Running Medicine and Rehab

Erin L . Meyer PT, DPT, C-PS

Disclosures

I have no relevant financial interests/relationships to disclose

Course Objectives

1. Understand components of adolescent running biomechanics
2. Learn differences between endurance running mechanics versus sprint mechanics
3. Introduction to 2D video gait analysis
4. Running Gait re-training and rehabilitation techniques

Demographics

- Running participation for preadolescents (</=12yo) and adolescents (13-18yo) as high as 40% in some regions of the world.

- Highest incidence in running related injuries (RRI) is 12-14yo populations (45.8%)

Strong Evidence	Limited Evidence	Not supported	Conflicting evidence
Prior injury	Anatomical • Quad angle >/=20 • LLD >1.5cm in boys	Height	Age/development
Sex- females>males	Training • Summer training <8wks • >33% wkly volume on hills • <25% wkly volume alternating short/long mileage	Weight	Muscle weakness • Hip abductors • Knee extensors • Knee flexors
Menstrual dysfunction	Low running step rate <166spm	Running surface	Footwear
BMI <19kg/m2 in females	Early sport specialization		Foot strike mechanics

Krabak BJ, Roberts WO, Tenforde AS, Ackerman KE, Adami PE, Baggish AL, Barrack M, Cianca J, Davis I, D'Hemecourt P, Fredericson M, Goldman JT, Harrast MA, Heiderscheit BC, Hollander K, Kraus E, Luke A, Miller E, Moyer M, Rauh MJ, Toresdahl BG, Wasfy MM. Youth running consensus statement: minimising risk of injury and illness in youth runners. Br J Sports Med. 2021 Mar;55(6):305-318. doi: 10.1136/bjsports-2020-102518. Epub 2020 Oct 29. PMID: 33122252.

Demographics

	Males	Females
Low Specializer	18.9 ± 21.1	21.1 ± 19.1
Moderate Specializer	35.2 ± 20.8	29.0 ± 21.9
High Specializer	58.3 ± 22.6	45.8 ± 30.9

SMART SERIES Children's Wisconsin

Garcia MC, Taylor-Haas JA, Rauh MJ, Toland MD, Bazett-Jones DM. Sport Specialization in Middle- and High-School Long-Distance Runners. J Athl Train. 2021 Jan 22. doi: 10.4085/462-20. Epub ahead of print. PMID: 33481024.

https://encrypted-tbn0.gstatic.com/images?q=tbn:ANd9GcQ3Iol2V0M62-MHKP8jJGHbPI2i6af8i2oKv45vsh1gliQbO1V6GJARJTDGDhFVyoov1rc&usqp=CAU

Biomechanics of running- gait cycle

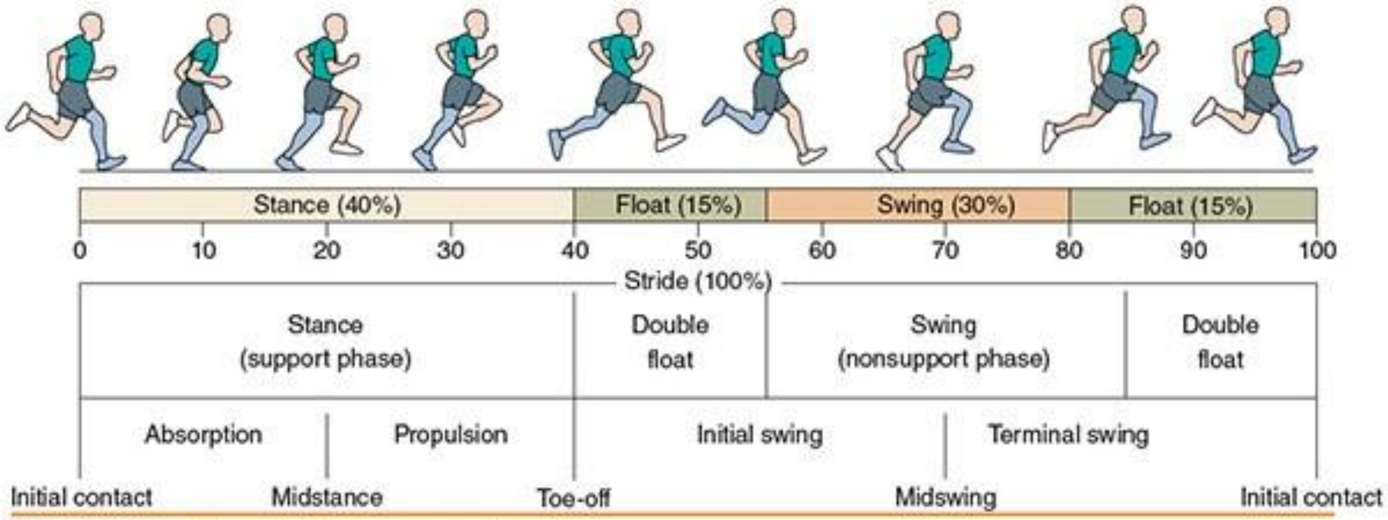


FIGURE 8.5 Phases of the running gait cycle.

Reprinted by permission from P.A. Houglum, *Therapeutic exercise for musculoskeletal injuries*, 4th ed. (Champaign, IL: Human Kinetics, 2016), 331.

- Understanding of common forces (external and internal) and resulting joint forces acting on the body in running helps the clinician identify tissue loading/injury risk and recovery

Orthopedic Management of the runner, cyclist, swimmer. Biomechanics of running 23.1.4. Orthopedic Section of APTA. 2013.

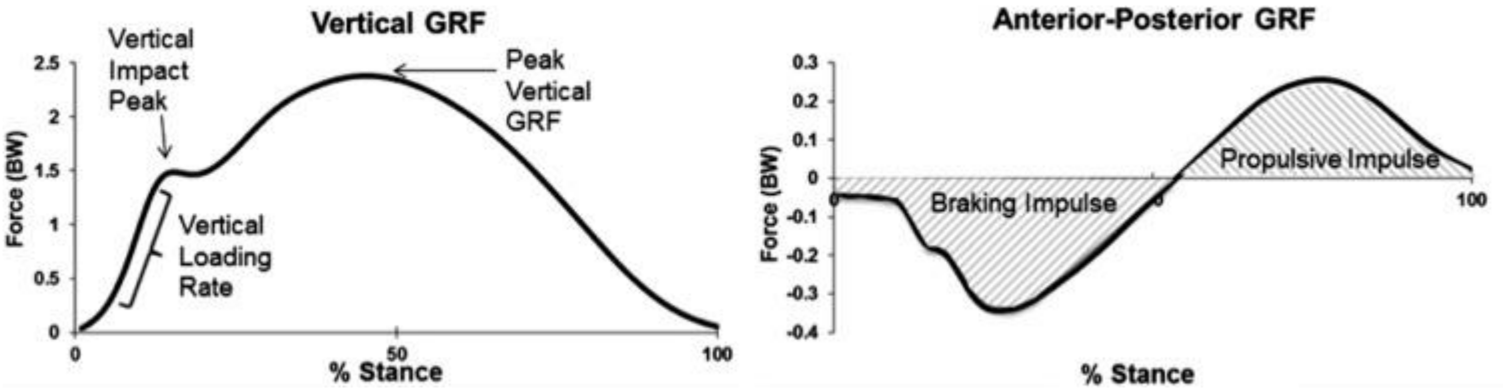
Spaciotemporal characteristics

- Stride length and time change with speed- length increases, time decreases
- Step width decreases with running speed
- Amount of foot placement angle (toe out/in) is variable with running speed

Orthopedic Management of the runner, cyclist, swimmer. Biomechanics of running 23.1.4. Orthopedic Section of APTA. 2013.

https://cdn10.phillymag.com/wp-content/uploads/2014/05/runners-legs.jpg

Ground Reaction Forces (GRF)



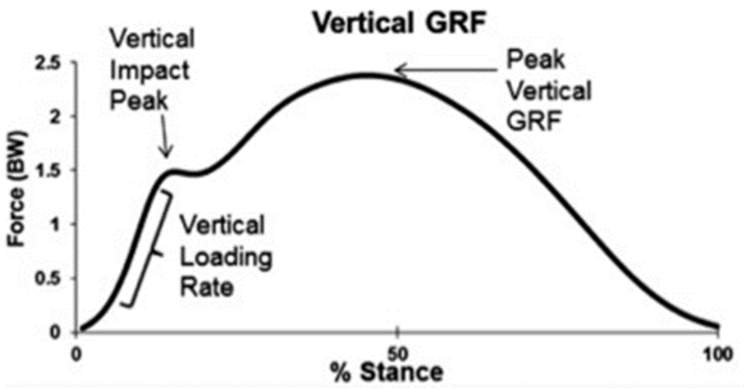
- Forces act on COM in 3 ways- vertical, A/P, and M/L
- Impact force- smaller vertical force occurring about 25ms after foot contact
  - Influenced in size by downhill running, slow cadence, and pronounced heel strike
  - Alone, these impact forces may not increase RRI, but coupled with abnormal running mechanics and poor training loads may be an influence
- Impact force accelerates segments from the leg towards the head

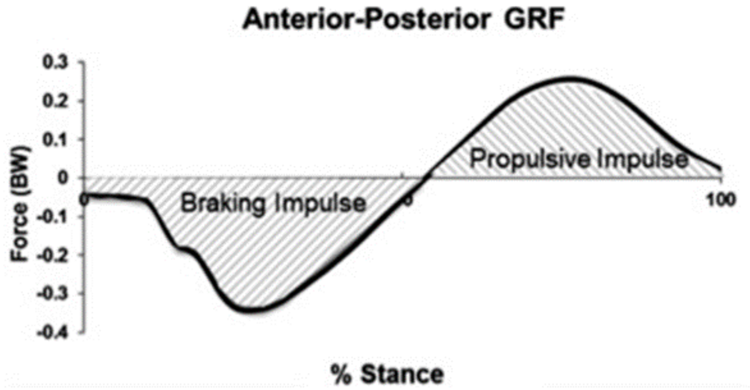
Orthopedic Management of the runner, cyclist, swimmer. Biomechanics of running 23.1.4. Orthopedic Section of APTA. 2013.

https://www.google.com/url?sa=i&url=https%3A%2F%2Feuropepmc.org%2Farticle%2Fpmc%2Fpmc6088121&psig=AOvVaw00urRaip_phtRuuG9bnm6p&ust=1643638786486000&source=images&cd=vfe&ved=0CAsQjRxqFwoTCLDTnubV2fUCFQAAAAAdAAAAABAJ

SMART SERIES Children's Wisconsin

Ground reactive forces (GRF)



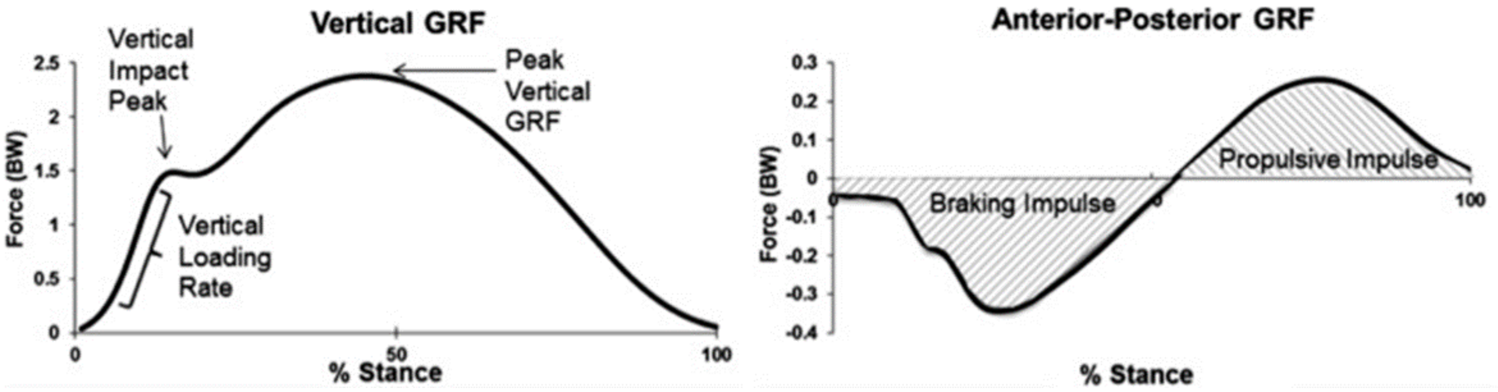


- The vertical GRF increases as COM moves downward, reaching its peak at midstance
- Vertical GRF is increasing as braking impulse (A/P GRF) increases to midstance- thus creating 3-5x great joint contact forces than at impact GRF
- Peak vertical GRF and braking impulse timing are where we can best understand joint and tissue loading.
  - Running re-training that focuses to increase step rate, decrease contact time and encourage foot contact closer to COM may be beneficial in reducing RRI
- Gravitational potential energy and kinetic energy simultaneously reach a low at midstance and COM reaches its lowest point- <5% mechanical work needed to then propel and accelerate the body after midstance is conserved.
  - Our bodies rely on storage and release of energy in elastic tissues.

Orthopedic Management of the runner, cyclist, swimmer. Biomechanics of running 23.1.4. Orthopedic Section of APTA. 2013.

https://www.google.com/url?sa=i&url=https%3A%2F%2Feuropepmc.org%2Farticle%2Fpmc%2Fpmc6088121&psig=AOvVaw00urRaip_phtRuuG9bnm6p&ust=1643638786486000&source=images&cd=vfe&ved=0CAsQjRxqFwoTCLDTnubV2fUCFQAAAAAdAAAAABAJ

Ground reactive forces (GRF)



- Braking impulse is the A/P GRF
- During first half of stance phase the force is directed posteriorly to decelerate the body, and 2nd half of stance phase the direction of force is anterior to promote acceleration or propulsion called the propulsive impulse

Orthopedic Management of the runner, cyclist, swimmer. Biomechanics of running 23.1.4. Orthopedic Section of APTA. 2013.

https://www.google.com/url?sa=i&url=https%3A%2F%2Feuropepmc.org%2Farticle%2Fpmc%2Fpmc6088121&psig=AOvVaw00urRaip_phtRuuG9bnm6p&ust=1643638786486000&source=images&cd=vfe&ved=0CAsQjRxqFwoTCLDTnubV2fUCFQAAAAAdAAAAABAJ

SMART SERIES Children's Wisconsin

Sagittal plane joint kinematics and kinetics

- Sagittal plane- loading responses are when eccentric forces are greatest
- The sequence of which these moments eccentrically occur are:
  - loading hip extension
  - knee extension
  - plantarflexion
  - with hip abd. playing a large role in stabilization
- Quads may play largest braking role, while gastroc/soleus may create largest propulsive role.

Orthopedic Management of the runner, cyclist, swimmer. Biomechanics of running 23.1.4. Orthopedic Section of APTA. 2013.

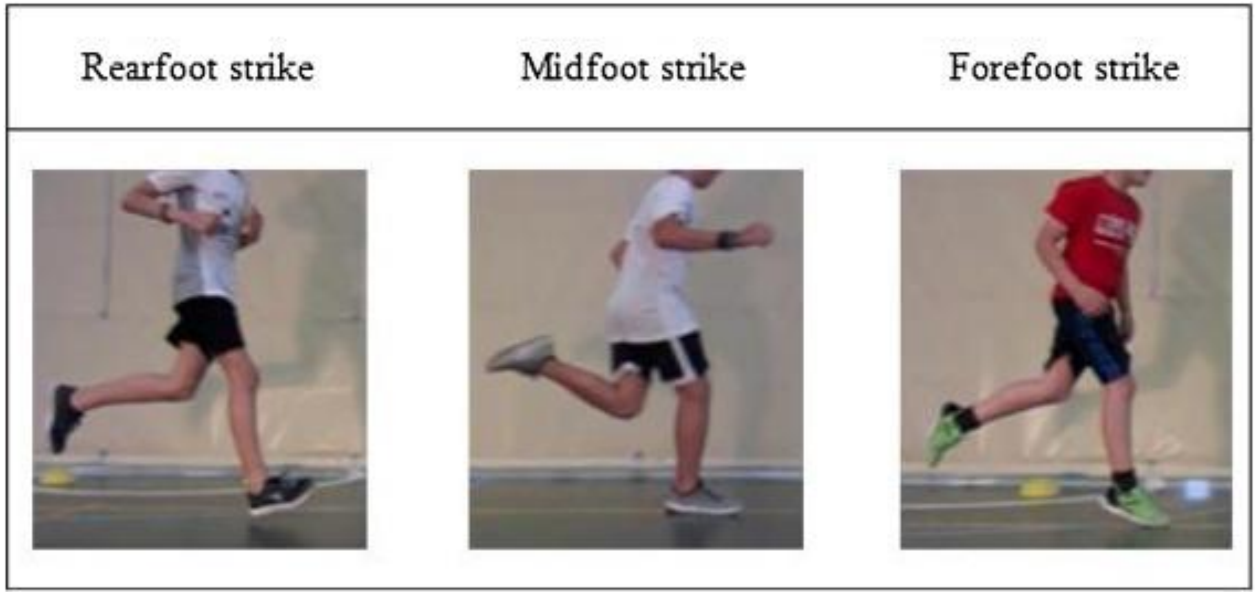
Frontal/Transverse plane

- Pronation and Valgus considerations
- Capturing rearfoot excursion in the frontal plane in gait analysis can be a helpful tool to gathering information of multiplanar forces acting on the runner
    - There is not clear evidence suggesting that pronation has a cause/effect or associative relationship with RRI
- Knee valgus patterns of hip add, femoral IR and knee flexion may help identify PFPS and ITband problems
    - Faulty control patterns may lead to increased GRFs so even a muscle normal in strength may be inadequate to stabilize the joints

Orthopedic Management of the runner, cyclist, swimmer. Biomechanics of running 23.1.4. Orthopedic Section of APTA. 2013.

https://thumbor.forbes.com/thumbor/711x404/https://blogs-images.forbes.com/leebelltech/files/2018/09/gat-analysis-1200x682.jpg?width=960

Adolescent considerations- foot strike

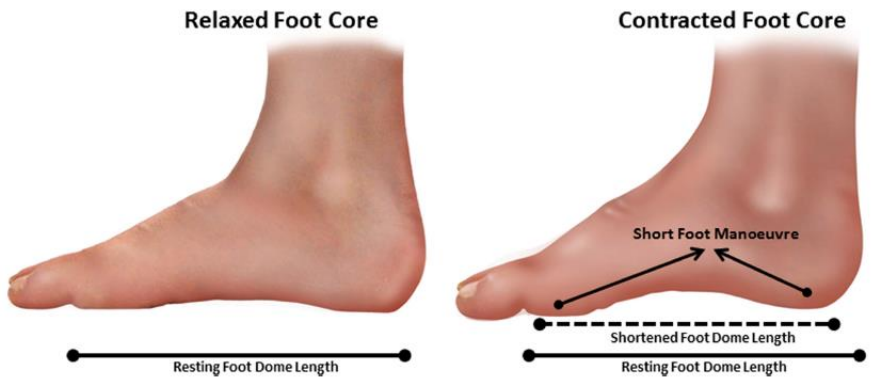


- Conflicting evidence on strike patterns across the research for adults and adolescents alike.
- Some evidence to support that different foot strike patterns may be related to different RRI
  - Heel striker- more plantar fasciitis, sometimes increased tibial stress
  - Mid- to forefoot striker- Achilles pathology, metatarsal pain

McSweeney SC, Grävare Silbernagel K, Gruber AH, Heiderscheit BC, Krabak BJ, Rauh MJ, Tenforde AS, Wearing SC, Zech A, Hollander K. Adolescent Running Biomechanics - Implications for Injury Prevention and Rehabilitation. Front Sports Act Living. 2021 Aug 26;3:689846. doi: 10.3389/fspor.2021.689846. PMID: 34514384; PMCID: PMC8432296.

https://ars.els-cdn.com/content/image/1-s2.0-S0966636220305695-gr2.jpg

Adolescent considerations- muscle strength



- Muscle weakness has not shown consistently to contribute RRI
- Despite this injury prevention programs including high intensity NM training with jumping, plyometrics and balance training are successful in reducing sports injuries in other youth athlete populations (basketball, soccer, football, volleyball)
- Isolated foot strengthening program reveals 2.4x lower injury rate

McSweeney SC, Grävare Silbernagel K, Gruber AH, Heiderscheit BC, Krabak BJ, Rauh MJ, Tenforde AS, Wearing SC, Zech A, Hollander K. Adolescent Running Biomechanics - Implications for Injury Prevention and Rehabilitation. Front Sports Act Living. 2021 Aug 26;3:689846. doi: 10.3389/fspor.2021.689846. PMID: 34514384; PMCID: PMC8432296.

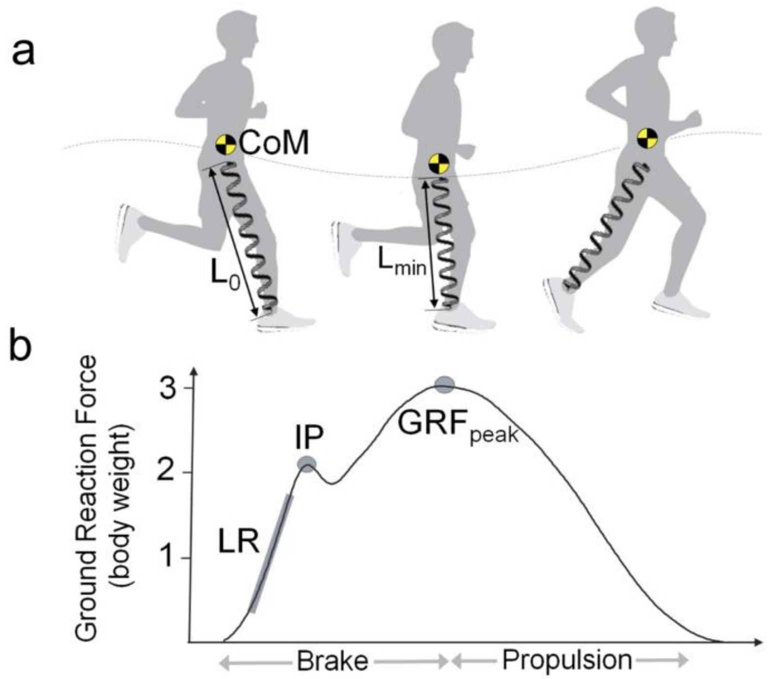
Taddei UT, Matias AB, Duarte M, Sacco ICN. Foot Core Training to Prevent Running-Related Injuries: A Survival Analysis of a Single-Blind, Randomized Controlled Trial. Am J Sports Med. 2020 Dec;48(14):3610-3619. doi: 10.1177/0363546520969205. Epub 2020 Nov 6. PMID: 33156692.

https://peakconditionpdx.com/wp-content/uploads/2016/04/plyo-soccer.jpg
https://i0.wp.com/alliedanatomy.com/wp-content/uploads/2020/08/arches.png?fit=878%2C380&ssl=1

SMART SERIES Children's Wisconsin

Adolescent considerations- tendon

- Muscle fascicles and tendons lengthen at a faster rate than cross sectional area
- In early adolescence- tendons improve material and biochemical properties- elastic/tensile strength, but hypertrophy of the tendon occurs later in adolescence
- The muscle develops progressively in adolescence- the mismatch may be a contributor to tendinopathies/tendon loading injuries
- Goal to increase/facilitate tendon stiffness- research is needed, but it is thought that youth strength programming would help with muscle strength as well as promote increased tendon stiffness



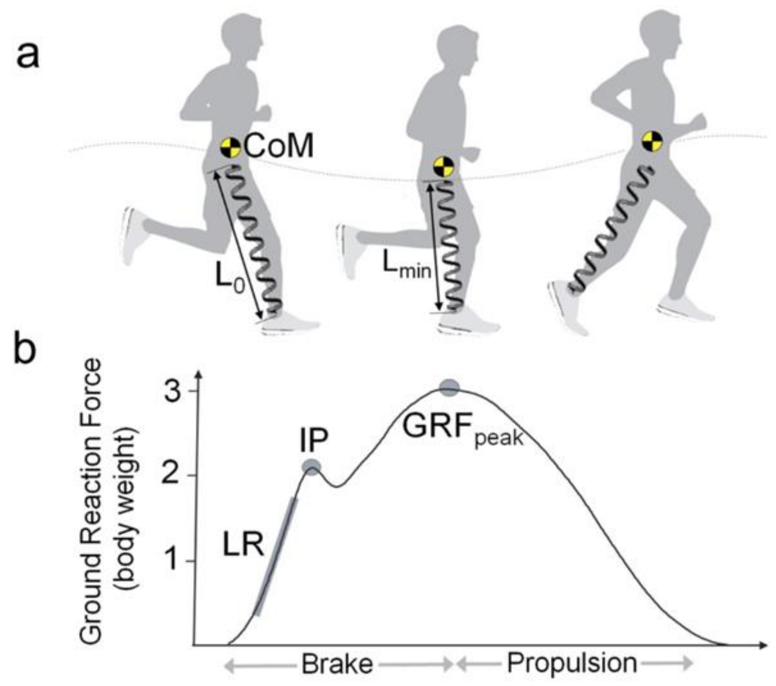
McSweeney SC, Grävare Silbernagel K, Gruber AH, Heiderscheit BC, Krabak BJ, Rauh MJ, Tenforde AS, Wearing SC, Zech A, Hollander K. Adolescent Running Biomechanics - Implications for Injury Prevention and Rehabilitation. Front Sports Act Living. 2021 Aug 26;3:689846. doi: 10.3389/fspor.2021.689846. PMID: 34514384; PMCID: PMC8432296.

Waugh CM, Blazevich AJ, Fath F, Korff T. Age-related changes in mechanical properties of the Achilles tendon. J Anat. 2012;220(2):144-155. doi:10.1111/j.1469-7580.2011.01461.x

https://media.springernature.com/m685/springer-static/image/art%3A10.1038%2Fs41598-018-35980-6/MediaObjects/41598_2018_35980_Fig1_HTML.png

Adolescent considerations- stiffness

- Stiffness is a quantitative measure of elastic properties in the body and determines the ability to accumulate potential energy
- Potential energy stored in muscle tendon units reduced metabolic energy spent by muscles
- Flexor and extensor co-activation just prior to IC facilitates “leg spring stiffness” to transfer forces
- There are different types of stiffness
  - Leg stiffness is ratio of change from GRF to “spring length” in legs
  - Vertical stiffness is ratio of changes from GRF respective to vertical displacement of COM



Struzik A, Karamanidis K, Lorimer A, Keogh JWL, Gajewski J. Application of Leg, Vertical, and Joint Stiffness in Running Performance: A Literature Overview. Appl Bionics Biomech. 2021;2021:9914278. Published 2021 Oct 21. doi:10.1155/2021/9914278

https://media.springernature.com/m685/springer-static/image/art%3A10.1038%2Fs41598-018-35980-6/MediaObjects/41598_2018_35980_Fig1_HTML.png

SMART SERIES

Children's Wisconsin

Adolescent considerations- stiffness

- Vertical stiffness increases with running velocity, stride frequency, and maturity
- Fatigue causes decreased vertical stiffness
- Leg spring stiffness increases with maturity, and can increase 2x by increasing stride frequency
- Runners adjust leg spring stiffness dependent on surface- soft surface leads to increased time on ground and lost potential energy
- Leg stiffness is not as affected by aerobic fatigue
- Forefoot strikers have greater leg stiffness

Struzik A, Karamanidis K, Lorimer A, Keogh JWL, Gajewski J. Application of Leg, Vertical, and Joint Stiffness in Running Performance: A Literature Overview. Appl Bionics Biomech. 2021;2021:9914278. Published 2021 Oct 21. doi:10.1155/2021/9914278

Adolescent considerations- temporospatial

- Kinetic and Temporospatial Variables
  - Prior to age 12, there is decreased step rate and decreased mass specific whole body vertical stiffness- there is increasing body mass but vertical stiffness remains constant
  - Between 12-18y.o vertical stiffness and step rate are constant because there is a more parallel increase in vertical stiffness and mass
  - As running speed increases both step rate and length increase across all ages
    - Athletes who have not yet reached peak height velocity step rate is most influential in speed
    - Athletes who are at or beyond peak height velocity, step length is the key factor.

SMART SERIES Children's Wisconsin

McSweeney SC, Grävare Silbernagel K, Gruber AH, Heiderscheit BC, Krabak BJ, Rauh MJ, Tenforde AS, Wearing SC, Zech A, Hollander K. Adolescent Running Biomechanics - Implications for Injury Prevention and Rehabilitation. Front Sports Act Living. 2021 Aug 26;3:689846. doi: 10.3389/fspor.2021.689846. PMID: 34514384; PMCID: PMC8432296

Endurance vs. Sprint

- Speed increases
  - Stride length and frequency increase- stride length most notable
  - Increased hip moments:
    - Hip flexion at initial swing, hip extension and knee flexion in terminal swing
    - Apophyseal and avulsion injuries with increased demands and common flexibility deficits
  - Ground contact time decreases- suggesting increased leg stiffness
  - Largest changes in GRF are observed from 40-60% of maximal speed compared with 60-100% max speed changes
    - Larger GRFs during sprint speed changes observed in adolescents
    - Poor NM control and lack of stiffness leave many adolescent sprinters unable to obtain max speed

Orthopedic Management of the runner, cyclist, swimmer. Biomechanics of running 23.1.4. Orthopedic Section of APTA. 2013.

2D running analysis

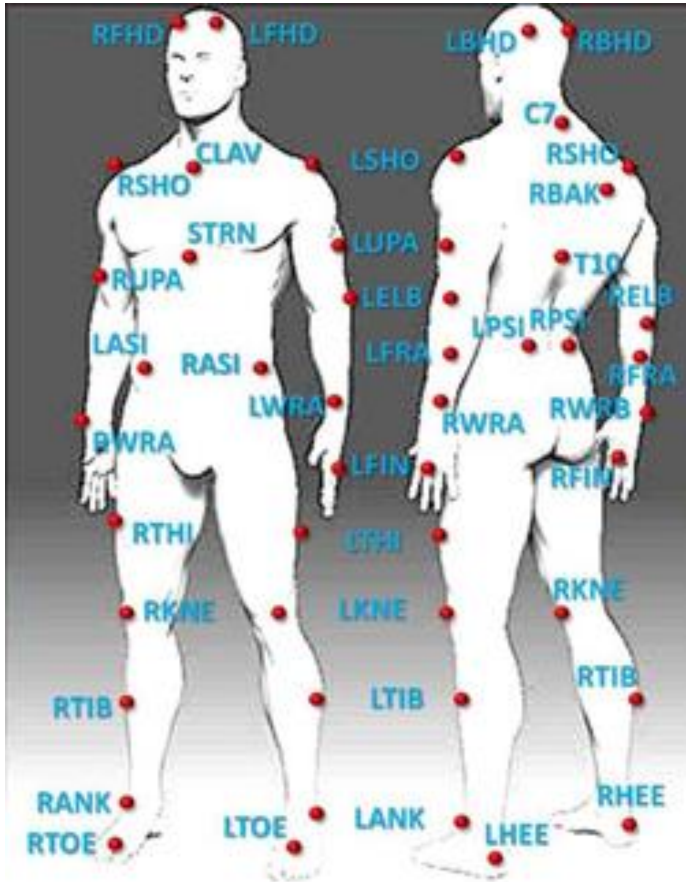
An efficient clinical tool helpful in identifying biomechanical factors related to running injuries- much more effective buy-in if we analyze what makes our patients hurt

Taylor-Haas, Jeff. Running Injuries Examination, Differential Diagnosis, and Treatment Interventions; April 9-10, 2011. Chicago, IL

Souza RB. An Evidence-Based Videotaped Running Biomechanics Analysis. Phys Med Rehabil Clin N Am. 2016 Feb;27(1):217-36. doi: 10.1016/j.pmr.2015.08.006. Epub 2015 Oct 20. PMID: 26616185; PMCID: PMC4714754.

https://www.vestedway.com/wp-content/uploads/2014/02/EK_Vested_Elephant_image_ph1.jpg

2D running analysis- Joint marker placement



- Posterior
  - PSIS
  - Bisection distal 1/3 Tib/Fib- in standing
  - Bisection calcaneus- in standing
- Anterior
  - ASIS
  - Midpoint patella-optional
  - Tibial tuberosity- optional
- Lateral
  - GT
  - Lateral femoral condyle
  - Lateral malleolus

Taylor-Haas, Jeff. Running Injuries Examination, Differential Diagnosis, and Treatment Interventions; April 9-10, 2011. Chicago, IL.

Reinking MF, Dugan L, Ripple N, Schleper K, Scholz H, Spadino J, Stahl C, McPoil TG. RELIABILITY OF TWO-DIMENSIONAL VIDEO-BASED RUNNING GAIT ANALYSIS. Int J Sports Phys Ther. 2018 Jun;13(3):453-461. PMID: 30038831; PMCID: PMC6044590

http://biomechanics2014.weebly.com/uploads/3/1/1/8/31181079/2012233.jpg?249

2D running analysis- Posterior View

- Head/trunk alignment
- Arm swing
- Pelvis
- Toe in/out
- Strike pattern
- Rearfoot angle at IC (supinated/inverted is WNL)
- Opposite limb in swing

IC

- Head/trunk alignment
- Arm swing
- Calcaneal eversion
- Forefoot abduction
- Knee valgus
- Hip drop
    - Trendelenburg
    - Opposite arm wide

Midstance

- Head/trunk alignment
- Arm swing
- Pelvis
- Calcaneal position
- Toe in/out

Pre-swing

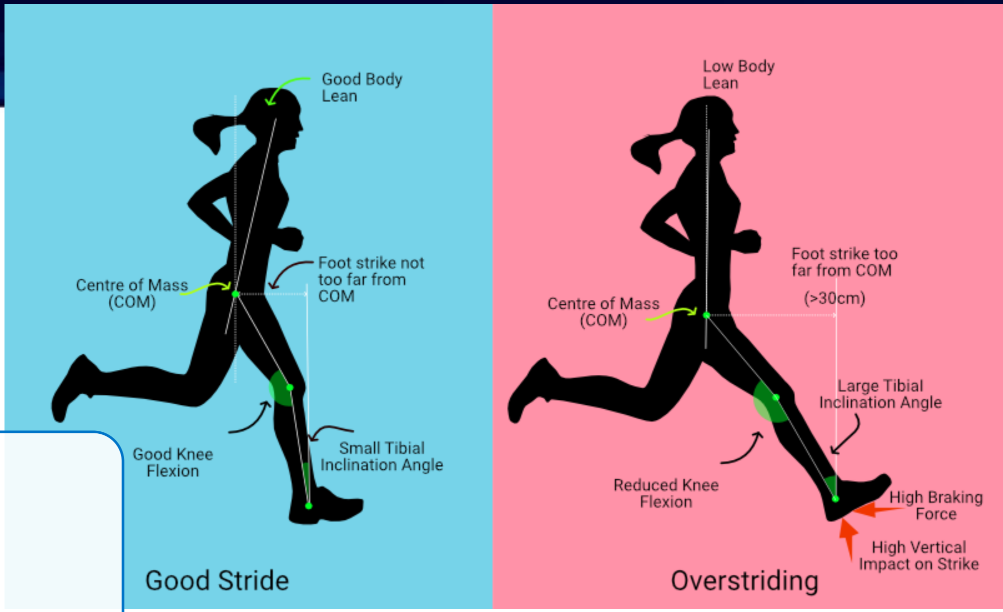
Taylor-Haas, Jeff. Running Injuries Examination, Differential Diagnosis, and Treatment Interventions; April 9-10, 2011. Chicago, IL.

Reinking MF, Dugan L, Ripple N, Schleper K, Scholz H, Spadino J, Stahl C, McPoil TG. RELIABILITY OF TWO-DIMENSIONAL VIDEO-BASED RUNNING GAIT ANALYSIS. Int J Sports Phys Ther. 2018 Jun;13(3):453-461. PMID: 30038831; PMCID: PMC6044590

Souza RB. An Evidence-Based Videotaped Running Biomechanics Analysis. Phys Med Rehabil Clin N Am. 2016 Feb;27(1):217-36. doi: 10.1016/j.pmr.2015.08.006. Epub 2015 Oct 20. PMID: 26616185; PMCID: PMC4714754.

https://www.runnersneed.com/content/dam/runnersneed/blog/gait-analysis/GAE-inline-supinaion-new.jpg/jcr:content/renditions/cq5dam.web.320.320.jpeg

2D analysis- lateral view



IC

- Strike pattern
- Angle of inclination
- Calcaneus to knee
- Knee flexion angle
- COM

Midstance

- Dorsiflexion
- Knee flexion
- Trunk position

Pre-swing-stance

- Knee flexion
- Pelvic tilt
- Forward lean

Souza RB. An Evidence-Based Videotaped Running Biomechanics Analysis. Phys Med Rehabil Clin N Am. 2016 Feb;27(1):217-36. doi:10.1016/j.pmr.2015.08.006. Epub 2015 Oct 20. PMID: 26616185; PMCID: PMC4714754.

Taylor-Haas, Jeff. Running Injuries Examination, Differential Diagnosis, and Treatment Interventions; April 9-10, 2011. Chicago, IL.

Reinking MF, Dugan L, Ripple N, Schleper K, Scholz H, Spadino J, Stahl C, McPoil TG. RELIABILITY OF TWO-DIMENSIONAL VIDEO-BASED RUNNING GAIT ANALYSIS. Int J Sports Phys Ther. 2018 Jun;13(3):453-461. PMID: 30038831; PMCID: PMC6044590

https://geeksonfeet.com/img/2021/01/overstriding.png

Goals of Re-training

- Increase cadence
- Decrease vertical oscillation
- Decrease ground contact time
- Optimize leg stiffness
- Optimize trunk alignment
- Patient education
  - Training workloads
  - Optimal tool for test re-test
  - Emotional components

Gait Re-training- Cadence

- Cadence or step rate- 5-10-15%
- Decreased demands on the knee at 5%
- Decreased hip joint loads at 10%
- 15% shows even greater decrease in inclination angle, vertical GRF and loading rates- but may begin to have a metabolic cost
    - Cueing: 10% increase in foot contacts
        - Ex: preferred step rate of 164steps/min- 41R foot contacts in 30sec
        - 41x 10% = 4.1- cue patient to aim for 45 R foot contacts in 30sec while maintaining same speed
- Results in decreased ground contact time, decreased loading rates, decreased braking impulse
- Significant findings of support in plantar fasciitis, Achilles tendinopathy, PFPS, Tibial stress, ITBS

Adams D, Pozzi F, Willy RW, Carrol A, Zeni J. ALTERING CADENCE OR VERTICAL OSCILLATION DURING RUNNING: EFFECTS ON RUNNING RELATED INJURY FACTORS. Int J Sports Phys Ther. 2018 Aug;13(4):633-642. PMID: 30140556; PMCID: PMC6088121.

Hobara H, Sato T, Sakaguchi M, Sato T, Nakazawa K. Step frequency and lower extremity loading during running. Int J Sports Med. 2012 Apr;33(4):310-3. doi: 10.1055/s-0031-1291232. Epub 2012 Mar 1. PMID: 22383130.

Heiderscheit BC, Chumanov ES, Michalski MP, Wille CM, Ryan MB. Effects of step rate manipulation on joint mechanics during running. Med Sci Sports Exerc. 2011 Feb;43(2):296-302. doi: 10.1249/MSS.0b013e3181ebedf4. PMID: 20581720; PMCID: PMC3022995.

Allen DJ, Heisler H, Mooney J, Kring R. THE EFFECT OF STEP RATE MANIPULATION ON FOOT STRIKE PATTERN OF LONG DISTANCE RUNNERS. Int J Sports Phys Ther. 2016 Feb;11(1):54-63. PMID: 26900500; PMCID: PMC4739048.

SMART SERIES Children's Wisconsin

Gait Re-training- vertical oscillation

- Vertical oscillation or bounce
  - Cueing: “keep body low to ground without slouching”
  - Cueing: less bounce/sway of the ponytail
- Results in decreased ground contact time, decreased loading rates, decreased vertical GRF
- Significant findings in support of tibial stress fractures, PFPS, ITBS

Adams D, Pozzi F, Willy RW, Carrol A, Zeni J. ALTERING CADENCE OR VERTICAL OSCILLATION DURING RUNNING: EFFECTS ON RUNNING RELATED INJURY FACTORS. Int J Sports Phys Ther. 2018 Aug;13(4):633-642. PMID: 30140556; PMCID: PMC6088121

SMART SERIES

Children's Wisconsin

Corrective interventions

- Mobility/function:
  - Thoracic mobility, lumbopelvic control, flexibility in anterior hip, rotators, posterior chain, and ankle mobility
- Strengthening:
  - Once the athlete has mobility, NM control/stability of movement patterns, then make sure to load them
- Plyometrics:
  - Explosive/reactive training- from DL to SL when appropriate control of patterns is demonstrated

Frequency:
2-3x/wk

Components:

- Heavy resistance training 60-85% 1RM
- Explosive resistance training (promote acceleration)
- Reactive Plyometrics

Interference phenomenon:

- Cautious of heavy resistance training 48hr prior to race, allows running economy to recover
- Conversely, allow 3 hrs after endurance training for maximizing gains in a strength workout

Length: 8-12 weeks

3-6wk cycles

Marcello RT, Greer BK, Greer AE. Acute effects of plyometric and resistance training on running economy in trained runners. *Journal of Strength and Conditioning Research.* 2017; 31(9): 2432-2436.
Blagrove RC, Howatson G, Hayes PR. Effects of strength training on the physiological determinants of middle- and long-distance running performance: a systematic review. *Sports Medicine.* 2018; 48: 1117-1149
Alexander JLN, Barton CJ, Willy RW. Infographic. Running myth: strength training should be high repetition low load to improve running performance. *British J Sports Med*. 2020; 54(13): 813-814

Training capacity

Weekly Volume	Acute:Chronic Workload Ratio (ACWR)
Injured runners change one or more variables compared to uninjured runners (velocity, distance, volume) Injured runners increased weekly distance by average 31% Uninjured runners increased by average 22% 10-24% range ideal	Acute load= cumulative load in recent 7 days Chronic load= cumulative load in prior 4 weeks ACWR= Acute load/Chronic load ACWR >1.5 is associated with increased RRI “Sweet spot”/Low Risk zone= .8-1.3 Example: Chronic load: 10, 15, 9, 21= 55/4= 13.75 Acute load: 21mile week: 21/13.75= 1.5

Damsted C, Glad S, Nielsen RO, Sørensen H, Malisoux L. IS THERE EVIDENCE FOR AN ASSOCIATION BETWEEN CHANGES IN TRAINING LOAD AND RUNNING-RELATED INJURIES? A SYSTEMATIC REVIEW. Int J Sports Phys Ther. 2018;13(6):931–942.
Damsted C, Parner ET, Sørensen H, Malisoux L, Hulme A, Nielsen RØ. The Association Between Changes in Weekly Running Distance and Running-Related Injury: Preparing for a Half Marathon. J Orthop Sports Phys Ther. 2019 Apr;49(4):230-238. doi: 10.2519/jospt.2019.8541. Epub 2018 Dec 7. PMID: 30526231.
Hulin BT, Gabbett TJ, Lawson DW, Caputi P, Sampson JA. The acute:chronic workload ratio predicts injury: high chronic workload may decrease injury risk in elite rugby league players. Br J Sports Med. 2016;50(4):231-236. doi:10.1136/bjsports-2015-094817

Clinical applications

- ❑Understand your runner's training hx and considerations such as estimated place in maturation, workload/training, specialization status
- ❑Timelines for goals on return to running
- ❑Don't forget the basics-tissue loading/phases of rehabilitation
- ❑ Optimize mobility, control, strength/load- goal to increase stability, NM control, strength and stiffness
- ❑Do complete a video running analysis and provide education early in the return to running program
- ❑Do work on step rate and vertical oscillation as 2 influenceable factors in reducing RRI
- ❑Do provide comprehensive HEP/ training volume education and talk about emotional wellness

References

- Krabak BJ, Roberts WO, Tenforde AS, Ackerman KE, Adami PE, Baggish AL, Barrack M, Cianca J, Davis I, D'Hemecourt P, Fredericson M, Goldman JT, Harrast MA, Heiderscheit BC, Hollander K, Kraus E, Luke A, Miller E, Moyer M, Rauh MJ, Toresdahl BG, Wasfy MM. Youth running consensus statement: minimising risk of injury and illness in youth runners. Br J Sports Med. 2021 Mar;55(6):305-318. doi: 10.1136/bjsports-2020-102518. Epub 2020 Oct 29. PMID: 33122252.
- Garcia MC, Taylor-Haas JA, Rauh MJ, Toland MD, Bazett-Jones DM. Sport Specialization in Middle- and High-School Long-Distance Runners. J Athl Train. 2021 Jan 22. doi: 10.4085/462-20. Epub ahead of print. PMID: 33481024.
- Orthopedic Management of the runner, cyclist, swimmer. Biomechanics of running 23.1.4. Orthopedic Section of APTA. 2013
- McSweeney SC, Grävare Silbernagel K, Gruber AH, Heiderscheit BC, Krabak BJ, Rauh MJ, Tenforde AS, Wearing SC, Zech A, Hollander K. Adolescent Running Biomechanics - Implications for Injury Prevention and Rehabilitation. Front Sports Act Living. 2021 Aug 26;3:689846. doi: 10.3389/fspor.2021.689846. PMID: 34514384; PMCID: PMC8432296
- Taddei UT, Matias AB, Duarte M, Sacco ICN. Foot Core Training to Prevent Running-Related Injuries: A Survival Analysis of a Single-Blind, Randomized Controlled Trial. Am J Sports Med. 2020 Dec;48(14):3610-3619. doi: 10.1177/0363546520969205. Epub 2020 Nov 6. PMID: 33156692.
- Waugh CM, Blazevich AJ, Fath F, Korff T. Age-related changes in mechanical properties of the Achilles tendon. J Anat. 2012;220(2):144-155. doi:10.1111/j.1469-7580.2011.01461.x
- Struzik A, Karamanidis K, Lorimer A, Keogh JWL, Gajewski J. Application of Leg, Vertical, and Joint Stiffness in Running Performance: A Literature Overview. *Appl Bionics Biomech*. 2021;2021:9914278. Published 2021 Oct 21. doi:10.1155/2021/9914278
- Taylor-Haas, Jeff. Running Injuries Examination, Differential Diagnosis, and Treatment Interventions; April 9-10, 2011. Chicago, IL.
- Souza RB. An Evidence-Based Videotaped Running Biomechanics Analysis. Phys Med Rehabil Clin N Am. 2016 Feb;27(1):217-36. doi: 10.1016/j.pmr.2015.08.006. Epub 2015 Oct 20. PMID: 26616185; PMCID: PMC4714754.
- Reinking MF, Dugan L, Ripple N, Schleper K, Scholz H, Spadino J, Stahl C, McPoil TG. RELIABILITY OF TWO-DIMENSIONAL VIDEO-BASED RUNNING GAIT ANALYSIS. Int J Sports Phys Ther. 2018 Jun;13(3):453-461. PMID: 30038831; PMCID: PMC6044590.
- Adams D, Pozzi F, Willy RW, Carrol A, Zeni J. ALTERING CADENCE OR VERTICAL OSCILLATION DURING RUNNING: EFFECTS ON RUNNING RELATED INJURY FACTORS. Int J Sports Phys Ther. 2018 Aug;13(4):633-642. PMID: 30140556; PMCID: PMC6088121.
- Hobara H, Sato T, Sakaguchi M, Sato T, Nakazawa K. Step frequency and lower extremity loading during running. Int J Sports Med. 2012 Apr;33(4):310-3. doi: 10.1055/s-0031-1291232. Epub 2012 Mar 1. PMID: 22383130.
- Heiderscheit BC, Chumanov ES, Michalski MP, Wille CM, Ryan MB. Effects of step rate manipulation on joint mechanics during running. Med Sci Sports Exerc. 2011 Feb;43(2):296-302. doi: 10.1249/MSS.0b013e3181ebedf4. PMID: 20581720; PMCID: PMC3022995.
- Allen DJ, Heisler H, Mooney J, Kring R. THE EFFECT OF STEP RATE MANIPULATION ON FOOT STRIKE PATTERN OF LONG DISTANCE RUNNERS. Int J Sports Phys Ther. 2016 Feb;11(1):54-63. PMID: 26900500; PMCID: PMC4739048.
- Marcello RT, Greer BK, Greer AE. Acute effects of plyometric and resistance training on running economy in trained runners. *Journal of Strength and Conditioning Research.* 2017; 31(9): 2432-2436.
- Blagrove RC, Howatson G, Hayes PR. Effects of strength training on the physiological determinants of middle- and long-distance running performance: a systematic review. *Sports Medicine.* 2018; 48: 1117-1149
- Alexander JLN, Barton CJ, Willy RW. Infographic. Running myth: strength training should be high repetition low load to improve running performance. *British J Sports Med*. 2020; 54(13): 813-814
- Damsted C, Glad S, Nielsen RO, Sørensen H, Malisoux L. IS THERE EVIDENCE FOR AN ASSOCIATION BETWEEN CHANGES IN TRAINING LOAD AND RUNNING-RELATED INJURIES? A SYSTEMATIC REVIEW. Int J Sports Phys Ther. 2018;13(6):931–942.
- Damsted C, Parner ET, Sørensen H, Malisoux L, Hulme A, Nielsen RØ. The Association Between Changes in Weekly Running Distance and Running-Related Injury: Preparing for a Half Marathon. J Orthop Sports Phys Ther. 2019 Apr;49(4):230-238. doi: 10.2519/jospt.2019.8541. Epub 2018 Dec 7. PMID: 30526231.
- Hulin BT, Gabbett TJ, Lawson DW, Caputi P, Sampson JA. The acute:chronic workload ratio predicts injury: high chronic workload may decrease injury risk in elite rugby league players. Br J Sports Med. 2016;50(4):231-236. doi:10.1136/bjsports-2015-094817

SMART SERIES

Children's Wisconsin

Q&A

https://miro.medium.com/max/603/1*1LzDyOaDaDrIDu9hksV35Q.jpeg