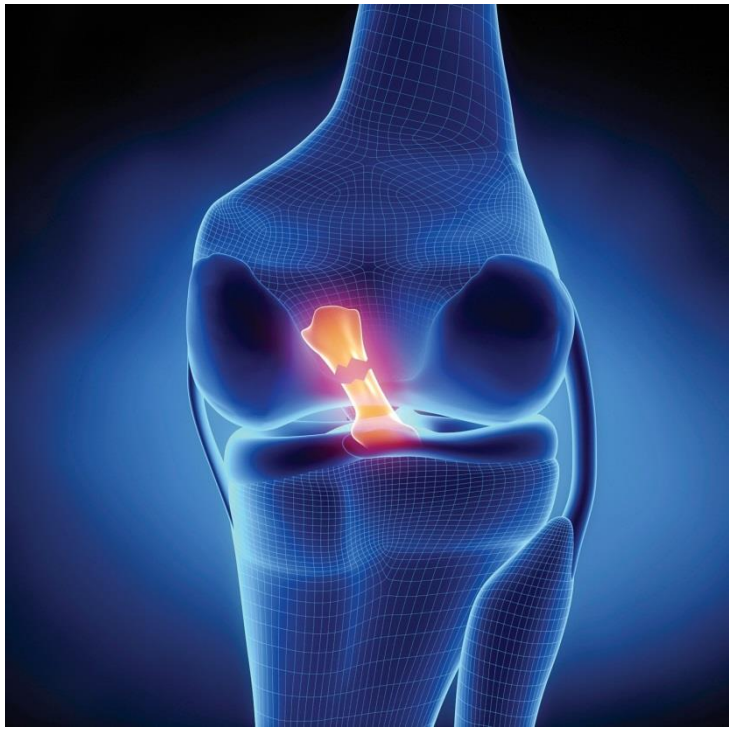
Anterior Cruciate Ligament (ACL) Injuries

- Approximately 200,000 ACL Reconstructions are performed annually



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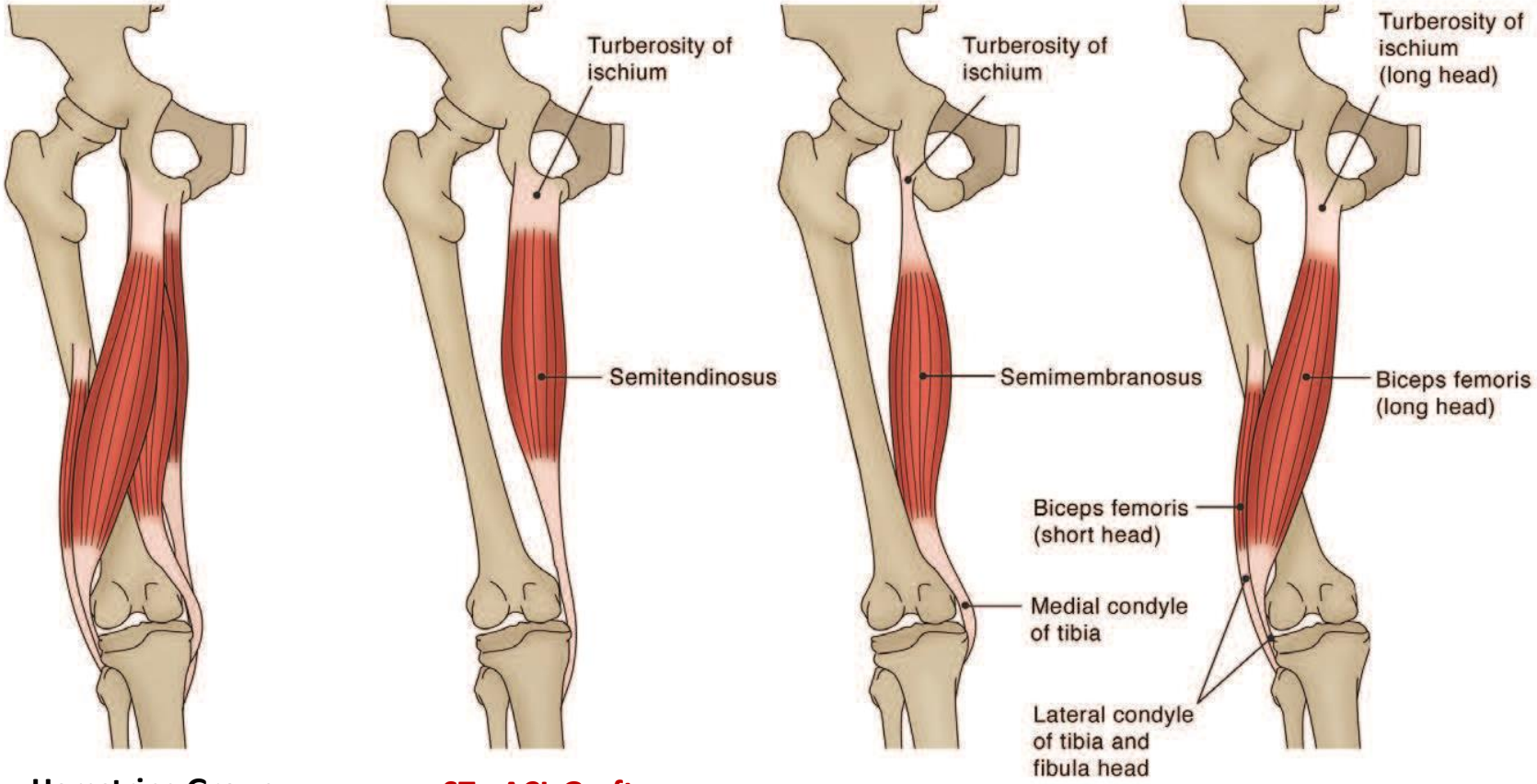
ACL Graft: The Hamstrings



Hamstring Group

ST - ACL Graft

SM

BF - 83% of all Running Injuries

Schuermans et al Br J Sports Med 2014

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ACL Graft: The Hamstrings

14,105 ACL Reconstructions (ACLR)
Kaiser Permanente Baldwin, California

ACL Graft	ACLR Percentage	ACLR Revision (Re-tear) Rate
Hamstrings	5,707 (40.7%)	3.5% (200)
Bone-Tendon-Bone	4557 (32.5%)	2.5% (113)
Allograft	3,751 (26.8%)	3.7% (139)

American Orthopedic Society for Sports Medicine

aossm™
American Orthopaedic Society for Sports Medicine

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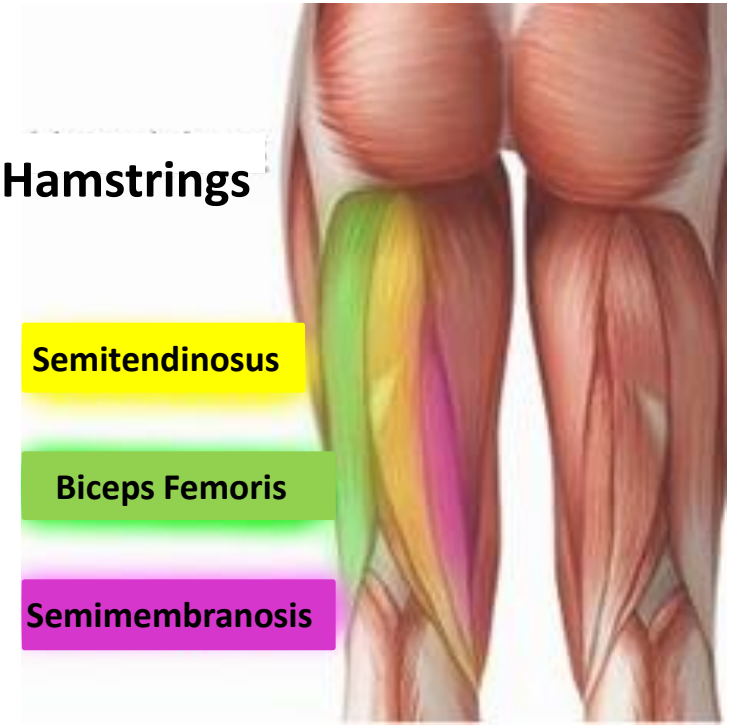
ACL Graft: The Hamstrings

- ACL Grafts
  - Central third patella tendon
  - *Hamstrings*
    - *Semitendinosus tendon*
    - *Gracilis tendon*
  - Quadriceps tendon
  - Allograft
- Hamstrings atrophy and weaken due to:
- The trauma of the initial injury and subsequent ACL surgery
- The initial period of reduced post-op activity
- Limited exercise performance
- Limited high intensity exercise performance
  - Heavy weights
  - Sprinting



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Hamstring Injury: ACL Reconstruction

- Hamstring graft
  - Semimembranosus
  - Gracilis
- Decreased hamstring strength due to:
  - Harvest of the hamstring graft
  - Post-op inactivity
    - Low exercise intensity
    - Lack of high intensity exercise i.e. sprinting

Semitendinosus and Gracilis ACL Graft

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Hamstring Graft: ACL Bracing

- Fairly rigid cylindrical brace
- Applied over muscle and fatty tissue
- No control of hip motion
- Allows 8 – 9 degrees of valgus/varus
- Allows 5 – 6 degrees of internal rotation

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ACL Bracing

- Neural Effect
  - Torn ACL results in lost afferent and efferent (proprioception) sensors
- Bracing
  - Provides extra-articular tactile sense
  - Establishes parallel “control circuits” for tactile sense

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ACL Bracing: Knee Sleeve

- Neural Effect
  - Torn ACL results in lost afferent and efferent (proprioception) sensors
- Knee Sleeve
  - Easier and cheaper
  - Provides extra-articular tactile sense
  - Establishes parallel “control circuits” for tactile sense

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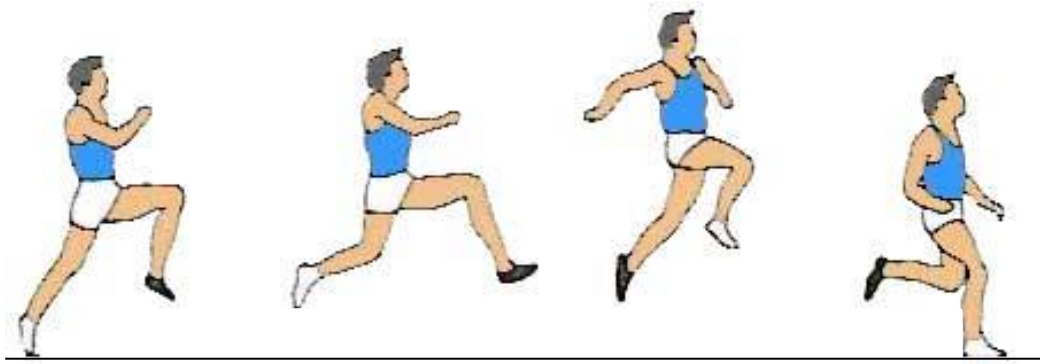
ACL Bracing

	Single Leg Jump	Muscle Activity		
Phase	**Time Interval**	**ST**	**BF**	**RF**
A1	**250 ms Preceding Foot Strike (Anticipation of foot strike)**	**Decreased 17%**		
A2	**125ms Following Foot Strike (Peak Force Attained)**		**Decreased 44%**	**Increased 21%**

Ramsey et al Clinc Biomech 2003

- **ST – Semitendinosus**
- **BF – Biceps Femoris**
- **RF – Rectus Femoris**



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ACL Bracing and Knee Sleeve

- Neuro motor standpoint
  - Are we creating a “crutch” for the patient?
- Tightening of the sleeve straps
  - Altering muscle activation
  - Reduced hamstring
    - Muscle fiber recruitment
    - Activity

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Hamstring Injuries

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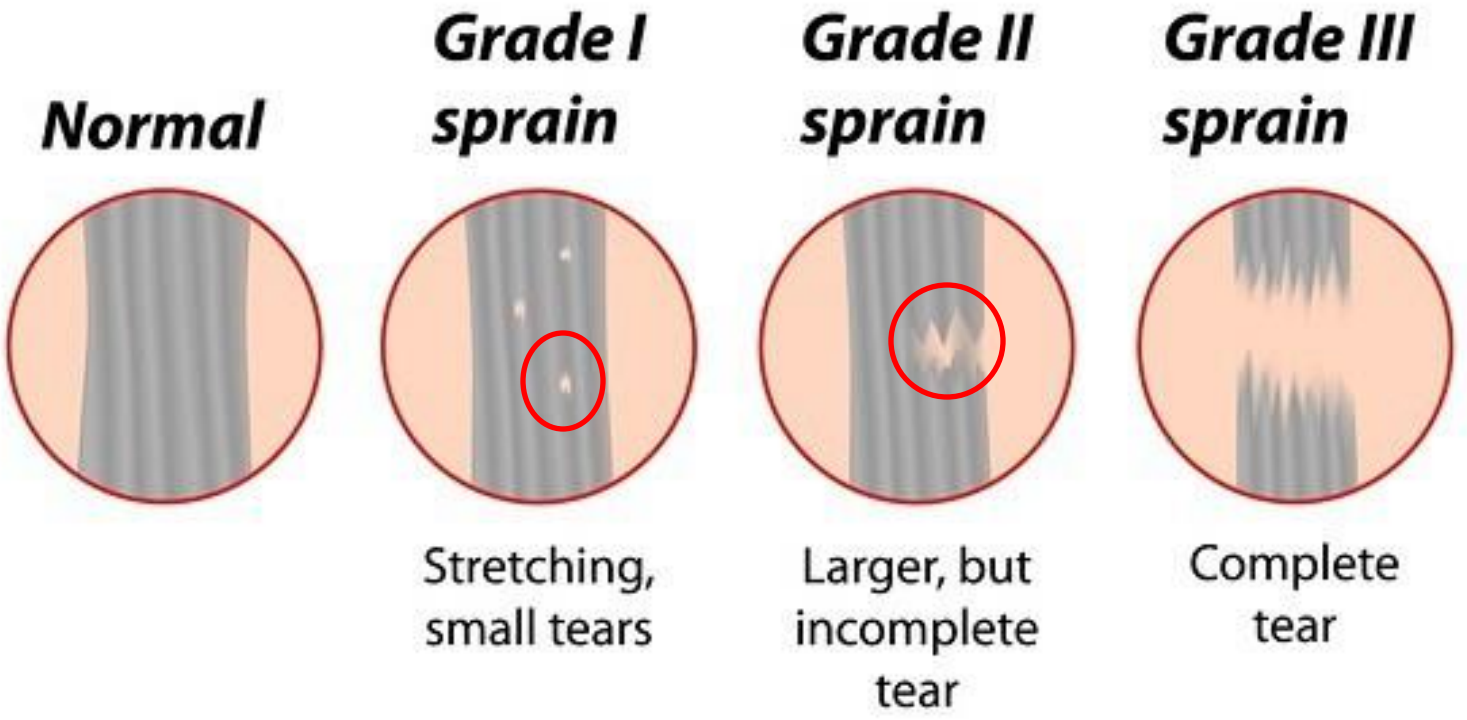
Hamstring Injuries



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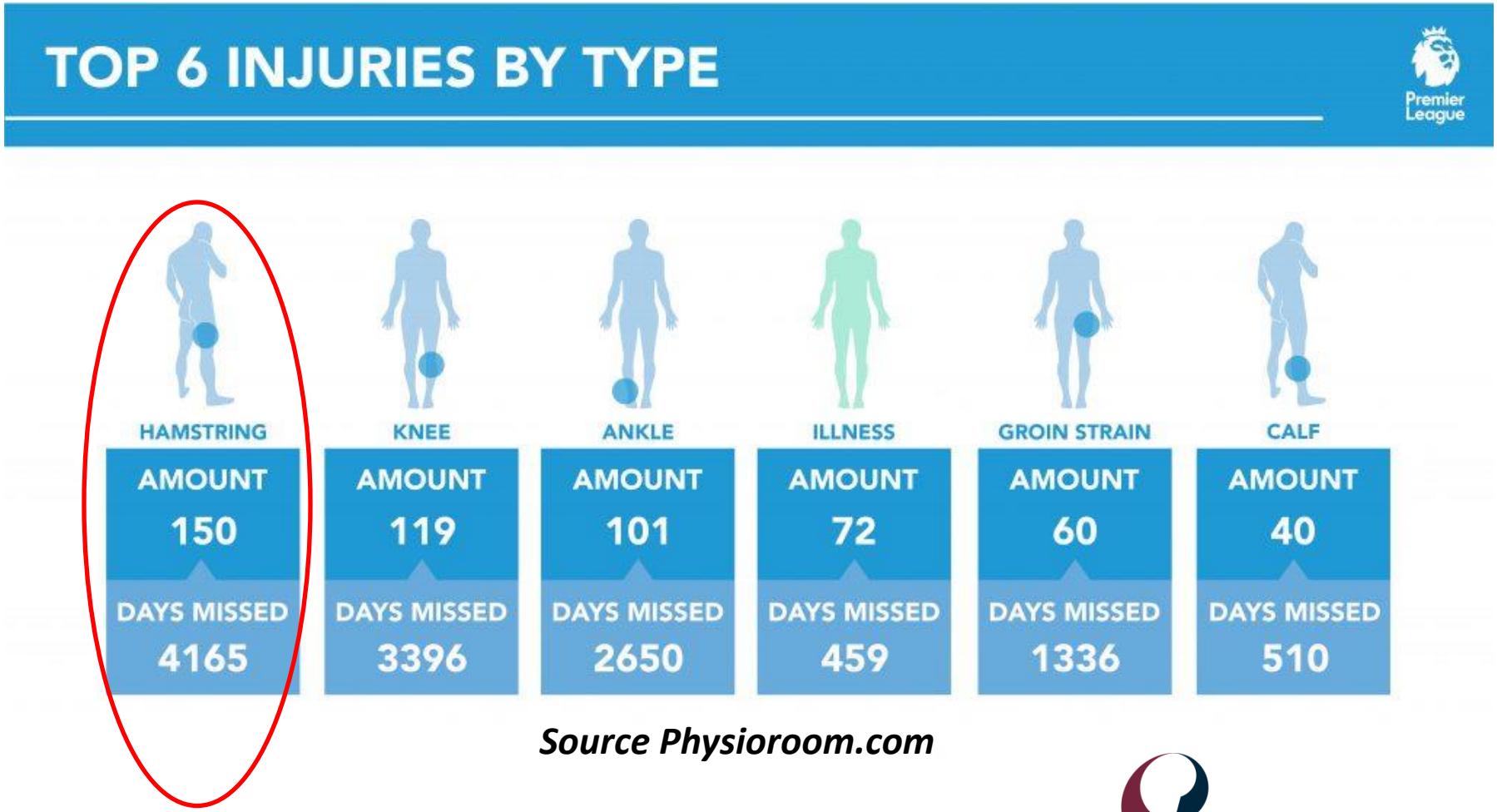
Hamstring Injuries: 2016 – 2017 Premier League Soccer Season



Source Physioroom.com

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Hamstring injuries

- Injury rate of 12% - 16% of all injuries to athletes
- Most common injury in male soccer players
- Re-injury rate reported as high as 22% - 34%

Ekstrand et al AJSM 2011
Elliott et al AJSM 2011
Verrall et al J Sci Med Sport 2006
Marcus et al AJSM 2011

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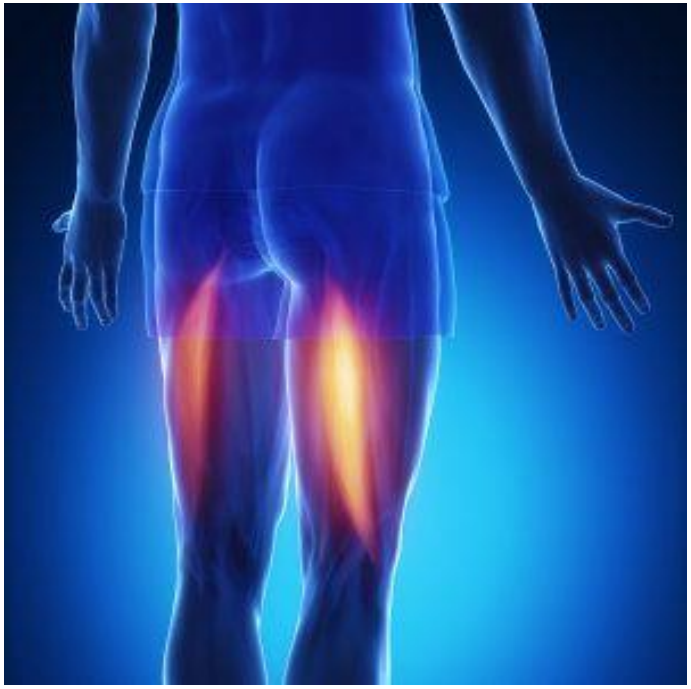
Hamstring Injuries

- Modifiable and Non-modifiable risk factors
- *Modifiable*
  - Rotated innominate
  - Hamstring weakness Orchard et al AJSM 1997
  - Poor flexibility Fousekis et al Br j Sports Med 2011
  - Poor warm-up Worrell Sports Med 1994
  - Muscular fatigue Small et al Int J Sports Med 2009
  - Poor core stability Sherry JOSPT 2004
  - Poor lumbar posture Hagglund et al Br J Sports Med 2006
- *Non-modifiable*
  - Age
  - Ethnicity
  - History of a previous hamstring injury*
    - *Most consistent risk factor
    - Increase risk reoccurrence 2 – 6 times

Engebretsen Am J Sports Med 2010



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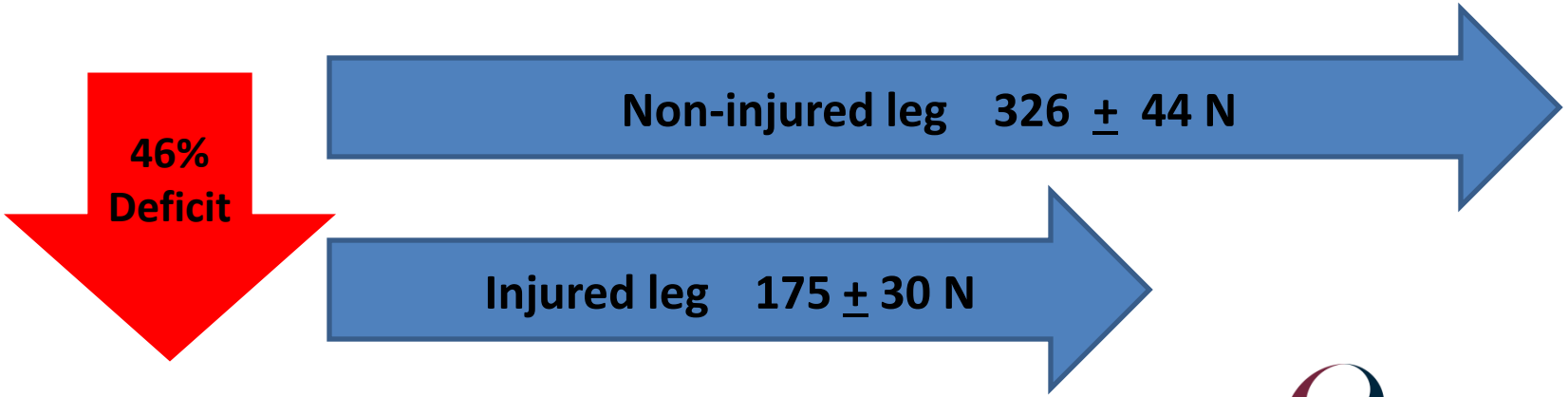
Hamstring Injuries

- Australian rules football players
- At least 1 acute hamstring injury in previous 2 years
- Running at 80% max velocity (Vmax)
- Deficits found in horizontal force

Brughelli M et al J Strength Cond Res 2010



Horizontal Force Production

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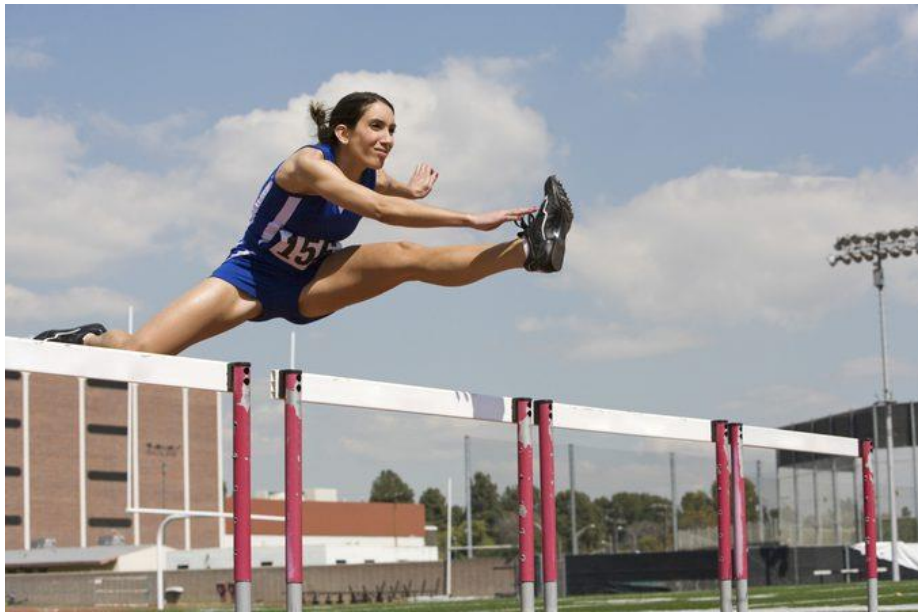
Rotated Innominate

- Rotated Anterior
- Rotated Posterior



Clinical Pearl: Rotated Innominate

- There is a normal rotation of each innominate (pelvis) during gait (walking) and sprinting
- When an innominate becomes “stuck”, and is unable to come out of this position, this limited pattern of movement may become a contributory mechanism for hamstring injury

Short Leg Side
Posterior Ilial Rotation

Long Leg Side
Anterior Ilial Rotation

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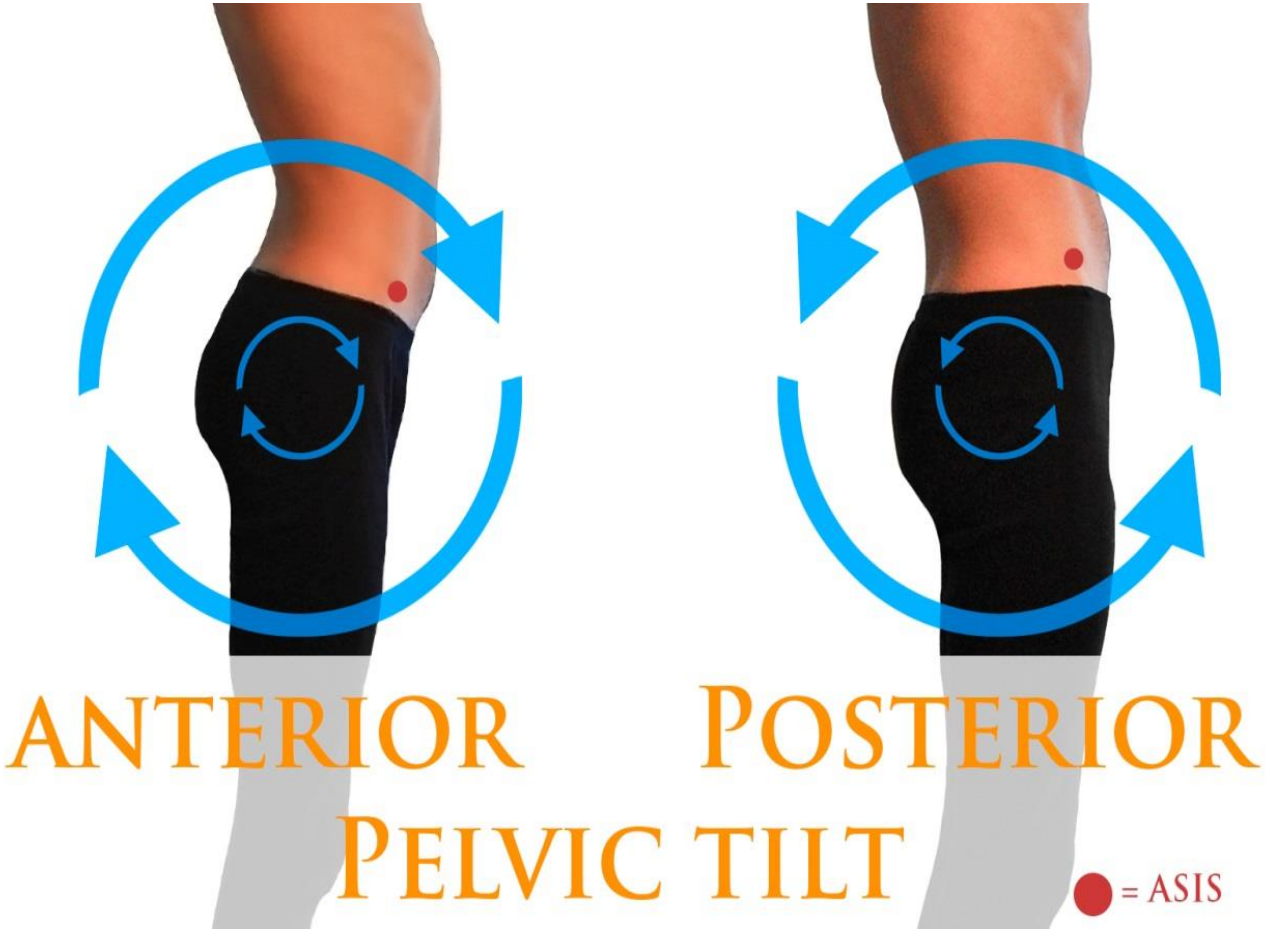
Hamstring Injury: Rotated Innominate



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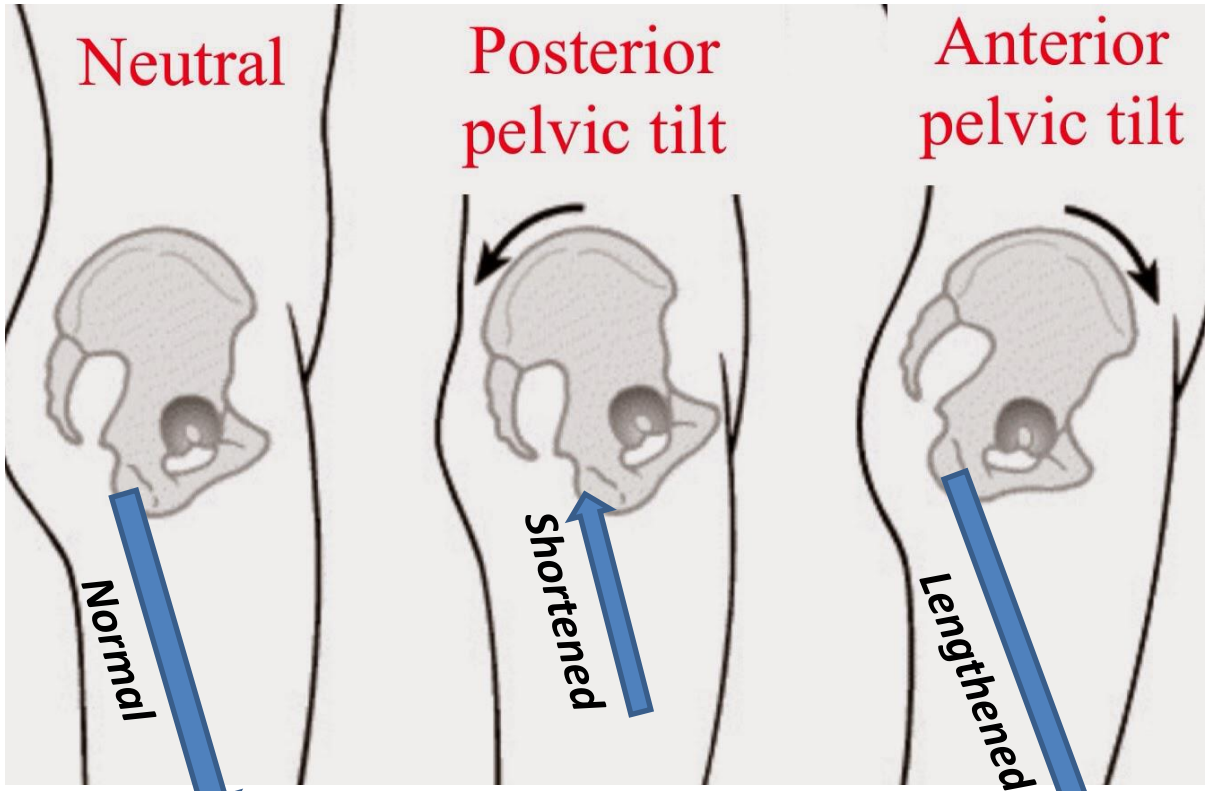
Rotated Innominate: Anterior or Posterior Pelvic Tilt



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Hamstrings: Mechanism of Injury

- Terminal swing phase of sprinting Schache et al Med Sci Sports Exer 2012
  - Eccentric contraction of lower limb
  - Absorb kinetic energy and slow the lower limb
- Early stance phase of sprinting
  - Muscles absorb high ground reaction forces
  - Higher forces in the concentric stance phase

Komi J Biomechanics 1990

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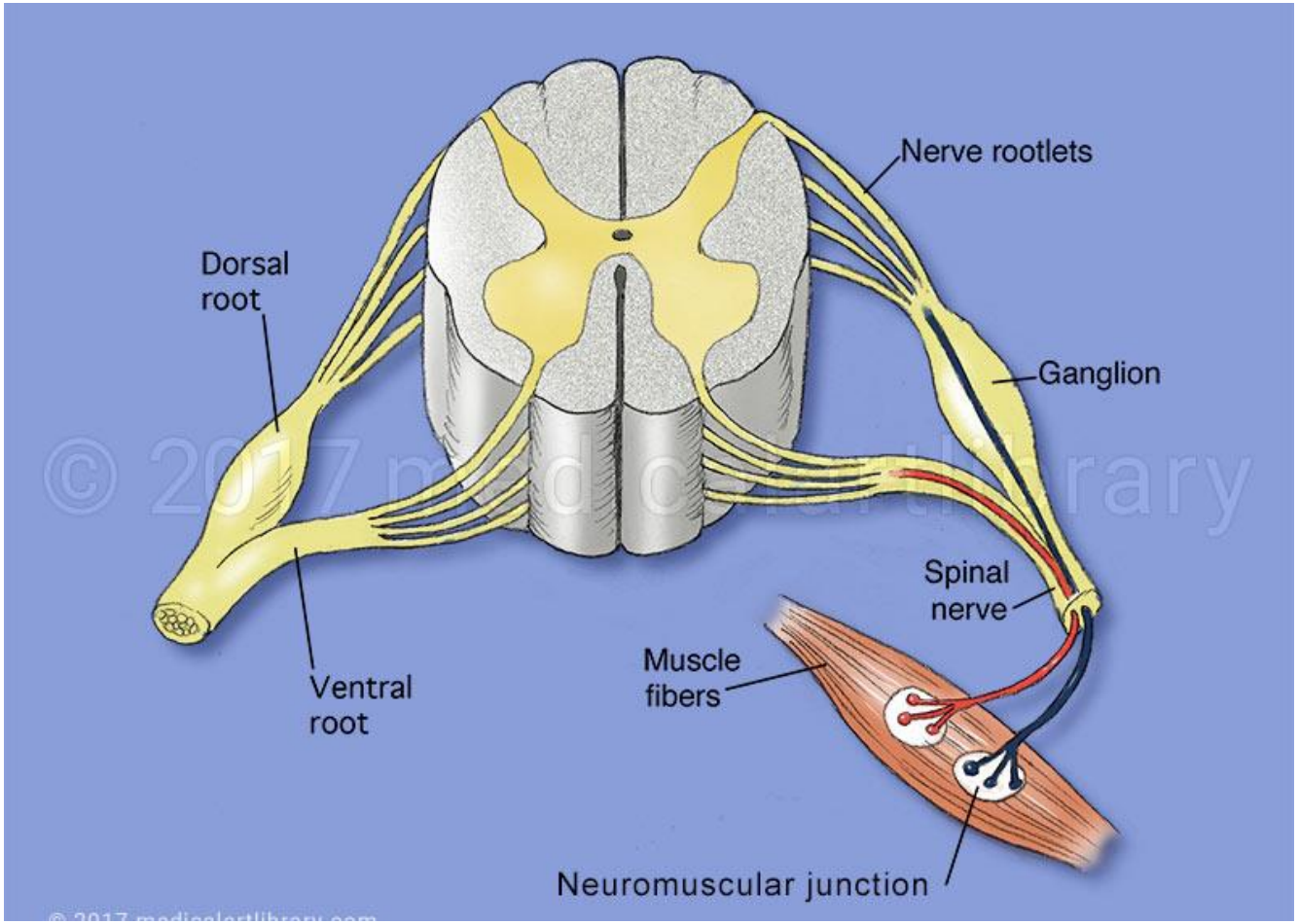
Hamstring Injuries: Neuromuscular Factors



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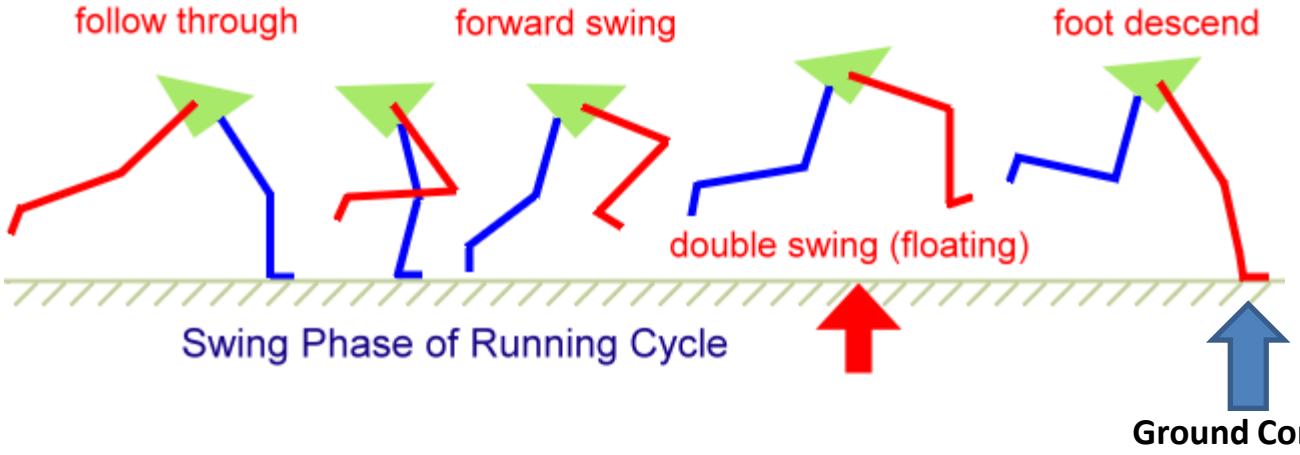
Hamstring Injuries: Neuromuscular Factors

- Maximum length of hamstring muscles noted at late swing phase of sprinting
- Biceps Femoris (BF) - Peak musculotendon length is synchronous with peak EMG activation
- Semitendinosus (ST) Muscle - Peak musculotendon length occurs significantly later than peak level EMG activation
- *These results suggest that the BF muscle is exposed to an instantaneous high tensile force during the late swing phase of sprinting, indicating a higher risk of muscle strain injury* Higashihara et al Eur J sport Sci 2016



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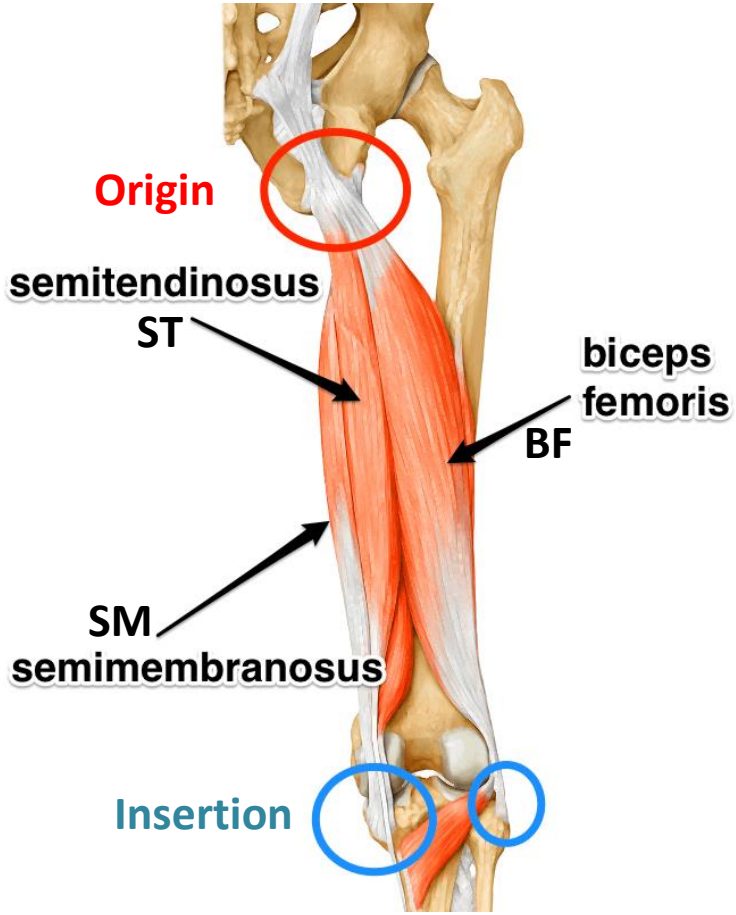
Hamstring Injuries – Neuromuscular Factors

- Hamstring muscle activation occurring at different running speeds of maximum velocity
- Running speed of 85% to 95% max velocity
  - Increased activation of hamstring muscles during late swing
  - No change in lower extremity kinematics
- 95% max running velocity
  - Significant different peak muscle activation time in BF vs. ST
  - P <0.05 stance phase
  - P<0.01 swing phase
- *Complex neuromuscular coordination patterns occur at maximal running velocities*



Higashihara et al J Sport Sci 2010

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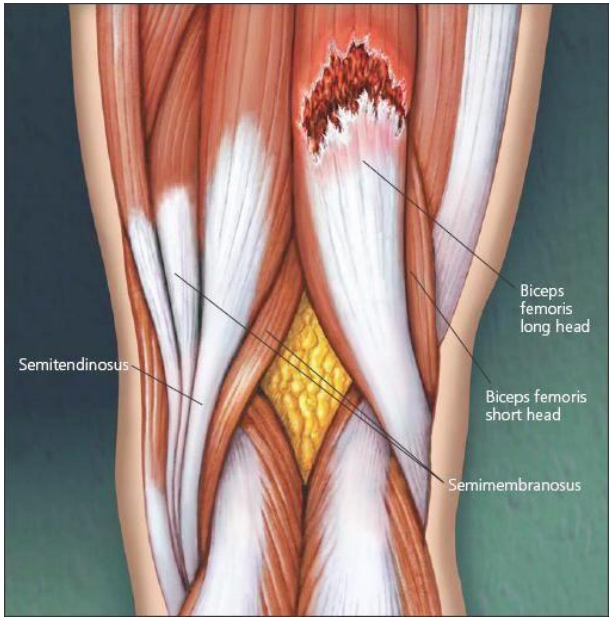
Hamstring Injuries: Neuromuscular Factors

- ST and BF engage in maximal eccentric activation throughout the swing phase
- These synergists work alternatingly (asymmetrical) in complex neuromuscular coordination
- Biceps Femoris
  - Predominate activity is middle to late swing
- Semitendinosus
  - Predominate activity is terminal swing
- Injured Hamstrings
    - More symmetrical muscle recruitment pattern
    - Compensatory recruitment pattern
  - Less economic hamstring activation
  - Lower strength endurance capacity
  - May increase the risk of re-injury



Schuermans et al Br J sports Med 2014

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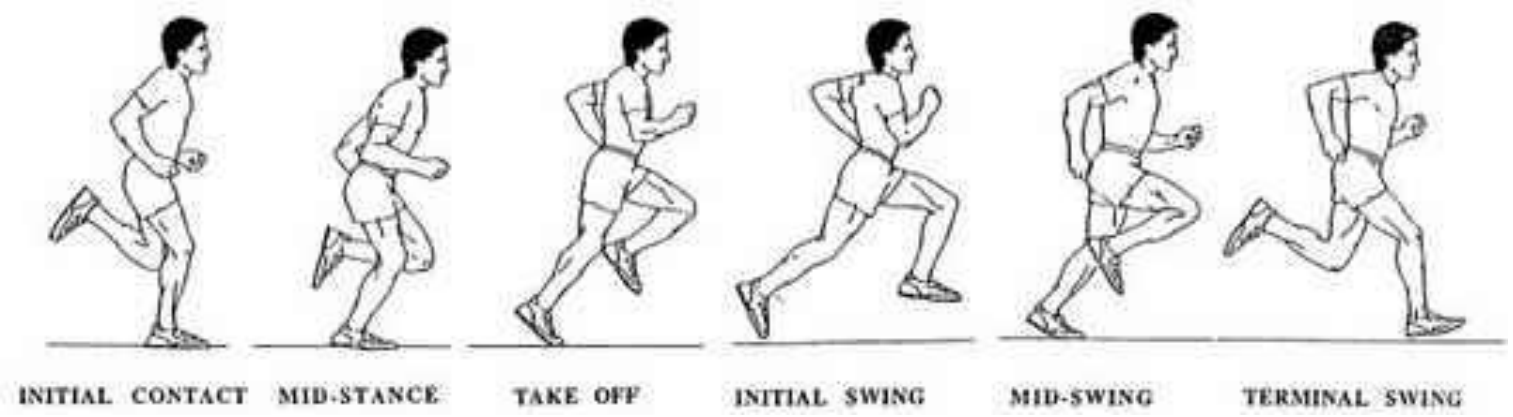
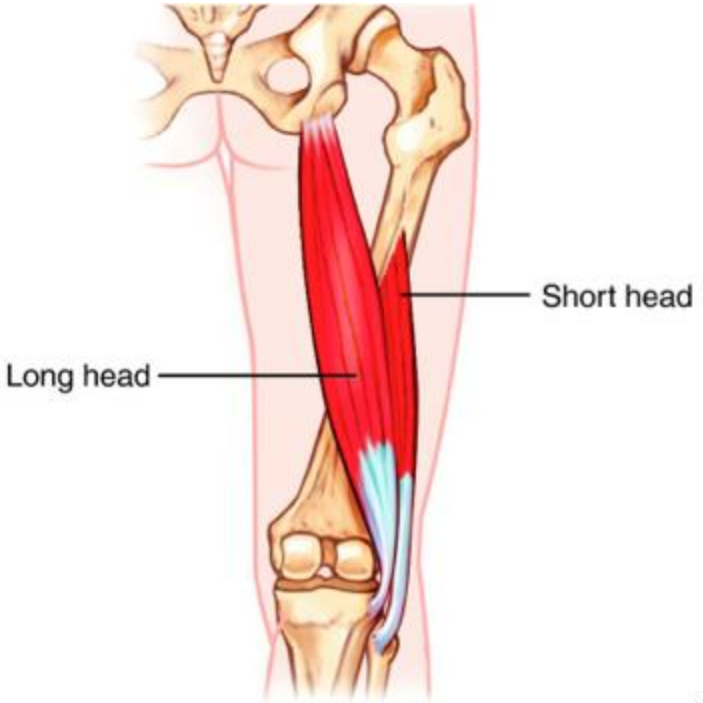
Hamstring Activation: Acceleration vs. Maximum Speed Phases

- Early stance acceleration phase
  - Hip extension torque is greater vs. max speed
  - EMG of BF (long head) greater than ST muscle
- Late stance and terminal mid-swing of max speed
  - Higher knee flexor moment and with greater extension vs. acceleration phase
  - EMG of ST great than BF long head
- Functional demands of medial and lateral hamstring differ at different phases of sprinting Higashihara et al J Sports Sci 2018



Hamstring Injuries: Neuromuscular Factors

- Biceps Femoris
  - Dual nerve innervation
  - Long head
    - Tibial branch of sciatic nerve
  - Short head
    - Common peroneal (fibular) branch of sciatic nerve



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Hamstring Neuromuscular Factors After ACL Reconstruction

- Hamstring activation and strength are important for:
  - Maintenance of appropriate tibiofemoral alignment
  - Prevention of excessive anterior tibial translation
- Athletes 1 – 6 years post ACLR have inter-limb activation differences in hamstring firing time compared to a healthy control cohort

Breim et al Knee Surg, Sports Trauma, Arthroscopy 2016

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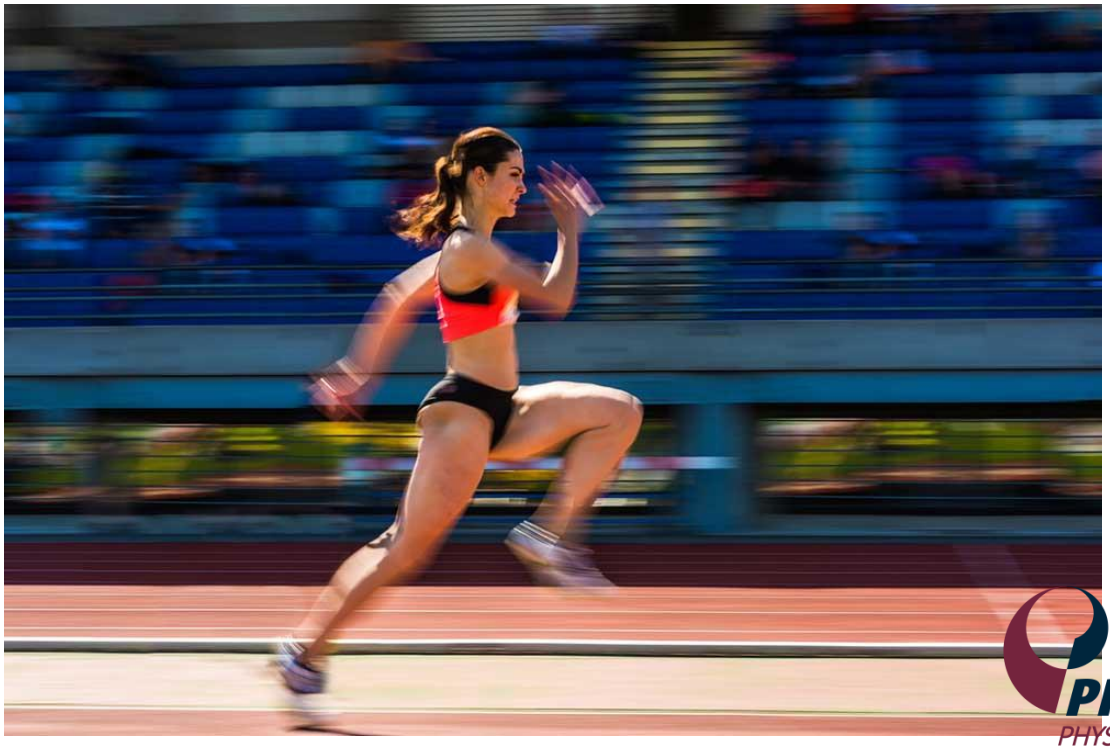
Restoration of Hamstring Neuromuscular Contributions

- Optimal restoration of the physical qualities
- Restoration of neuromuscular control and timing
- Progressive training program of sprinting velocities



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Hamstring Injuries: The Physical Quality of Strength

- *Strength*
  - CORE
  - Hip musculature
  - Lower extremity musculature

Vermeil's Hierarchy of Athletic Development

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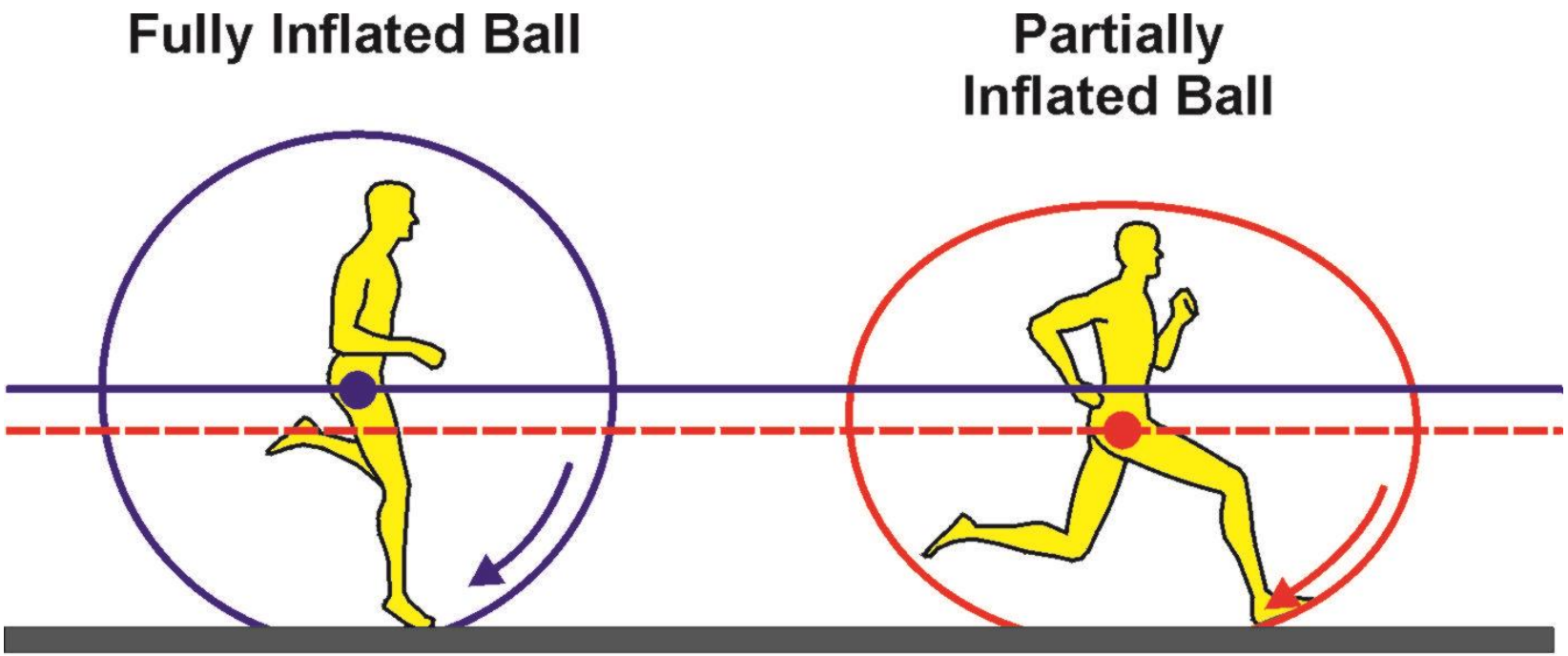
CORE: Influence of Gravity and Elasticity



- Greater vertical force production
- Less horizontal braking forces
- Less eccentric load on hamstring
- Longer lever on ground contact

- Less vertical force production
- Greater horizontal braking forces
- Greater eccentric load on hamstring
- Shorter lever on ground contact

Courtesy Derek Hansen

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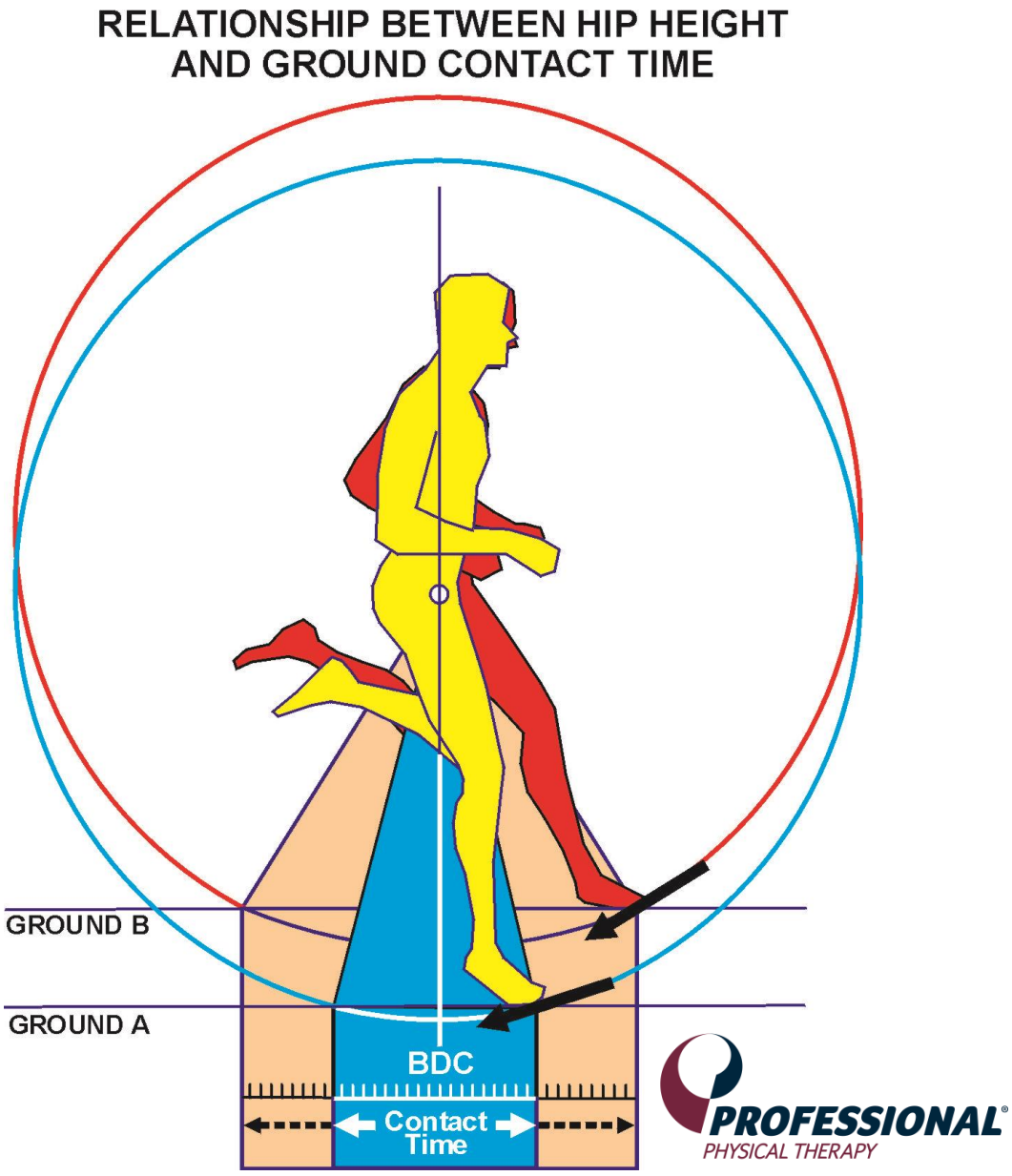
Hip Height and Ground Contact Time

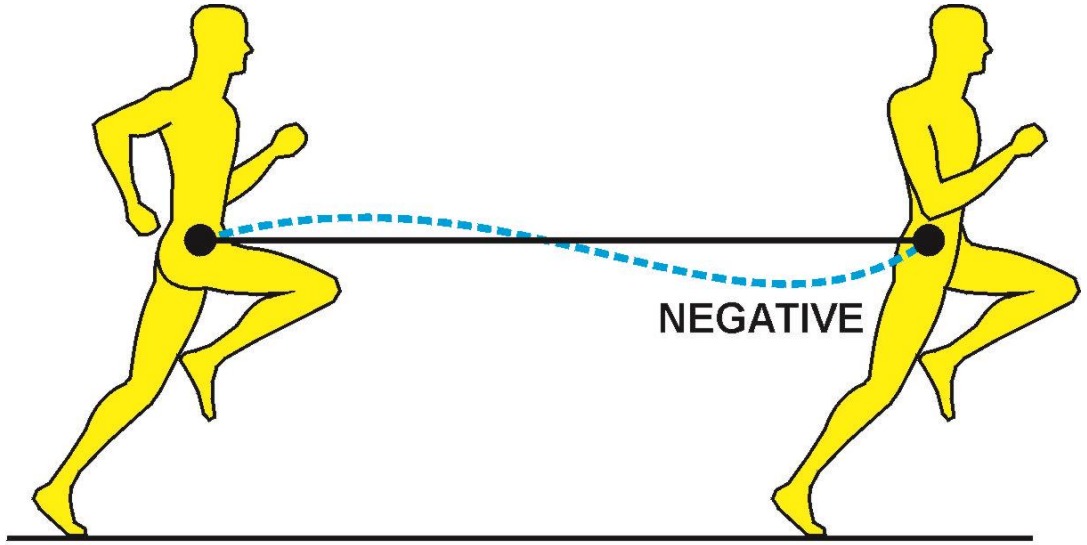
Proper Vertical hip height

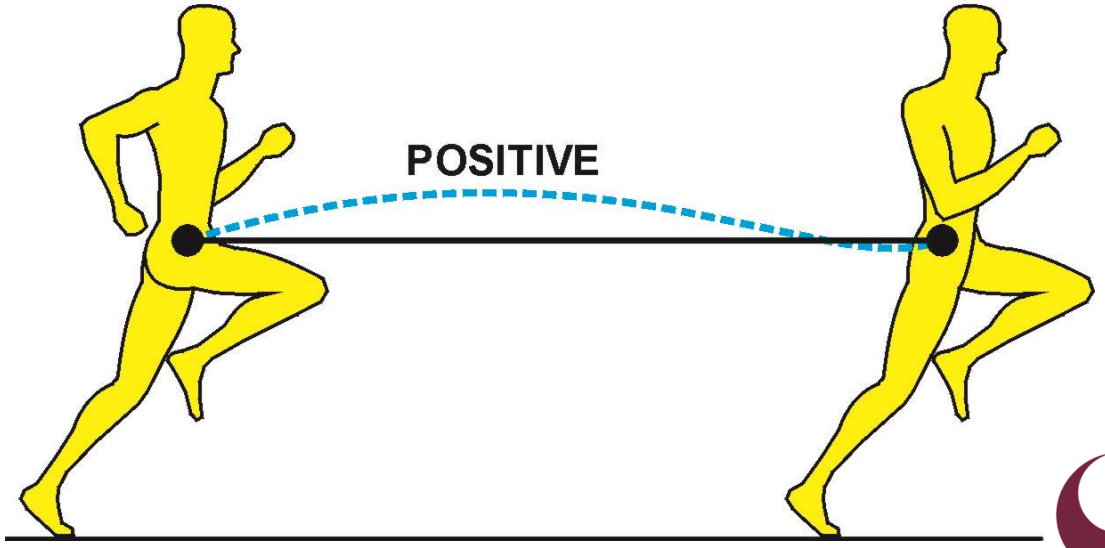
- Increases both flight time and a greater distance covered due to the “toe off” occurring closer to the body’s center of mass
- Reduces ground contact time (amortization) resulting in an optimal Stretch Shortening Cycle (SSC)

Courtesy Derek Hansen



Positive and Negative Vertical Displacement





Courtesy of Derek Hansen

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CORE Exercise

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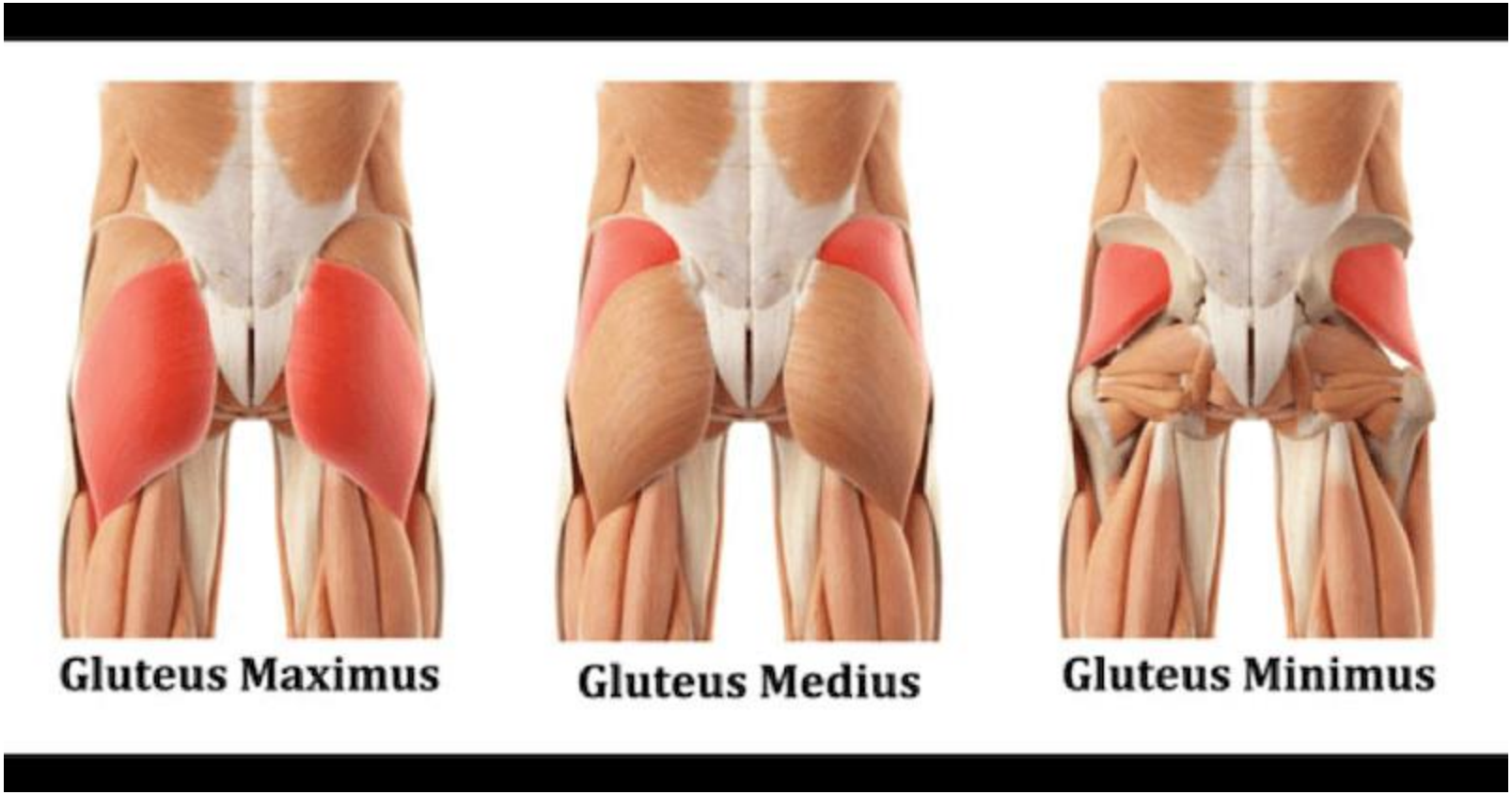
Hip (Gluteal) Strength

- Propulsion
- Deceleration
- Change of Direction (COD)



Testing for Gluteal Strength

Positioned for Hamstring Active Insufficiency

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Active Insufficiency of a Muscle

- Active Insufficiency occurs when a multi-joint muscle reaches a length (shortened) where it can no longer apply an effective force

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Testing for Gluteal Strength

Bi-lateral Leg Bridge

Single Leg Bridge

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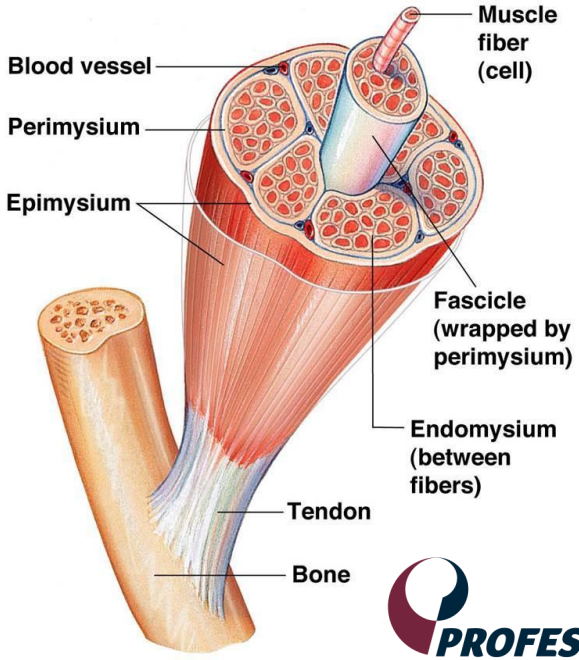
Hamstring Injury

- Tearing of soft tissue
  - Grade I, II, or III
  - ST Hamstring ACL graft
- Healing occurs via muscle scaring
  - Shortening of the muscle fascicles
  - 10 to 100 muscle fibers in a fascicle



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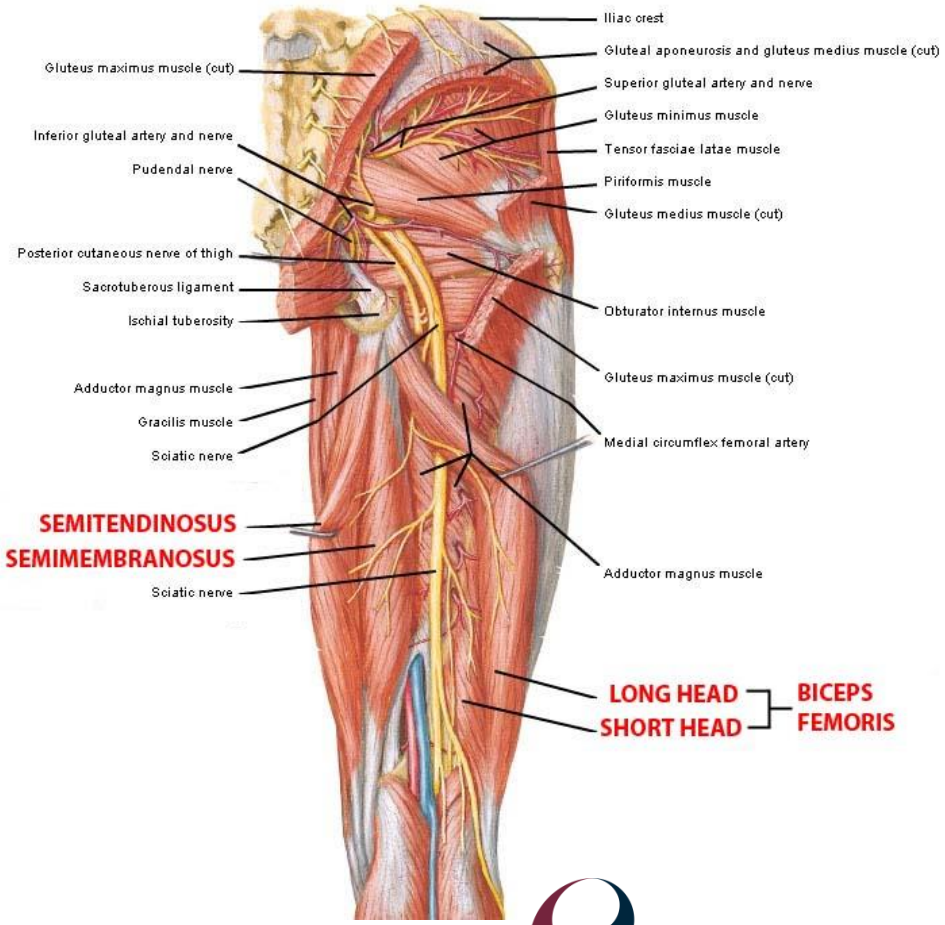
Hamstring Injury: Nerve Entrapment

- Sciatic Nerve
  - Scar formation may “restrict” the sciatic nerve



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Hamstring Injury: Nerve Glides

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Hamstring Force Production

- Peak hamstring torque occurs at significantly shorter muscle lengths in injured hamstrings
  Brockett el al Med Sci Sports Exerc 2004
- Potential weakness at longer (previous) muscle lengths
- Eccentric training in the lengthened state may shift the torque curve at the end ROM
  Schmitt et al int J Sports Phys Ther 2012

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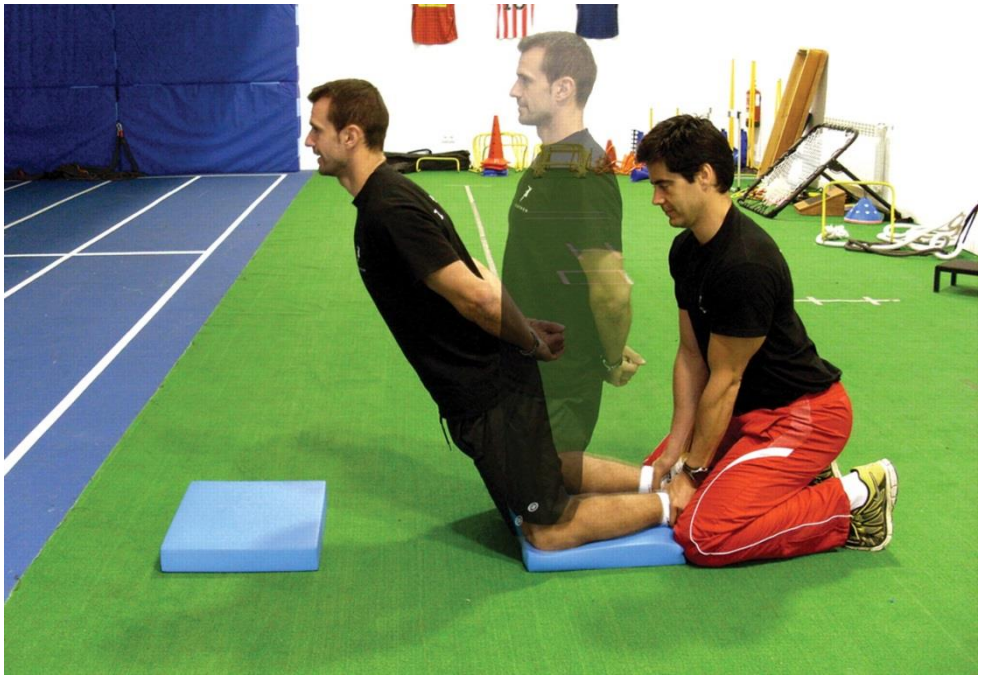
Hamstring Injury: Strength Training

- Strengthen muscle fibers
- Strengthen at a lengthened muscle fascicles/fiber position
  - Terminal knee/hamstring muscle lengths
- Romanian Deadlift (RDL's)
- Nordic hamstring exercises



Nordic hamstring exercise does not achieve terminal length strengthening

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Hamstring Strengthening: Terminal Knee Extension

Hamstring Strengthening: Terminal Knee Extension

- Romanian Deadlift (RDL)

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Hamstring Strengthening: Terminal Knee Extension

Romanian Deadlift (RDL)

Ground Contact

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Hamstring Strengthening: Kettlebell Swings

Swing Type	Portion of ROM	Medial Hamstring % EMG	Biceps Femoris % EMG	MH vs. BF % EMG
Hip Hinge	Concentric	44.89 ± 25.02	32.65 ± 14.47	12.24 ± 10.55
	Eccentric	28.80 ± 16.36	21.51 ± 15.04	7.29 ± 1.32

Del Monte et al J Strength Cond Res 2018

Hip Hinge Kettlebell Swing

- Medial Hamstrings are used as an ACL graft
- May be initiated early in the rehab process
- MH strength and power
- Initiate deceleration abilities
  - Eccentric muscle contraction

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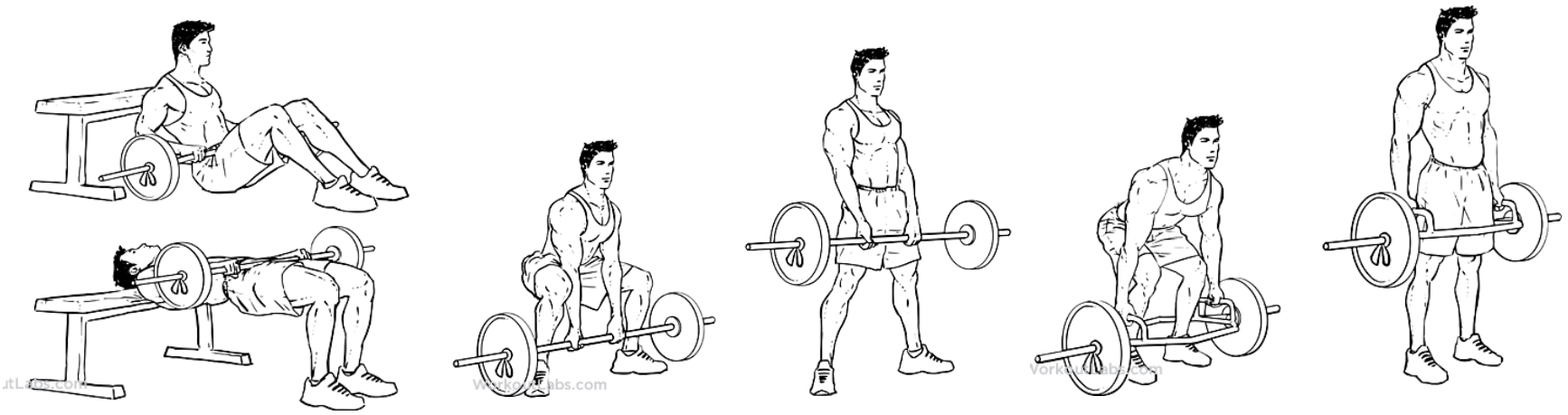
Gluteus Maximus and Hamstring Strength Development

Concentric Phase of the Exercise Performance

Exercise	Gluteus Maximus	Biceps Femoris	Erector Spinae
Hip Thrust	1	3	No
Barbell Deadlift	3	1	Significant
Hex Bar Deadlift	2	2	Difference

Andersen et al J Strength Cond Res 2018



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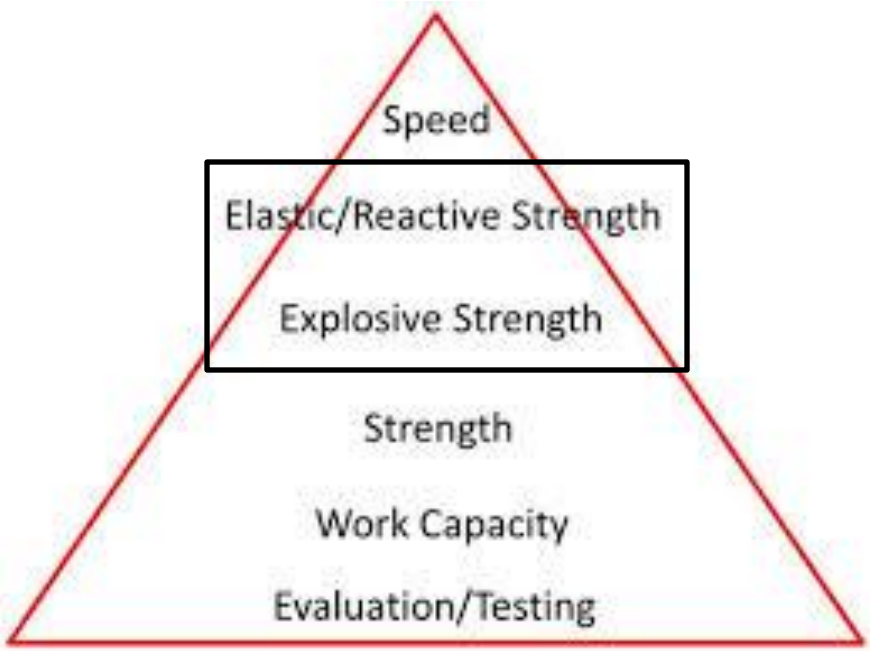
Hamstring Injury: The Physical Qualities of Explosive and Elastic/Reactive Strength

- Explosive Strength
  - Olympic Lifts
    - Pulls
  - Maximal effort jumps
  - Medicine ball tempo
- Elastic/Reactive Strength
  - Plyometrics
    - i.e. Multiple jumps and hops
  - Sprinting
    - Purest form of plyometric training



Vermeil's Hierarchy of Athletic Development

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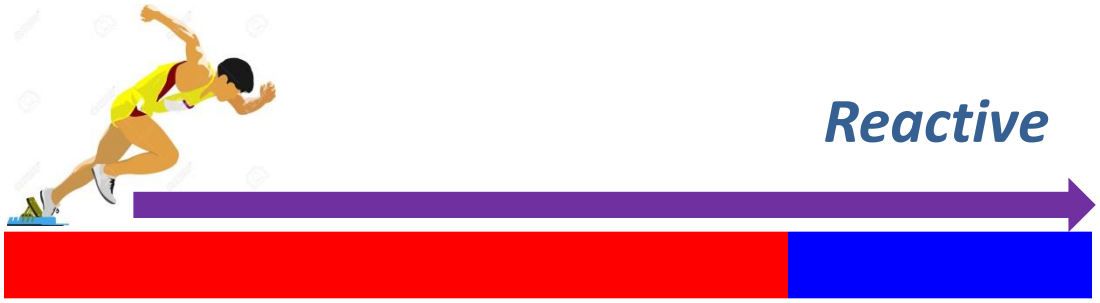
Elastic/Reactive Qualities of Sprinting

- 4.6 Second 40 Yard Dash
- Sprinting Velocity of approximately 9-10 m/s
- Initial speeds up to 7 m/s requires more “strength” qualities
- Speed exceeding 7 m/s requires “elastic strength” qualities Cavagna J Physio 1971



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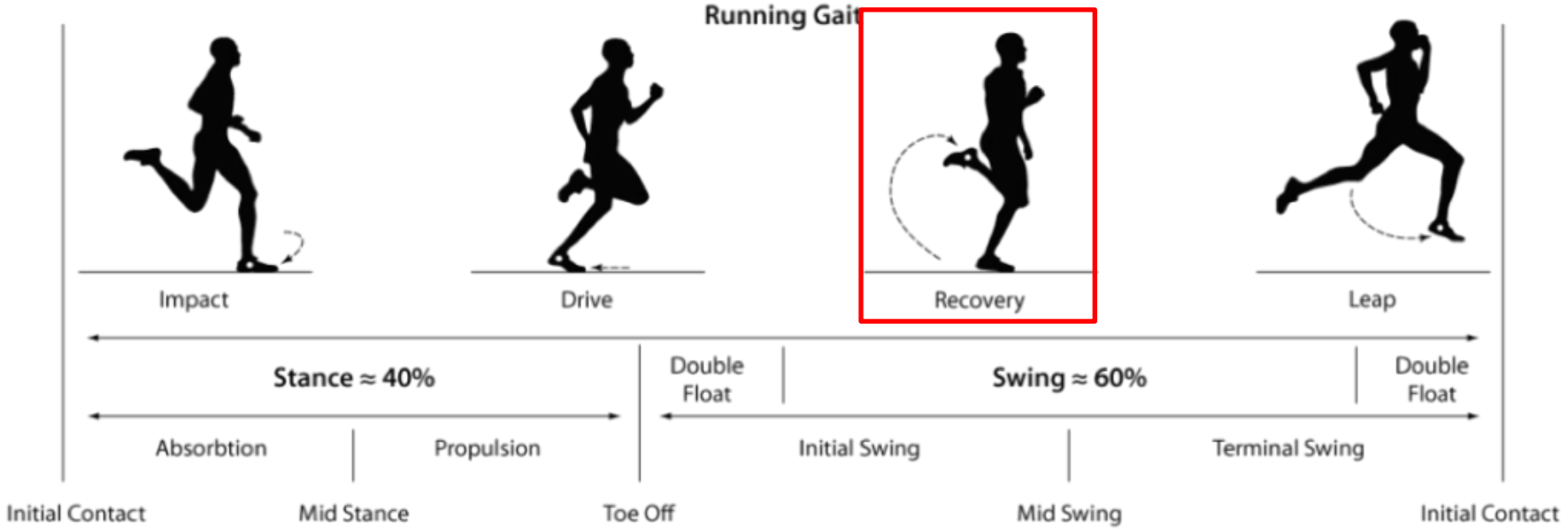
The Physical Quality of Speed

- Re-establish Velocity Training
  - Linear velocity
  - Neuromuscular Timing
  - Sprinting patterns
    - Swing Phase
      - ***Active*** hip and knee ROM
      - Heel position at gluteal fold
    - Float Phase
      - Neither foot in contact with the ground surface area
    - Stance Phase
      - Initial ground contact
      - Eccentric to concentric

Vermeil's Hierarchy of Athletic Development

Restoring Active Knee Range of Motion (AROM)



The Running Gait Cycle

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Knee AROM - The Swing Phase

- Moment arms (distance) of heel to butt

Figure 1

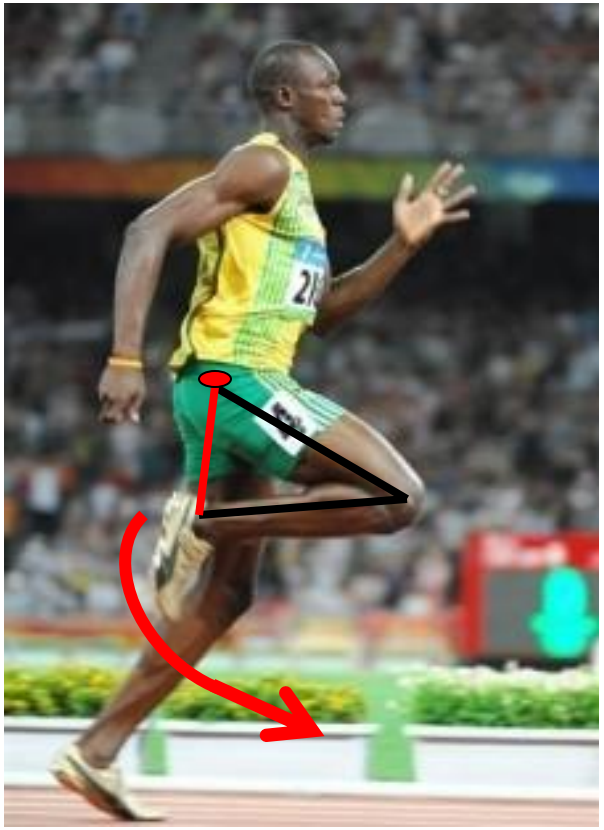

Figure 2

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The Running Gait Cycle

The Running Gait Cycle is just that, a “Cycle”. If you negatively affect one phase of the cycle, you negatively affect the entire cycle.

Poor Stance Phase

Poor Swing Phase

Poor Left Lower Extremity

Poor Right Lower Extremity

=

Poor Running Cycle

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Velocity Training - Modified Running Progressions and Mach Drills

- "A", "B", and "C" running drill series developed by track & field coach Gerard Mach
- Clinical Progression
  - "A" walks/marches
  - "A" skips low
  - "A" skips (high)
  - "A" runs
- Running
  - 10 yard sprints

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Velocity Progressions

Modified Mach Drills

Poor Strength Qualities	Fair/Good Strength Qualities	Good/Excellent Strength Qualities
Marching/Walking “A”’s	“A” Skips partial/full ROM	Running A’s perfect technique
Mirror Drills	Running “A”’s partial/full ROM	Bounding
Seated arm action activities		Sprinting

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Hamstring: Velocity Progressions

- Velocity Progression
  - Modified Mach Drills
  - Mach Drills
    - "A" Series
  - 10 Yard Sprints

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"A" Marches/Walks

- Simple means of controlling running limb mechanics in a slow disciplined fashion
- Fascicle length and proper alignment of scar tissue
- A rehearsal of the vertical qualities of stepping from stride to stride
- Coordinate arm movements to match the front side characteristics of the legs
- Teaches swing leg to a maximum height to the level of the hip
- Instills foot decent in a vertical movement pattern (vs. horizontal) with ground placement a few inches anterior to the support leg
- Vertical limb patterns assist in teaching the prevention of over striding
- The exercise should initially be performed walking heel to (rehabilitation) and progressed onto the balls of the feet with the heels slightly off the ground

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Fascicle Length and Scar Tissue Alignment

CPM Machine

“A” Walks “A” Skips

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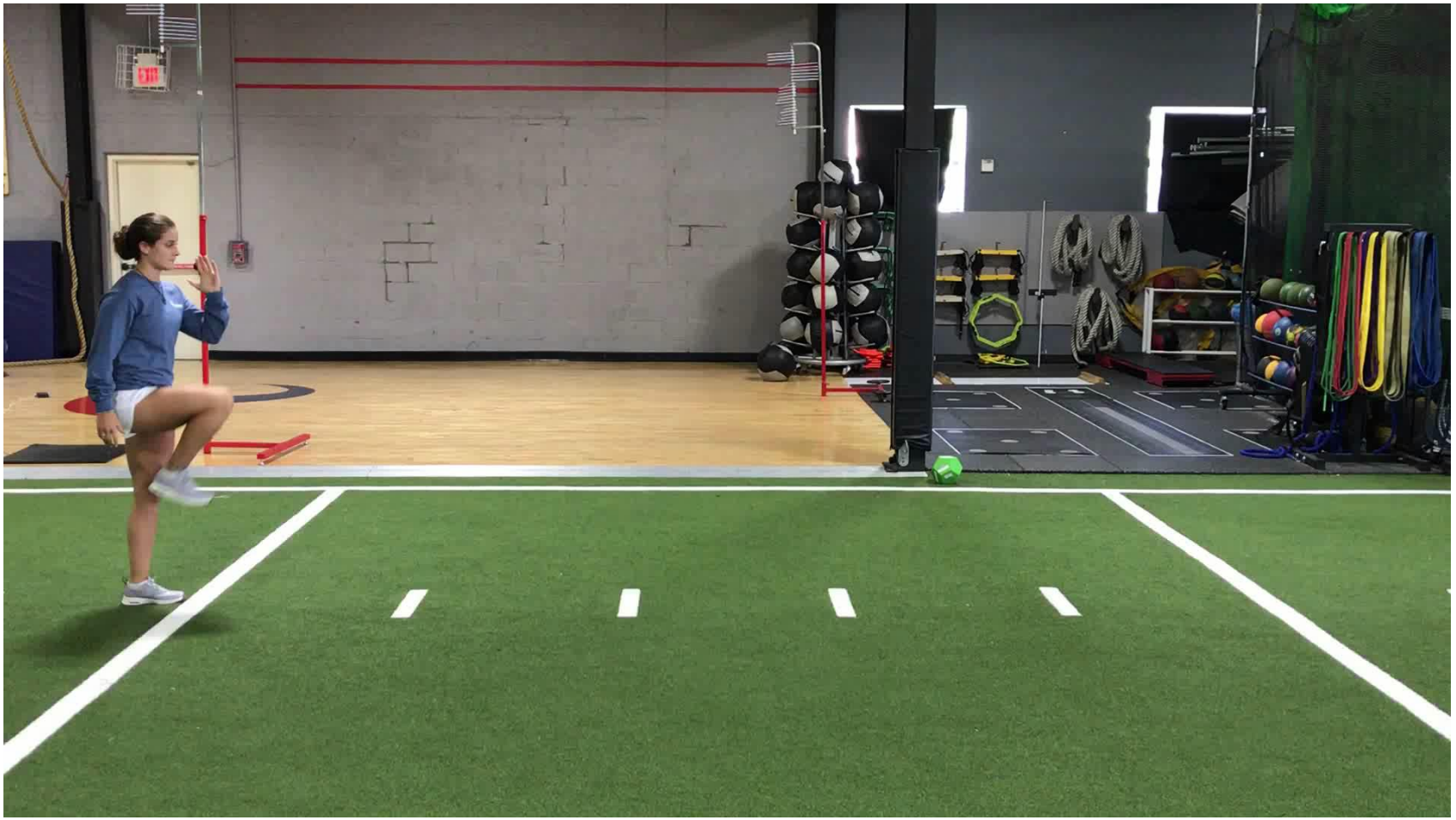
“A” Marches/Walks



Low "A" Skips and "A" Skips

- Bridges the gap from "A" Marches/Walks to "A" Runs
- Low "A" Skips are a rehabilitation progression
- Performed with the same posture and limb paths as "A" Marches/Walks
- Adds limb velocity, vertical force production, and elastic components vs. the "A" March/Walk exercise
- Acceleration of the foot downward to the ground evokes:
  - Stretch reflexes of the foot and lower leg
  - Vertical displacement of the body
- Perform light and quick foot contacts

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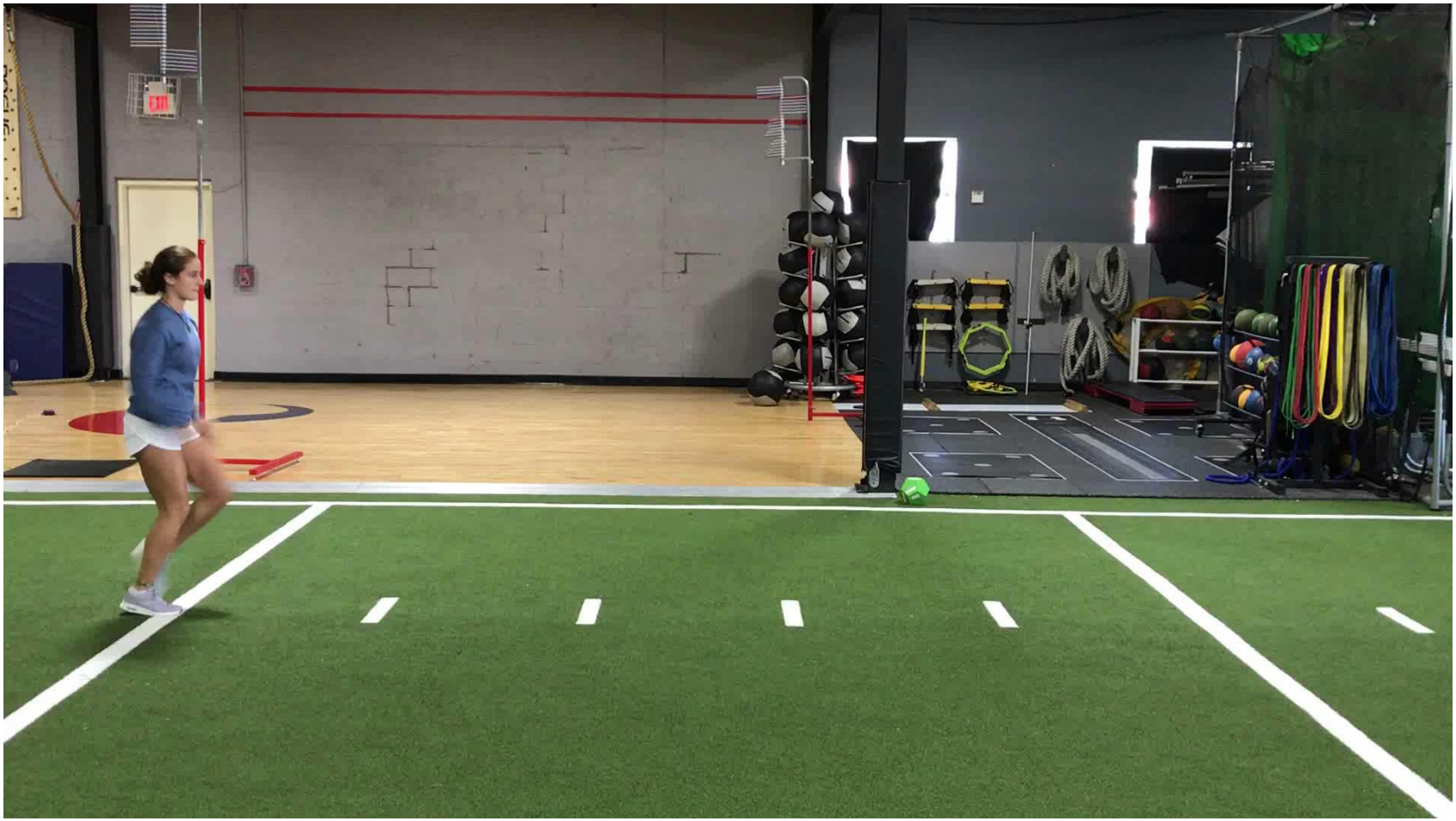
Low “A” Skips

“A” Skips



"A" Runs

- Cyclical stimulation of actual sprinting
- Preparation for stride frequency and vertical force production
- "Step over" cueing (are related to stance limb) progression:
  - Ankle
  - Calf
  - Knee
- Goal is 30 strides over 10 yards
  - Metabolic requirements of sprinters

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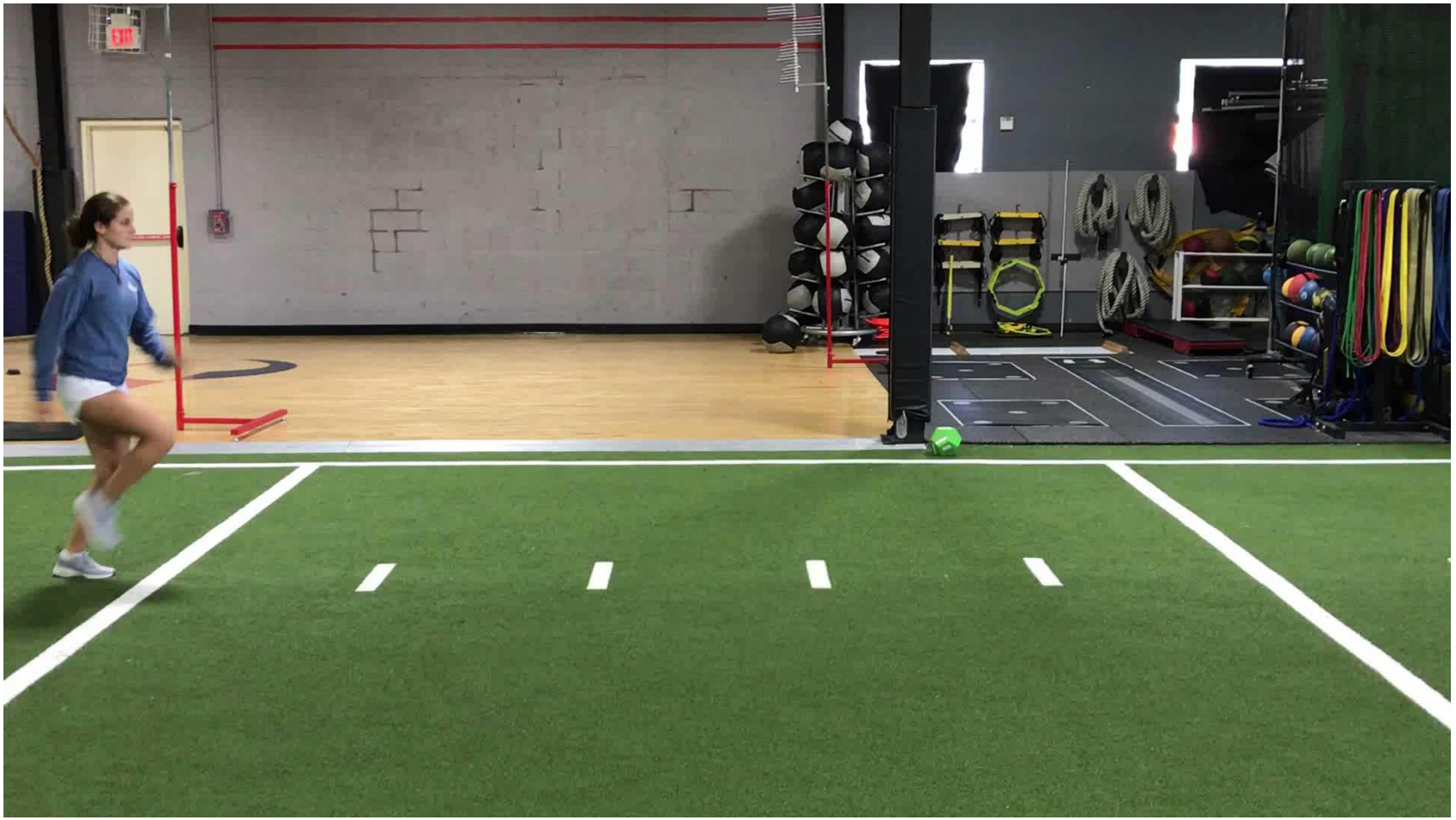
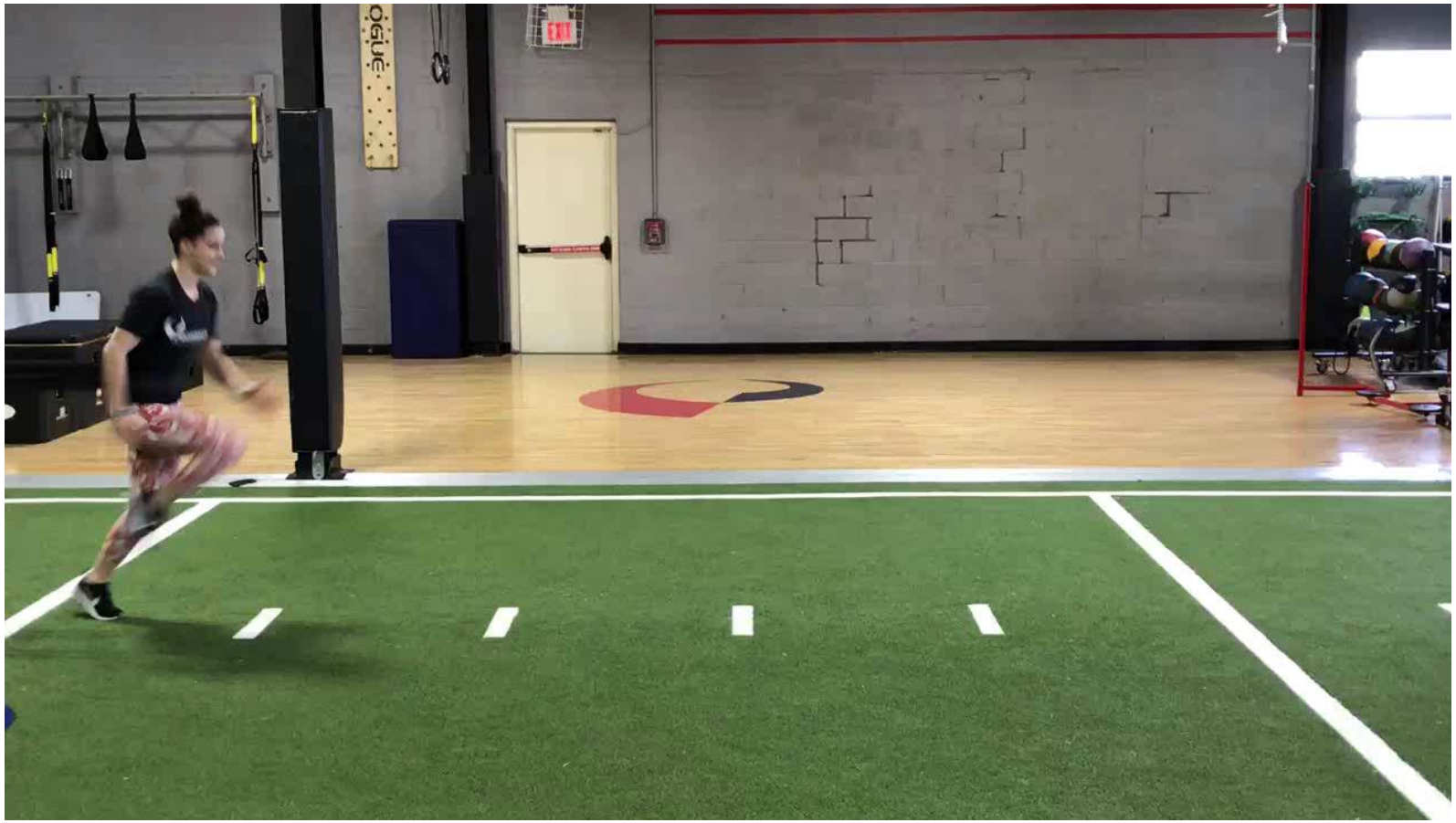
“A” Runs



Resisted "A" Runs

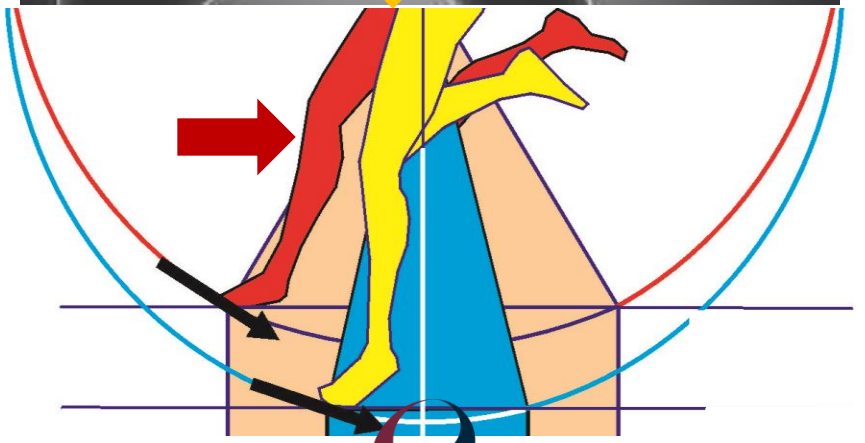


10 Yard Sprints

10 Yard Sprint

Clinical Pearl: Sprinting Volumes

- Sprint Acceleration in a *fatigued environment:*
- Decrease in:
  - Maximal power
  - Horizontal force production
    - Hips and center of mass drops
    - Increased braking forces
- Decrease in concentric peak torque during swing and terminal swing phases:
  - Knee flexors
  - Gluteal maximus
  - Vastus lateralis
- Increased Swing and GC times



Edouard et al Frontiers 2018
Evans et al J Phys Ther Sports Med 2018

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ACL Hamstring Graft/Hamstring Injury: Return to Play

Vermeil's Hierarchy of Athletic Development

A need for a sprinting progression and the need to maintain maximal velocity sprint training ⇒ re-establish/maintain neuromuscular timing

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