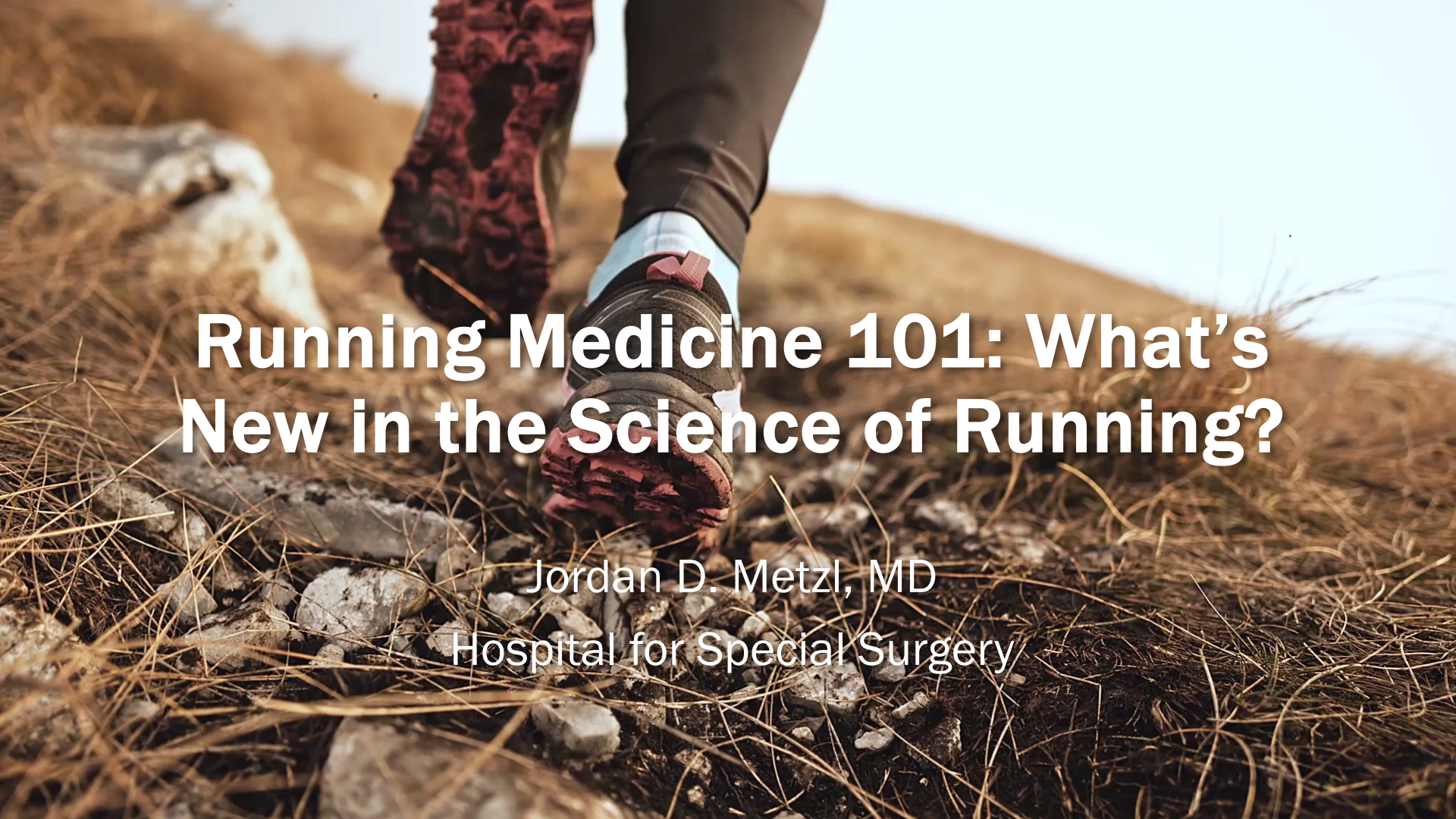


# Running Medicine 101: What's New in the Science of Running?

Jordan D. Metzl, MD

Hospital for Special Surgery

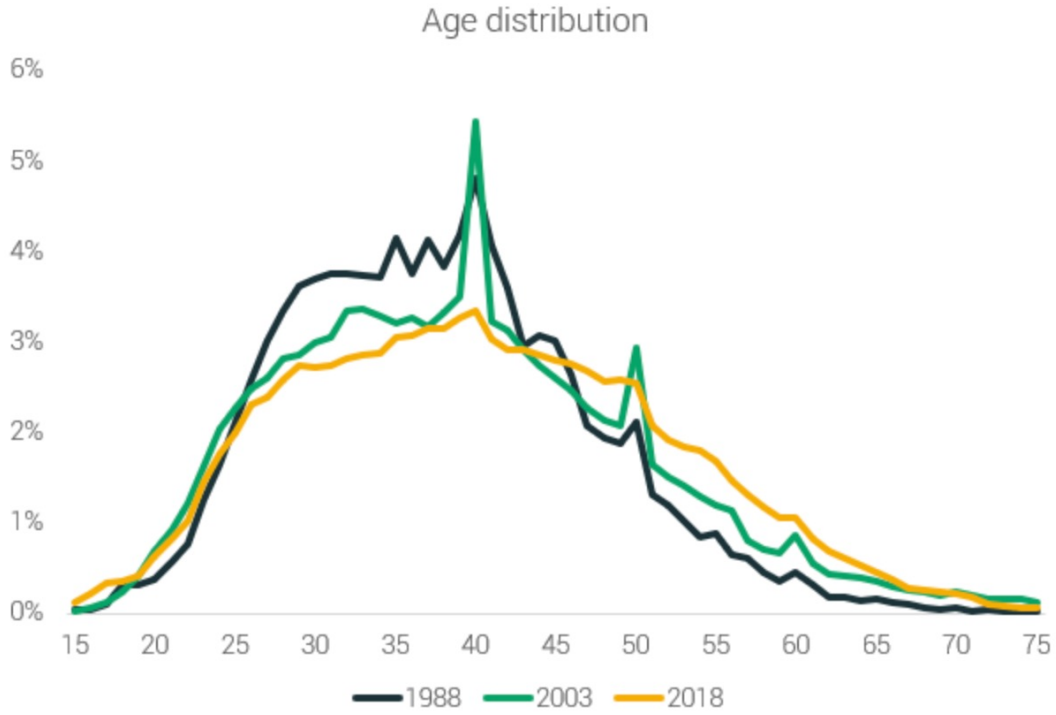
- I have no conflicts of interest to disclose

# “Dr. Metzl, My Hip Hurts”

Typical patient visit..

- I’m doing an accelerated marathon program
- I’m going to push through the pain
- I don’t care if it hurts
- I can do this

# Running Demographics: Where Are We?




The State of Running 2019. Report.



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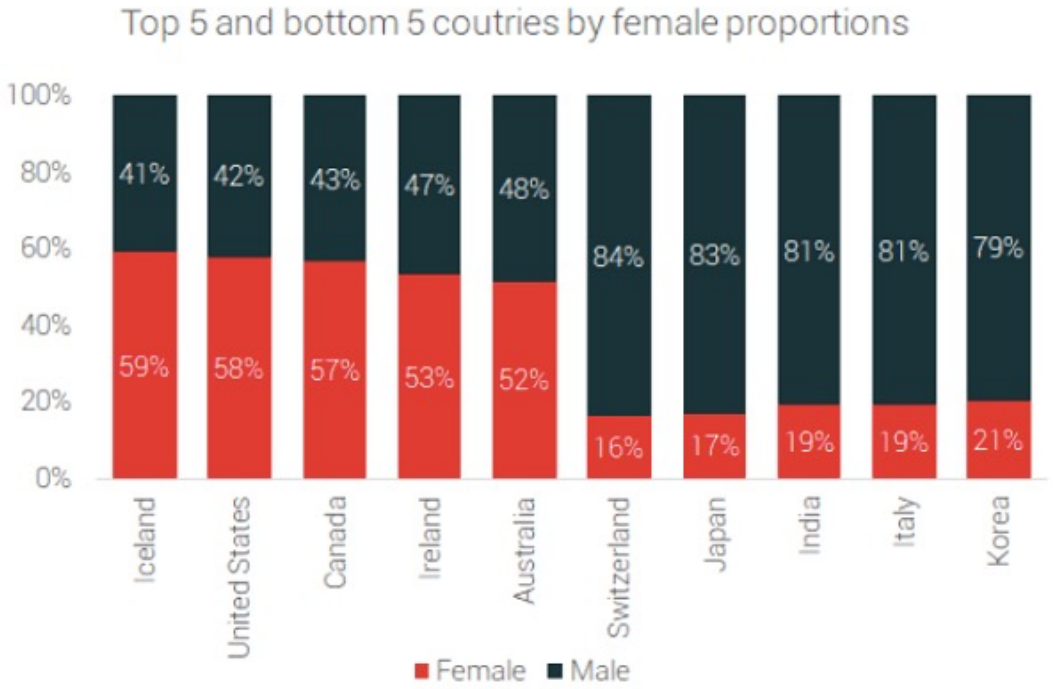
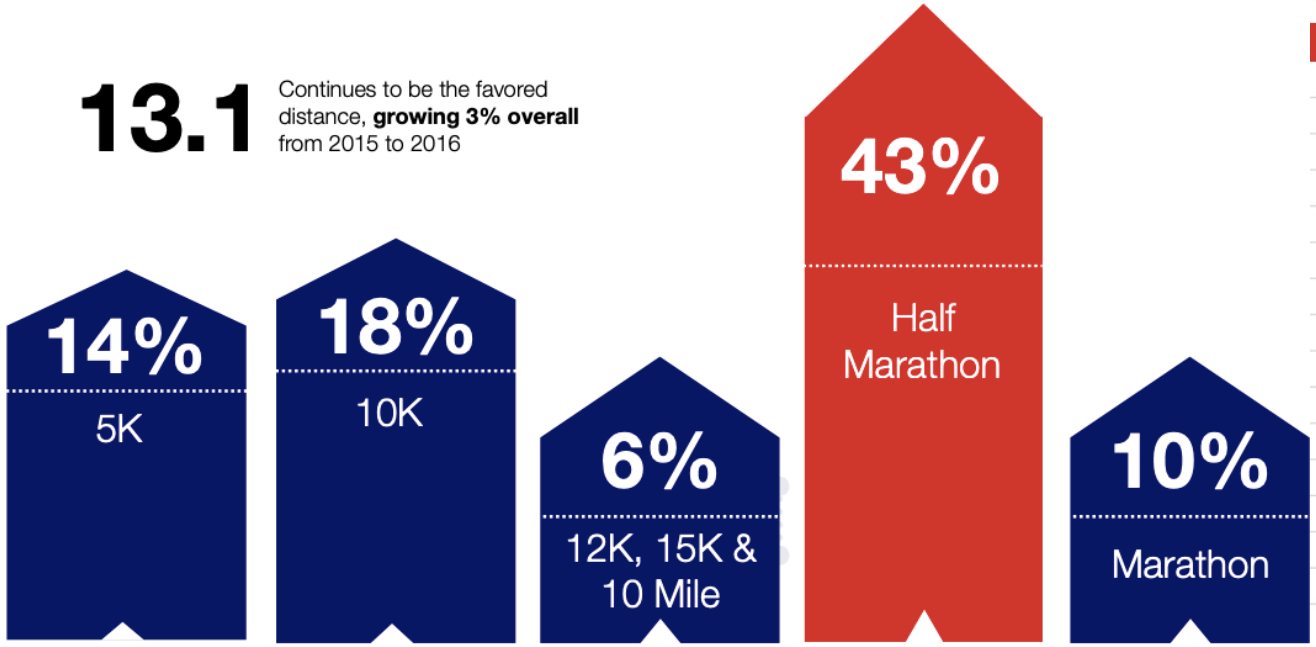
# Global Trends in Running



# Who Are Runners in the USA?

## Favorite Race Distance



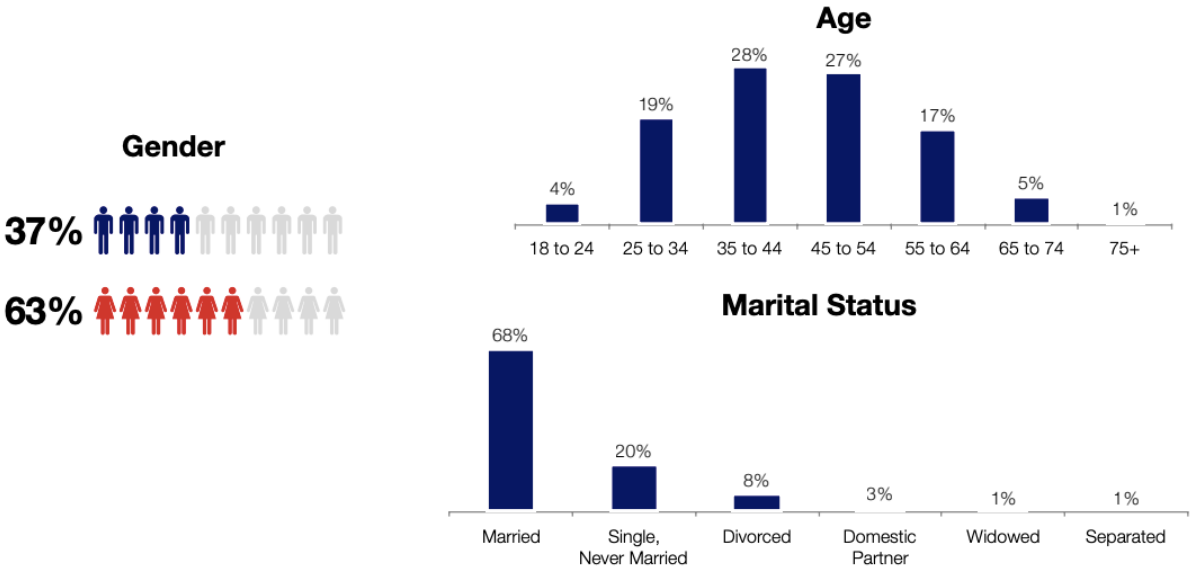

| % |
|---|
| 77 |
| 73 |
| 62 |
| 62 |
| 55 |
| 54 |
| 53 |
| 53 |
| 53 |
| 46 |
| 41 |
| 39 |
| 39 |
| 31 |
| 22 |
| 13 |



rvey and Running USA

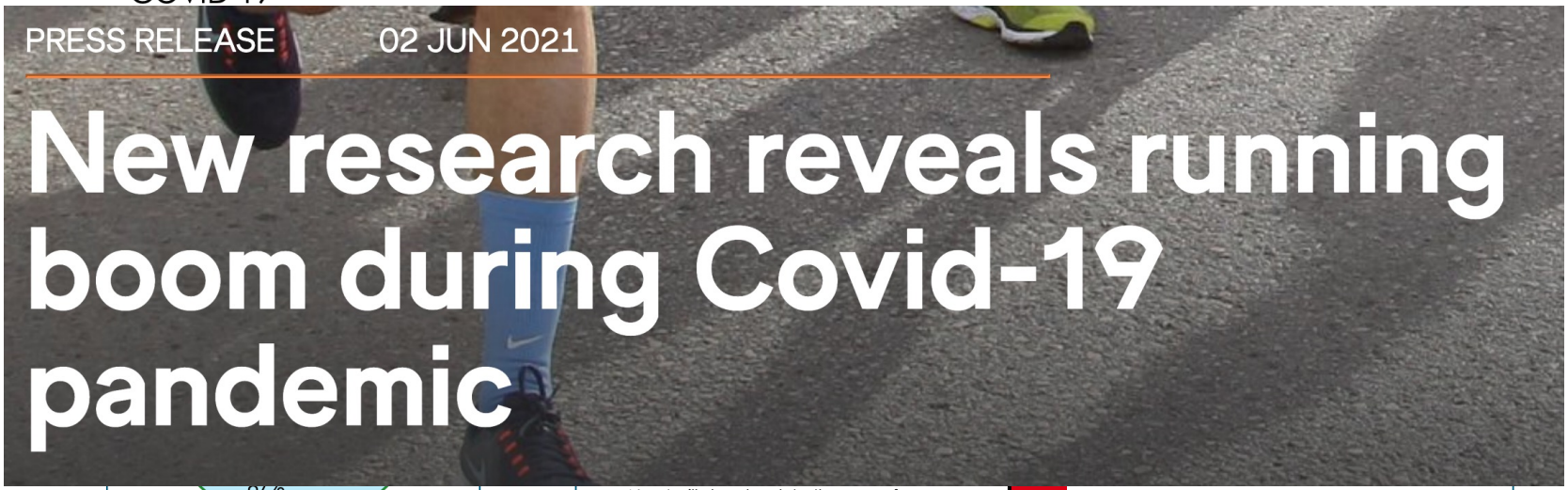
# Who Are Runners in the USA?

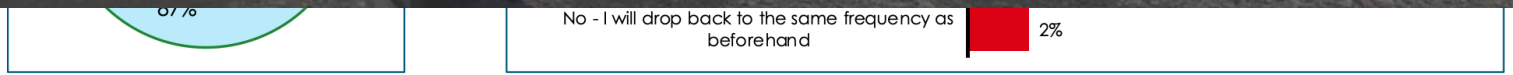
## Demographics - Overview



# Running Participation and the COVID-19 Pandemic

- Over a fifth (22%) of all runners claim to run more often than they did previously as a result of COVID-19




Changes in Exercise and Running Behavior: Nielson Sports, 2021

# What Do We Know About Runners?

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# Running and Longevity

- Copenhagen Heart Study. Schnohr P et al, *AJE*, 177(7) 2013

- 17,589 M/W, 20-98 y/o

- 1878 runners, 20 year study

- Age adjusted longevity was 6.2 years for men, 5.6 years for women

# Running Will Destroy Your Knees

- Metanalysis - 17 studies, 7194 runners and 6947 nonrunners. Prospective.
- Follow-up time - 55.8 months in the runner group and 99.7 months in the nonrunner group
- Mean age was 56.2 years in the runner group and 61.6 years in the nonrunner group
- Higher prevalence of knee pain in the nonrunner group ($P < .0001$)
- No significant differences in the prevalence of radiographic knee OA (based on TF/PF joint-space narrowing or Kellgren-Lawrence grade) or cartilage thickness on MRI between runners and nonrunners ($P > .05$)

doi: 10.1177/23259671231152900, 2023

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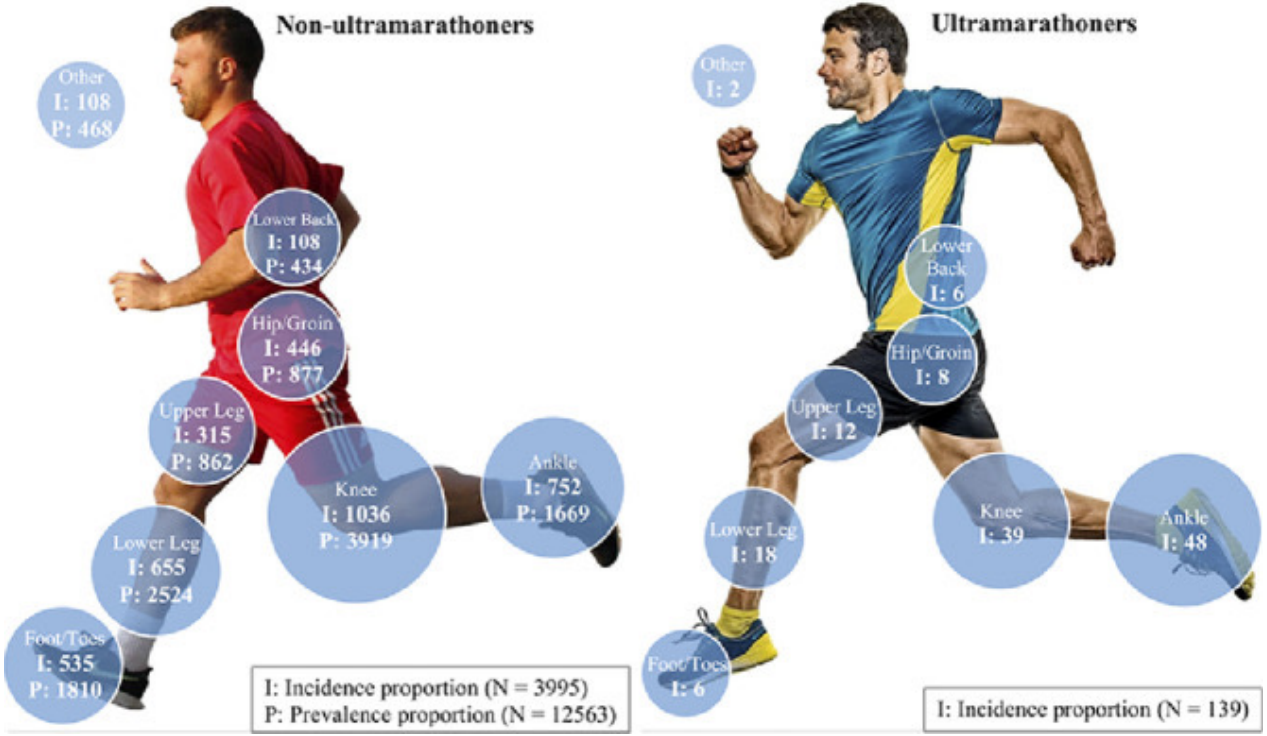
# What Issues Affect Runners?

- Health
  - Orthopedic
  - Medical
- Performance
- Nutrition
- Consistency

# What Do We Know About Running Injury?

# Orthopedic Issues Affecting Runners




Nicolas N et al. Systematic Review of running-related musculoskeletal injuries in runners, JI Sport and Health Science/ 2021,

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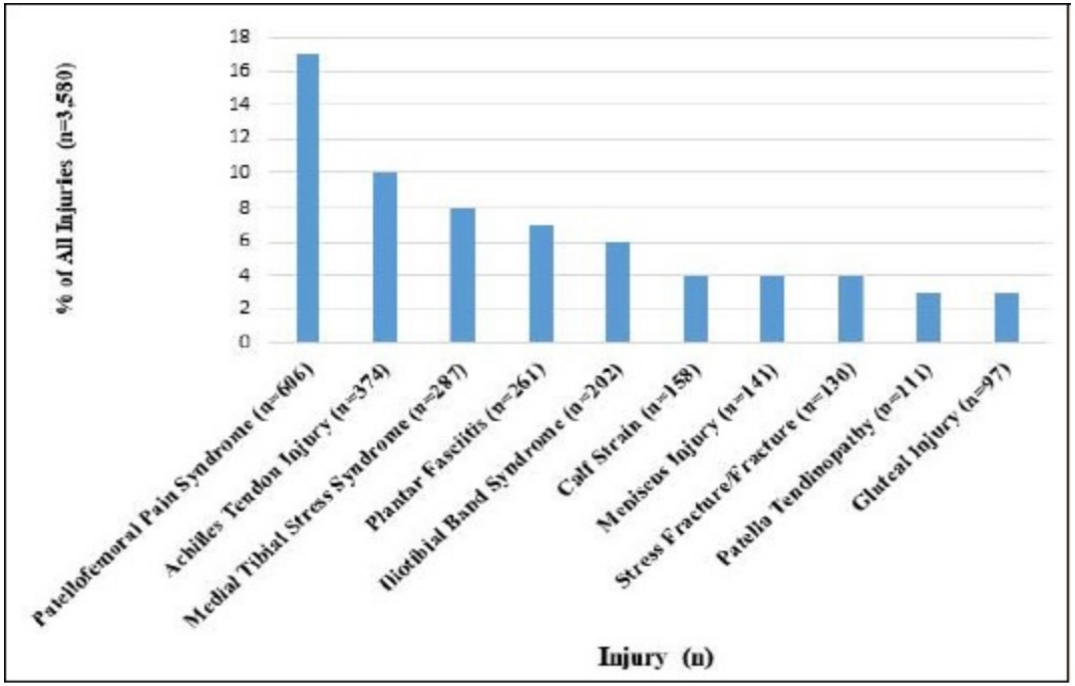
# Common Injury Patterns in Runners




Francis P et al. The Proportion of Lower Limb Running Injuries by Gender, Anatomical Location and Specific Pathology: A Systematic Review. *Jl Sports Sci Med*, 2019

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## Injury Data in Runners

- Running injury is common, increases with longer distances, and is dependent upon multiple factors. Kluitenberg 2015
- In a two-year prospective study, **66%** of runners suffered an injury that required more than 10 days of time away from running. Messier 2018
- It is estimated that **30%** of runners training for a marathon will suffer an injury and **15%** will never make it to the starting line. Mohseni 2021

# Walking vs. Running Ground Reactive Forces

- Walking 70-80%

- Running 275-300%

# Runner vs. Ground

- Foot and Ankle
- Knee and Hip
- Eccentric muscle
- Cartilage compression

# Injury Prevention and Running

- Stretching does not seem to reduce running injury risk. Alexander. 2019
- BMI and running distance were correlated with increased injury-risk in 1-year prospective study. Winter 2020
- Flexibility, arch height, quadriceps angle, rearfoot motion, lower extremity strength, weekly mileage, footwear, and previous injury are not significant etiologic factors in 2-year prospective study. Messier 2021

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# Risk Factors for Running Injury

Injuries in Runners; A Systematic Review on Risk Factors and Sex Differences. Van Der Wong el at, *PLOS*, 2015

400 studies on running injury, 11 considered high quality

All levels of runners studied, Novice to Elite

Ages, severity of injury, were varied

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# Risk Factors for Running Injury

## Personal Factors

**Gender** – no evidence on overall injury risk

**Age** – limited evidence that posterior chain (Achilles and Hamstring increase with age > 40)

**BMI** – higher BMI associated with injury men>women

**Navicular Drop** - >10mm associated with medial overload

**Alignment** – cavus foot, valgus knee associated with knee injury

Van Der Wong el at, *PLOS*, 2015

HSS

# Risk Factors for Running Injury

## Training Factors

**Running Experience** – limited evidence that running < 1 year and running > 5 years correlated to injury

**Training** – moderate evidence that running > 6 x/week was associated with injury

**Surface** – limited evidence that running surface affects back, hip, or knee injury

**Racing** – moderate evidence that >6 races/year increases injury

Van Der Wong el at, *PLOS*, 2015

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# Risk Factors for Running Injury

## Heath/Lifestyle Factors

**History of Previous Injury** –strong evidence correlating to injury

**Running Shoes** – limited evidence that changing shoes frequently reduces injury risk

**Orthotics** – limited evidence that orthotic use reduces injury risk

Van Der Wong el at, *PLOS*, 2015

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# Running Medicine HSS

Brittany Ammerman, MD

Polly deMille, RA,MA,RCEP

Sam Dixit, MD

Mark Fontana, PhD

Pamela Geisel, MS, CSCS

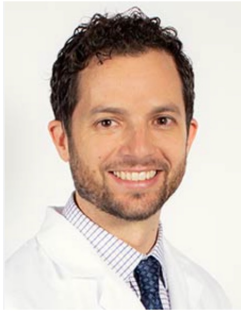
James Kinderknecht, MD

Kathryn McElheny, MD

Jordan Metzl, MD

Brianna Quijano, ATC

James Robinson, MD



Brett Toresdahl, MD

NEW YORK ROAD RUNNERS

STRAVA

HSS

# What Do We Know About Running Injury?

- Runners have a high rate of injury
- Runners want to run
- Our goal is to keep them running

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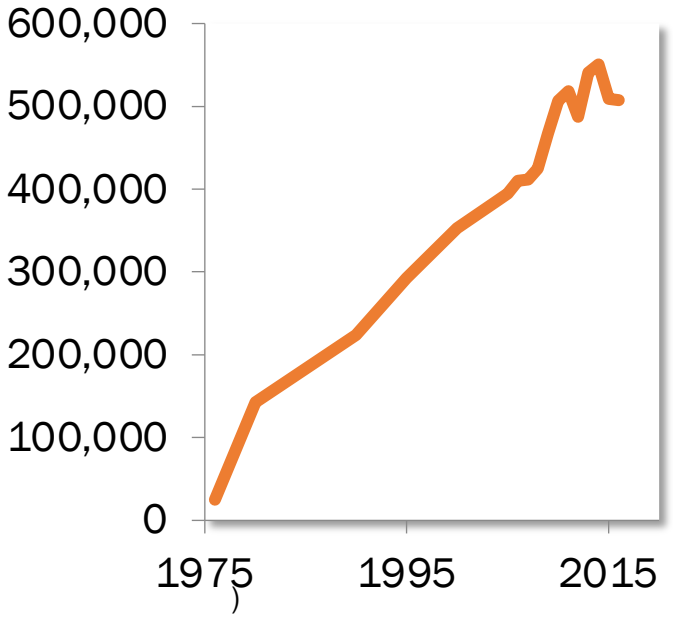
# History of NYC Marathon + HSS

- NYC Marathon
  - NYRR founded in 1958
  - First race 1970 in Central Park with 55 finishers
  - Largest marathon in world with >53,000 finishers

- HSS Partnership
  - Began in 2009
  - Educational programming
  - HSS Recovery Zone
  - Research

# Background

- Marathon finishers in the United States
- Existing research on marathon running-related injuries
  - Primarily based on race day medical events
  - Few prospective studies of injuries in runners training for a marathon




Source: Running USA (2016)

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# Background

- TCS New York City Marathon
  - Largest marathon in the world
  - 52,813 finishers in 2018


NEW YORK ROAD RUNNERS

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# Purpose

- To determine risk factors associated with injury in first-time marathon runners based on:
    - Baseline characteristics
    - Training patterns

Toresdahl B et all. Risk Factors Associated with Injuries in First-Time Marathon Runners: A 12-week Prospective Study, 2018

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# Methods

- Recruited runners by email sent to all registrants
    - First time marathon runners, age ≥18 years, no current injury
    - Monitored using online surveys
    - Every 2 weeks beginning 12 weeks before the race
        - Number of training runs
        - Weekly mileage
        - Injuries affecting training
    - 1 week after the race
        - Injuries affecting race completion/performance

Toresdahl B et all. Risk Factors Associated with Injuries in First-Time Marathon Runners: A 12-week Prospective Study

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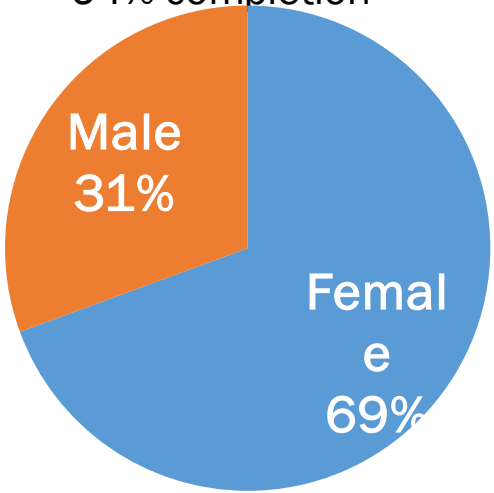
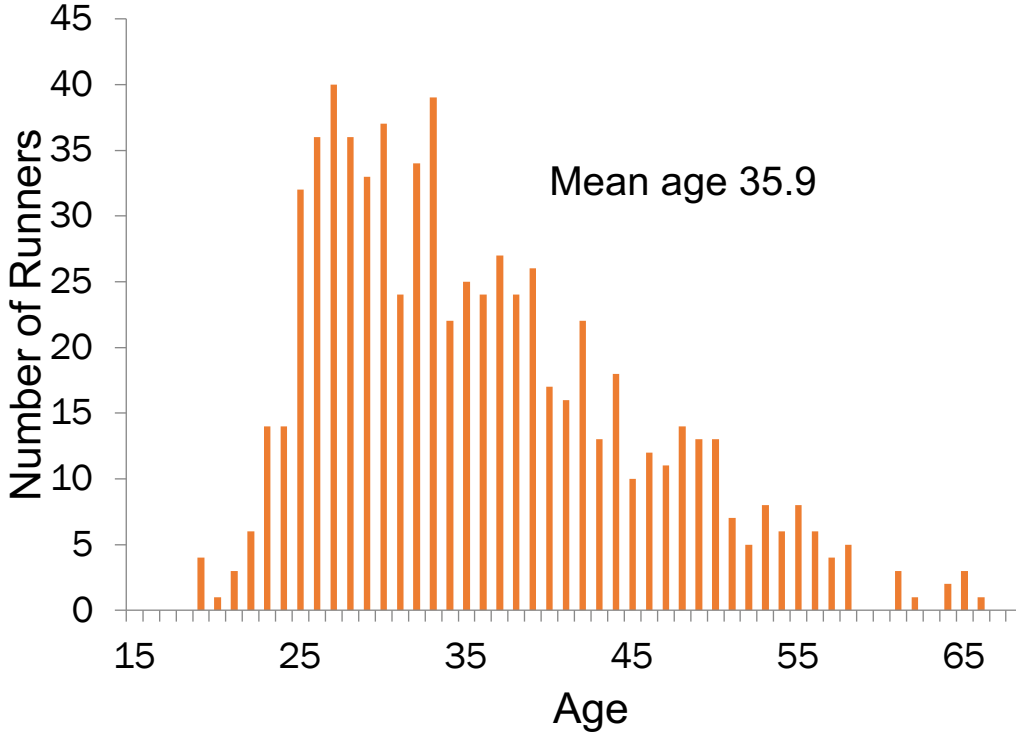
# Results

- Participants
  - 720 runners enrolled,
  - 94% completion




Toresdahl B et all. Risk Factors Associated with Injuries in First-Time Marathon Runners: A 12-week Prospective Study

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# Results

- Marathon completion
  - 583 started
    - 579 (99%) completed
  - Average finishing time
    - 4 hours 59 minutes ± 57 minutes

Toresdahl B et all. Risk Factors Associated with Injuries in First-Time Marathon Runners: A 12-week Prospective Study

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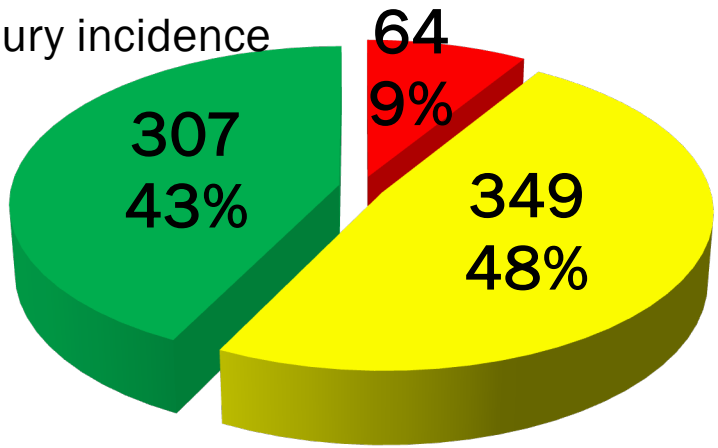
# Results

- Injury incidence




- Major Injury = unable to continue training/racing

Toresdahl B et all. Risk Factors Associated with Injuries in First-Time Marathon Runners: A 12-week Prospective Study

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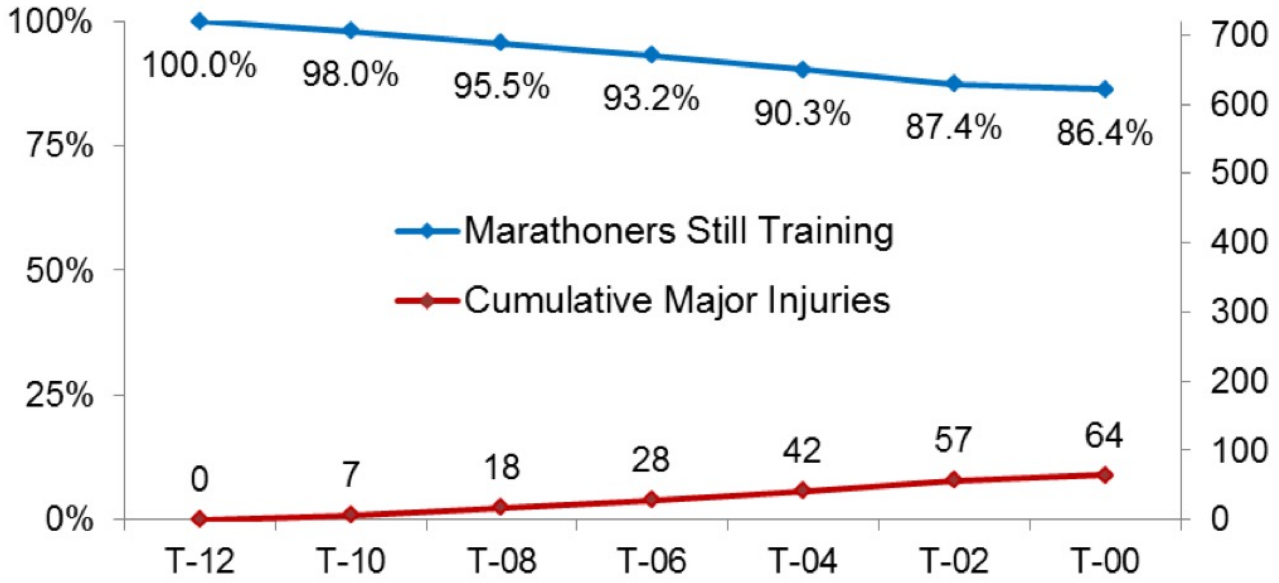
# Timeline of Percent Training and Major Injuries




Toresdahl B et all. Risk Factors Associated with Injuries in First-Time Marathon Runners: A 12-week Prospective Study

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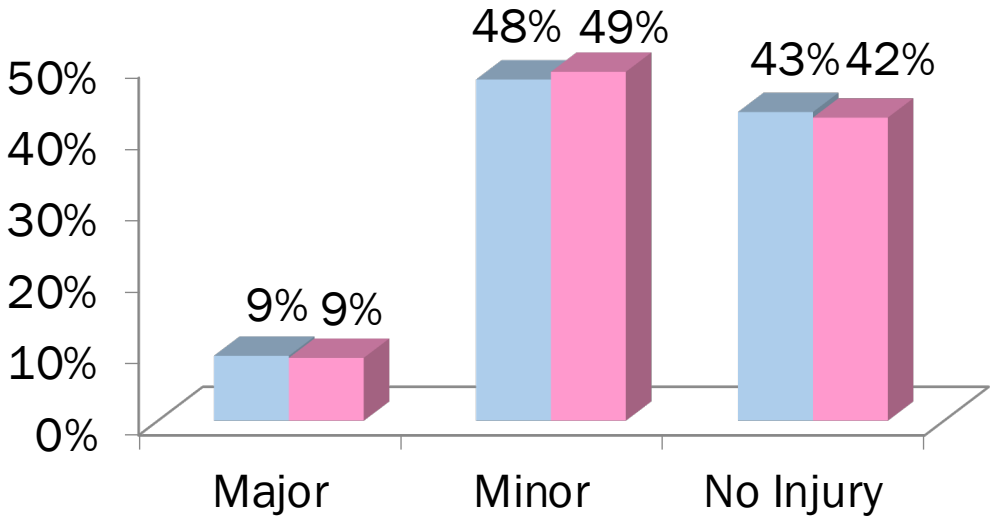
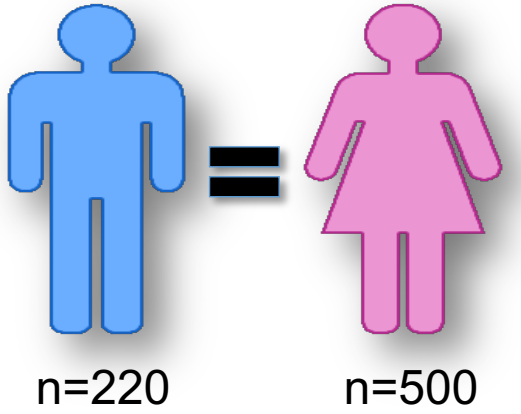
# Results

- Injury incidence based on sex




Toresdahl B et all. Risk Factors Associated with Injuries in First-Time Marathon Runners: A 12-week Prospective Study

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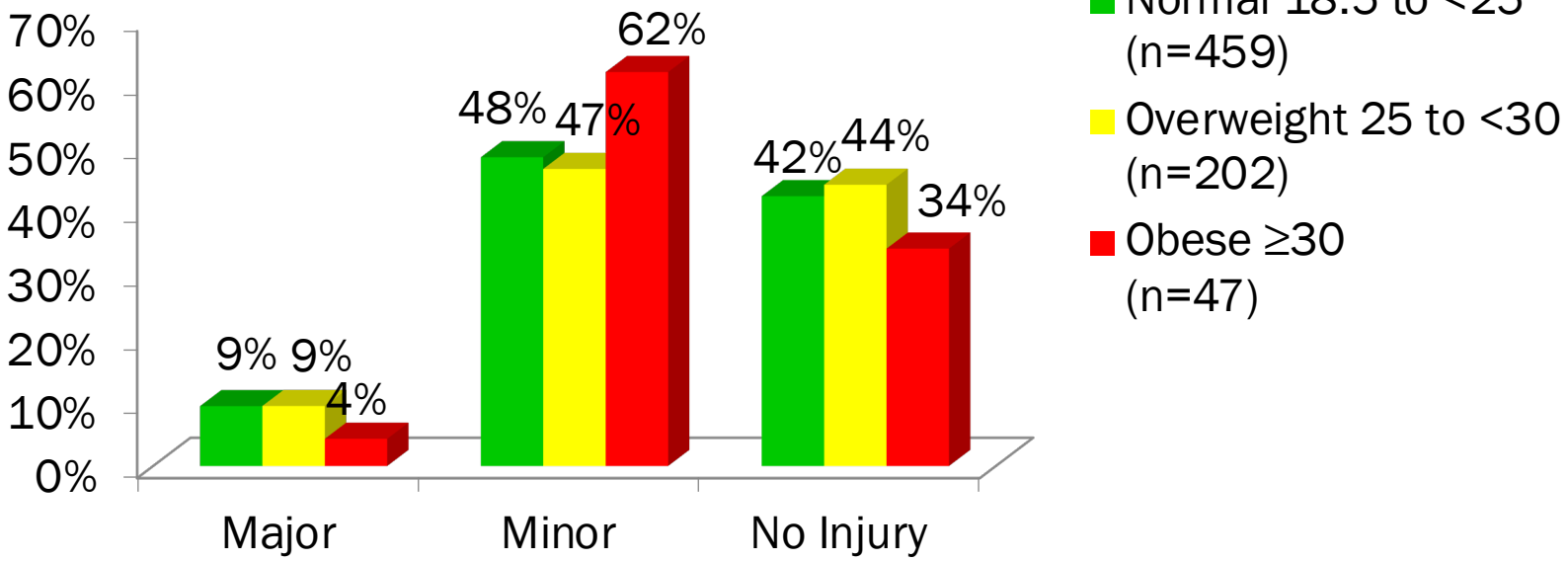
# Results

- Injury incidence based on BMI




Toresdahl B et all. Risk Factors Associated with Injuries in First-Time Marathon Runners: A 12-week Prospective Study

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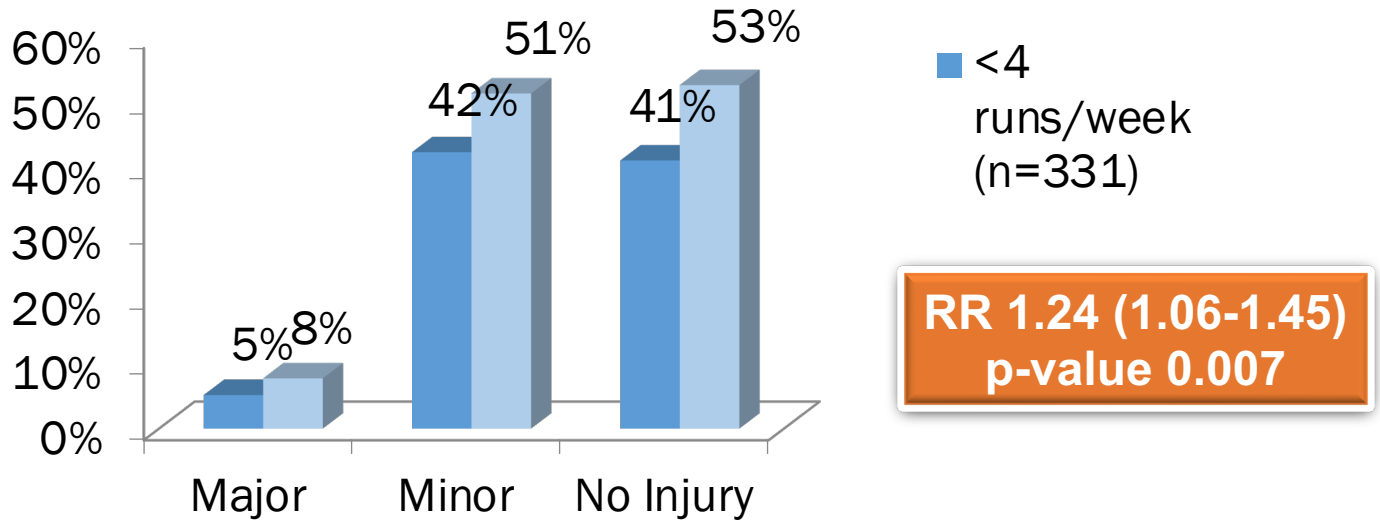
# Results

- Injury incidence based on average weekly training runs (before becoming injured)




Toresdahl B et all. Risk Factors Associated with Injuries in First-Time Marathon Runners: A 12-week Prospective Study

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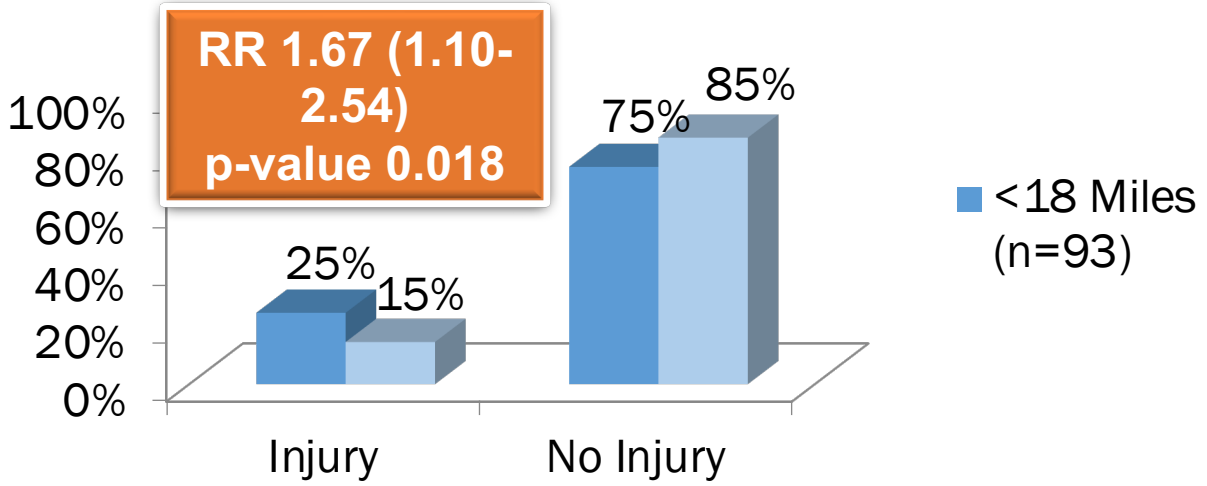
# Results

- Injury incidence during race based on longest training run




Toresdahl B et all. Risk Factors Associated with Injuries in First-Time Marathon Runners: A 12-week Prospective Study

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# Training and Race Outcomes

| | Strength | Control |
|---|---|---|
| Marathon Completion Rate | 86.8% (276/318) | 86.8% (310/357) |
| Average Finishing Time (min) | 5h 2m | 4h 59m |
| Injury Incidence (Major) | 10.1% (32/318) | 9.0% (32/357) |
| # Acute Injuries | 7 | 6 |
| # Overuse Injurie | 25 | 26 |
| # Bone Stress | 8 | 12 |
| # Muscle | 5 | 4 |
| # Joint | 6 | 2 |
| # Tendon/Fascia | 6 | 5 |
| # Other | 0 | 3 |
| Injury Incidence (Minor) | 47.2% (150/318) | 51.3% (183/357) |
| Average Pain Score During Race | 3.1/10 | 3.4/10 |
| Use of Medical Tent | 2.3% (6/277) | 3.9% (12/310) |

McElheny K. A Randomized Study of a Strength Training Program to Prevent Injuries in Runners of the New York City Marathon. *Sports Health* 2019

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# 2019 Marathon Study

- What is the correlation between training volume and injury risk?
- Can we reduce injury rates through better plans?

# 2019 Marathon Study

Purpose

Evaluate the association between training patterns and injury/illness in runners training for the marathon

Methods

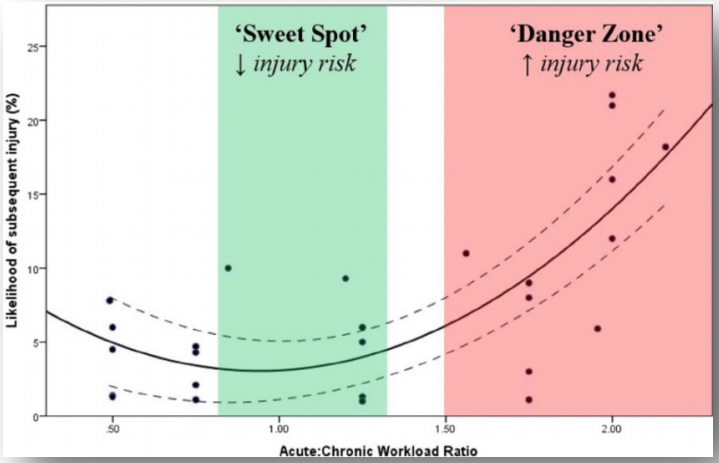
Recruited runners of all experience levels

Age ≥18 years, no current injury

Pre-race surveys every 4 weeks starting 16 weeks before

Post-race survey

Received training data from Strava at end of study



# 2019 Marathon Study

Results:

1090 participated

49% female

Mean age 42

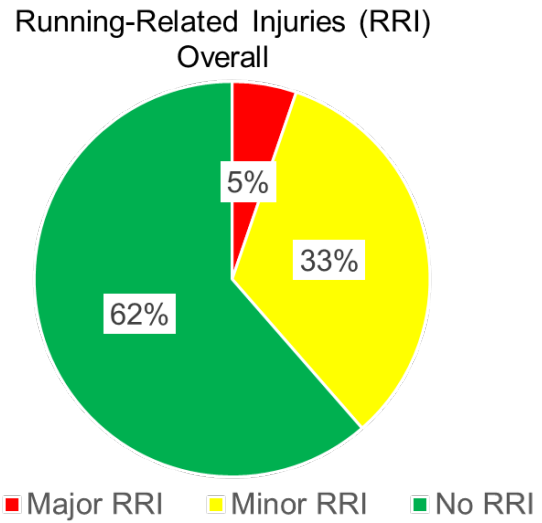
**Marathon completion**

907 started the race, 99% completed

Average finishing time. 4 hours 27 minutes

Strava data

**57,546 training runs logged**



# 2019 Marathon Study

**Table 2** Training patterns of runners without injury or illness as collected by Strava

| Training quarter | TQ1 (n=594) | TQ2 (n=540) | TQ3 (n=495) | TQ4 (n=490) |
|---|---|---|---|---|
| Days per week running, median (IQR) | 3.8 (3–4.8) | 4 (3–5) | 4 (3–5) | 3.7 (3–4.7) |
| Distance per week (miles), mean (SD) | 27.6 (13.9) | 32.0 (14.7) | 33.9 (15.3) | 29.7 (14.2) |
| Longest run (miles), mean (SD) | 14.2 (4.7) | 17.3 (6.2) | 22.2 (7.0) | 18.5 (5.5) |
| No of weeks when exceeded '10% rule', median (IQR) | 2 (1–2) | 1 (1–2) | 2 (1–2) | 1 (1–2) |
| No of days when ACWR ≥1.5, median (IQR) | 0 (0–1) | 0 (0–2) | 0 (0–2) | 0 (0–0) |
| No of days when ACWR ≥1.3, median (IQR) | 1 (0–5) | 3 (1–7) | 2 (0–7) | 0 (0–0) |

ACWR, acute:chronic workload ratio; TQ, training quarters.

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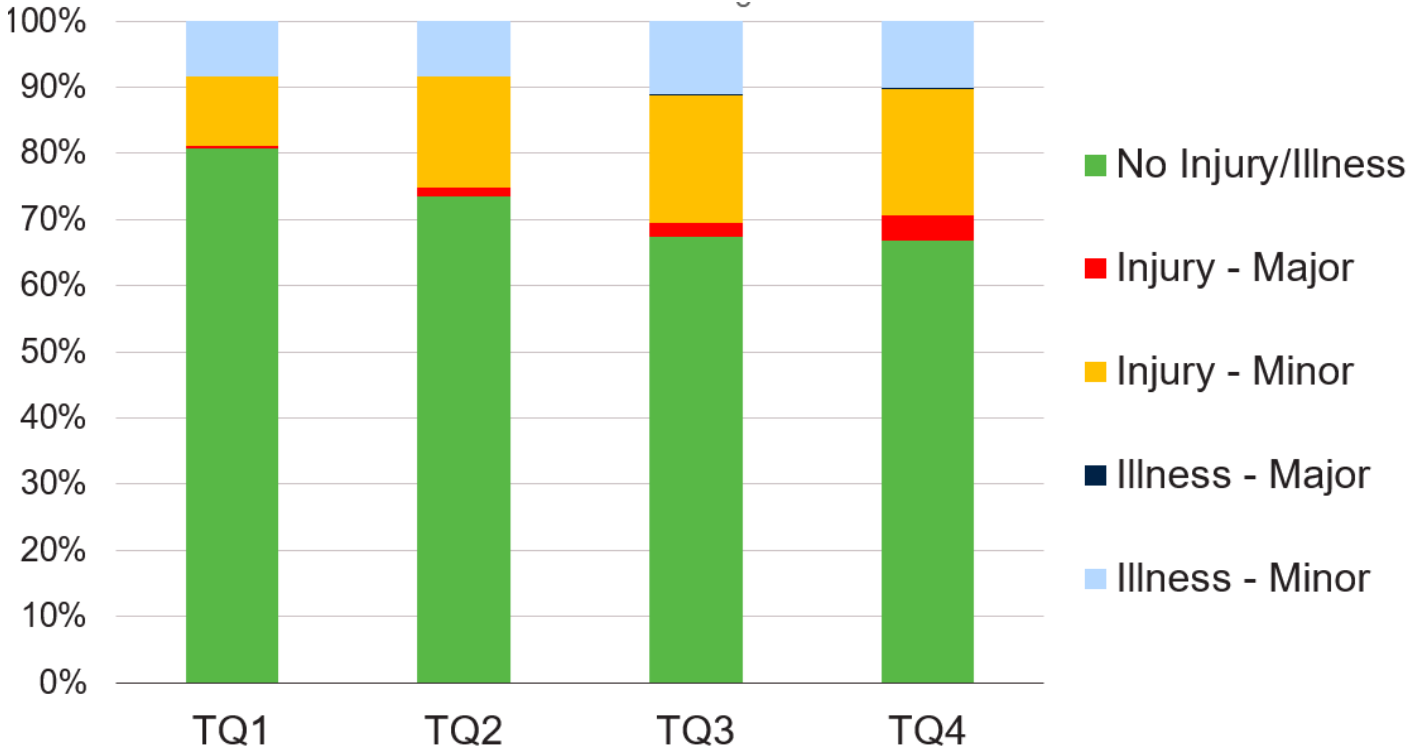
# 2019 Marathon Study




BJSM. 2023 Feb;57(3):146-152. doi: 10.1136

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# 2019 Marathon Study

**Table 7** Association of injuries during TQ4–TQ1 with demographics, running experience and training patterns

| | Injury† (n=294) | No injury† (n=441) | Univariable OR (95% CI) | Multivariable OR (95% CI) |
|---|---|---|---|---|
| Age | 41.1 (10.7) | 41.0 (10.7) | 1.00 (0.99 to 1.02) | 1.01 (0.99 to 1.02) |
| Sex | | | | |
| Female | 131 (44.6%) | 207 (46.9%) | Reference | Reference |
| Male | 163 (55.4%) | 234 (53.1%) | 1.10 (0.82 to 1.48) | 1.11 (0.66 to 1.86) |
| Body mass index | 23.7 (3.5) | 23.3 (2.9) | 1.04 (0.99 to 1.09) | 1.02 (0.98 to 1.07) |
| Marathon finishing time goal (minutes) | 240.8 (47.4) | 237.2 (42.8) | 1.00 (1.00 to 1.01) | 1.00 (1.00 to 1.00) |
| Running distance/week in the month before the study (miles) | 30.7 (41.9) | 30.8 (26.9) | 1.00 (1.00 to 1.00) | 1.00 (1.00 to 1.01) |
| Running days/week running in the month before the study | 4 (3, 5) | 4 (3, 5) | 0.97 (0.88 to 1.08) | 1.04 (0.94 to 1.15) |
| No of half marathons completed | 10 (4, 15) | 10 (5, 19) | 0.98 (0.96 to 1.00) | 0.99 (0.96 to 1.01) |
| No of marathons completed | 2.5 (1, 7) | 3 (1, 8) | 0.97 (0.93 to 1.01) | 0.99 (0.94 to 1.04) |
| No of weeks per TQ when exceeded 10% rule | 1 (0, 2) | 1 (1, 2) | 0.88 (0.76 to 1.02) | 0.88 (0.76 to 1.02) |
| No of days per TQ when ACWR ≥1.5 | 0 (0, 2) | 0 (0, 1) | 1.06 (1.03 to 1.10)** | 1.06 (1.02 to 1.10)** |

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# Is There a BEST Way to Run?

- There are many ways to run
- There is no definitive “best” way to run
- There are some general trends that are helpful

# Run Mechanics and Injury

- Runners 18-40 yrs, >20 mi/week, injury free at time of enrollment and for 6 months prior
- ONLY heel strikers were enrolled (249)
- Gait mechanics included vertical landing force measured
- Runners studied for 2 year period, injury history recorded

Davis et al, BJSM 2015

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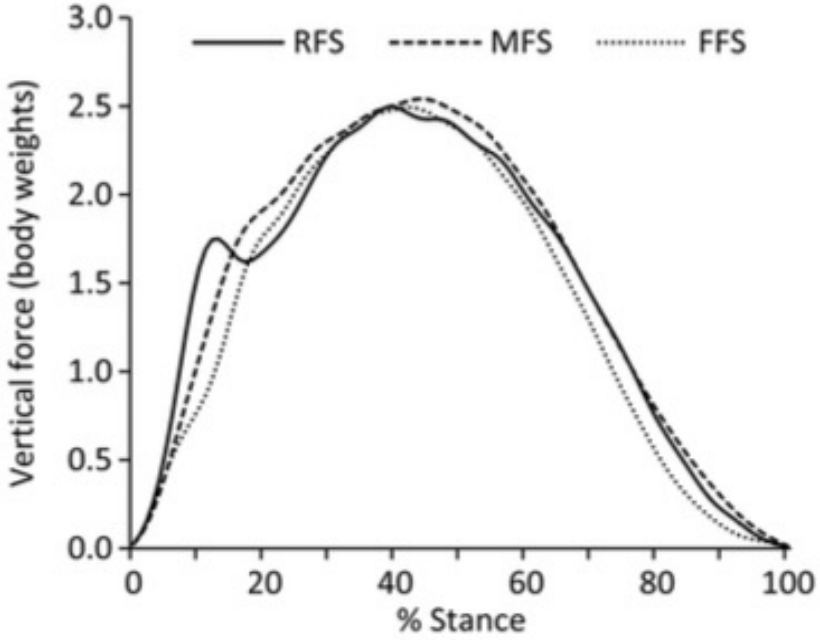
# Run Mechanics and Injury




Davis et al, BJSM 2015

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# Run Mechanics and Injury

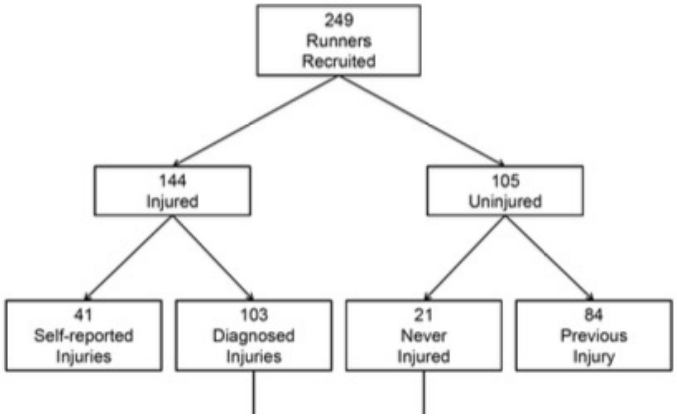




**Table 1** Demographics of the analysed groups

| | ALL injuries | | | | Medically DX injuries | | | |
|---|---|---|---|---|---|---|---|---|
| Variable | INJ (n=144) | UNINJ (n=105) | p Value | ES | DX_INJ (n=103) | NEV_INJ (n=21) | p Value | ES |
| Age (years) | 26.4±9.2 | 25.4±9.2 | 0.540 | 0.04 | 25.7±9.2 | 25.0±10.0 | 0.801 | 0.02 |
| Mileage/month | 117±54 | 107±54 | 0.964 | 0.01 | 120±54 | 94±34 | 0.041 | 0.18 |

DX_INJ, diagnosed injured group; INJ, injured; NEV_INJ, never-injured; UNINJ, uninjured.

# Run Mechanics and Injury: Results

- Impact-related variables were higher in those with medically diagnosed injuries compared with those who had never been injured
- ***Greater impact loading was associated with bony and soft-tissue injuries***

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# Stride? Injury Risk and Cadence?

- 28 runners,  9 men/19 women, training for half marathon
- 42.9% of participants had cadence below 163 and had injury rates of 66.7%.
- 32.1% of participants had cadence above 168 and their injury rates were 22.2%

Stride Frequency And Injury Rates Training For A Half-marathon.  Morgan J et al

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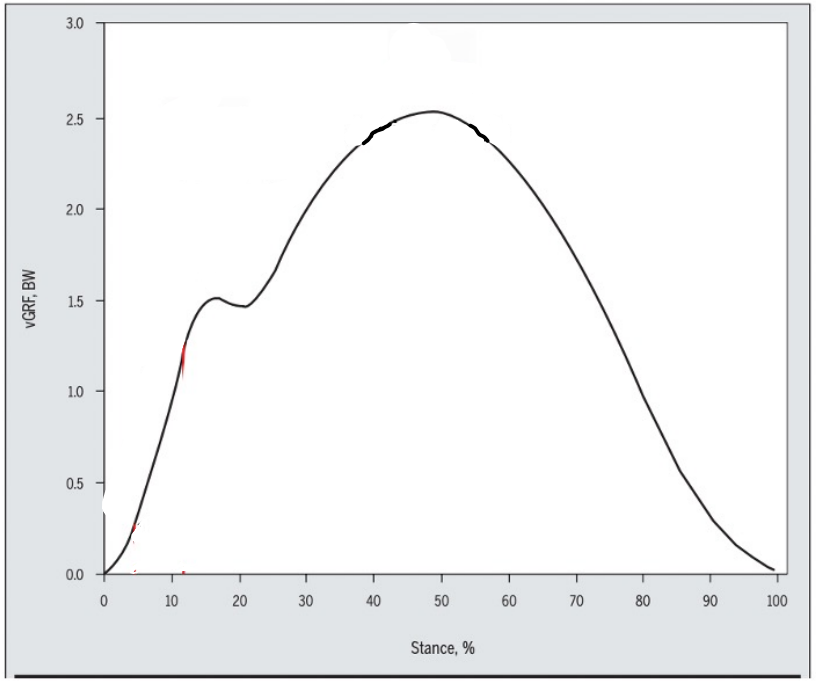
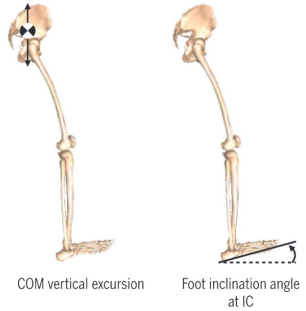
# Ground Reaction Forces




**Sagittal Kinematics Estimate GRF**

1. center of mass vertical excursion
2. foot inclination angle at initial contact
3. step rate

Goss, 2013
Wille, 2014

HSS

# Initial Contact: Foot Inclination

- Goal: <10°


Appropriate

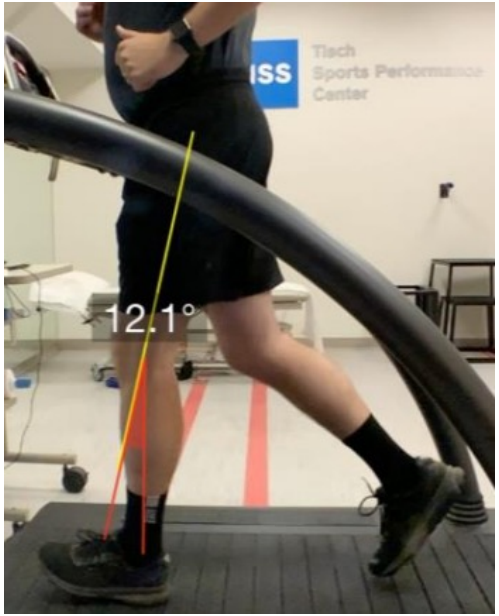

Excessive

HSS

# Initial Contact: Knee Flexion

- Goal: 15-20°

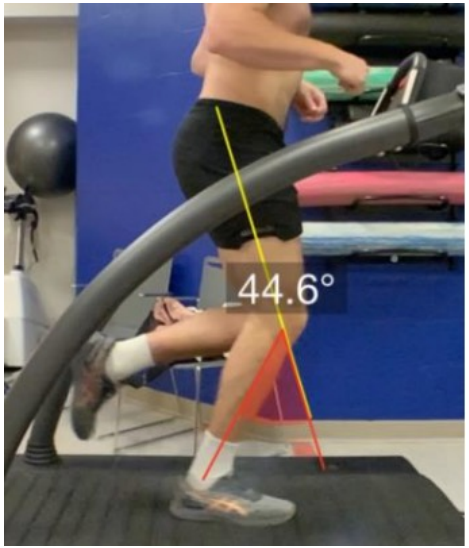

Appropriate



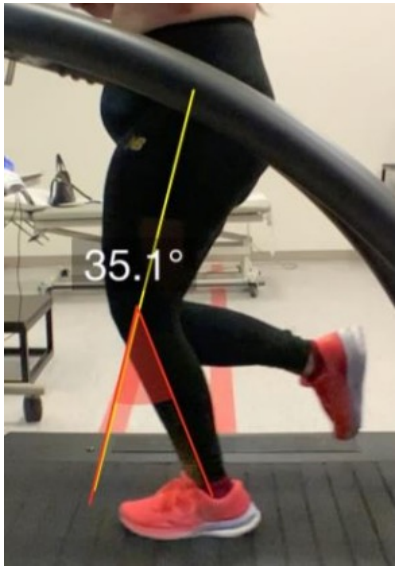

Stiff

# Mid Stance: Knee Flexion

- Goal: 45°




Appropriate




Stiff

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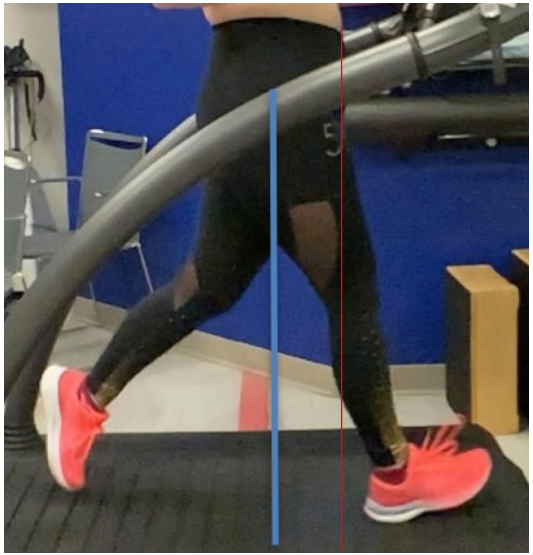
# Initial Contact: Stride Length

- Goal: heel strike near center of mass

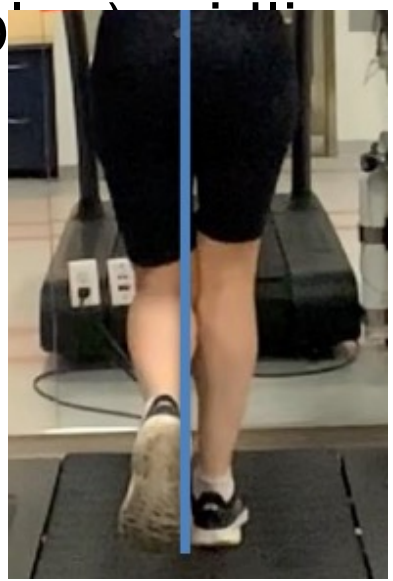
Appropriate



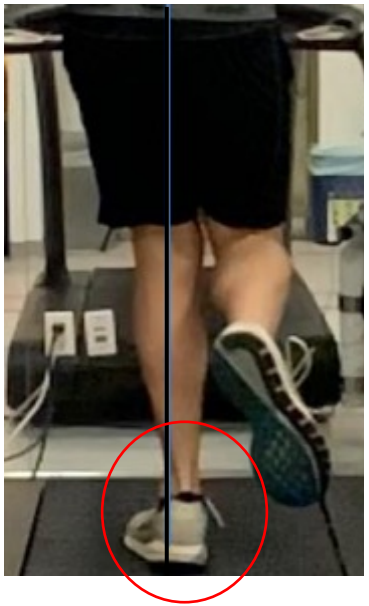
High

# Mid Stance: Cross Over

- Goal: foot is close but not crossing (b



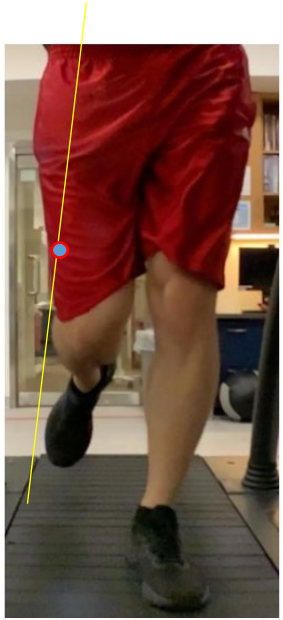
Appropriate



Cross Over

# Mid Stance: Knee Alignment

- Goal: Knee in line with hip and ankle

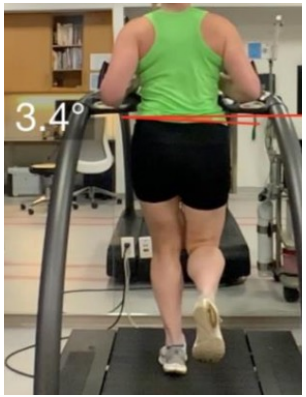


Appropriate

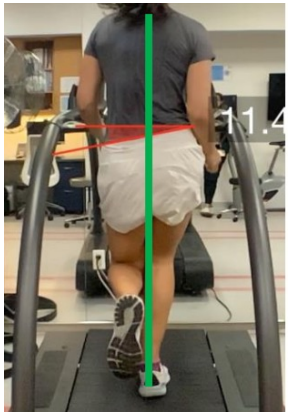
Dynamic genu valgus

# Mid Stance: Pelvic Drop

- Goal:
- <5-7° in females
- <3-5° in males



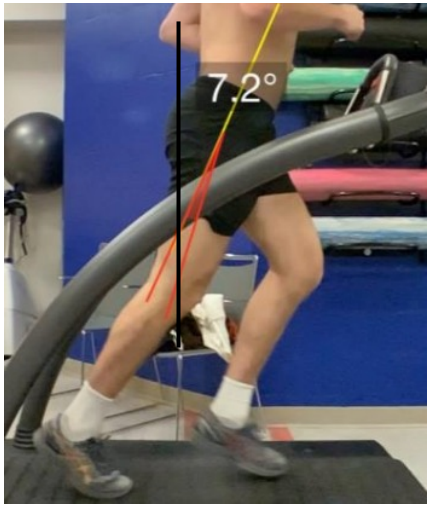

Appropriate



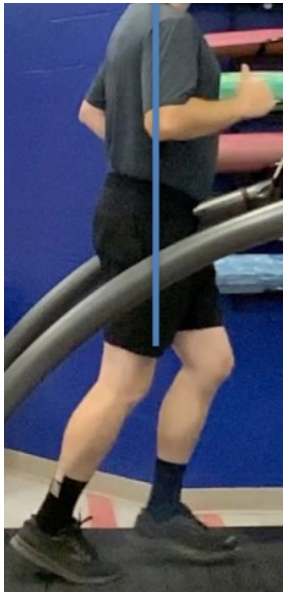
High

# Toe Off: Forward Trunk Lean

- Goal: Trunk is slightly forward of the blue vertical line




Appropriate



Upright

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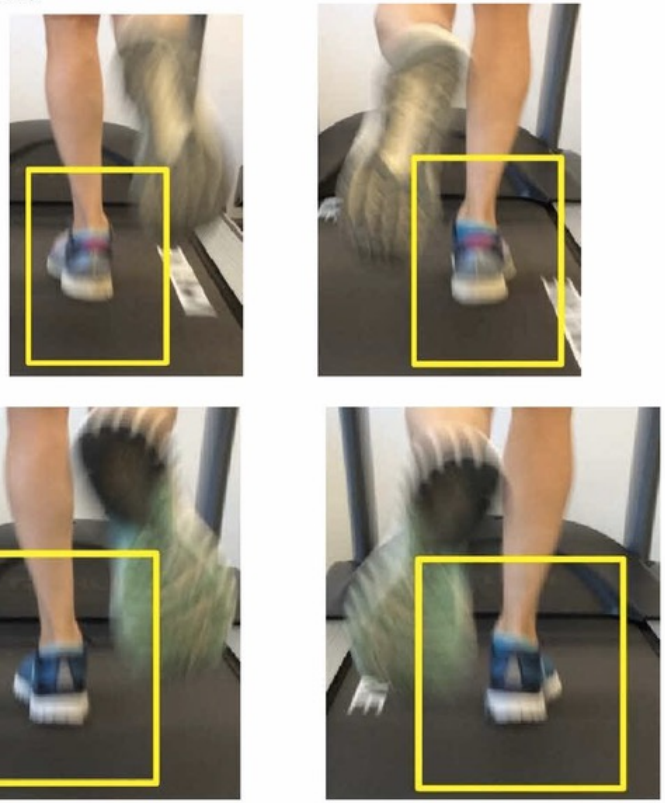
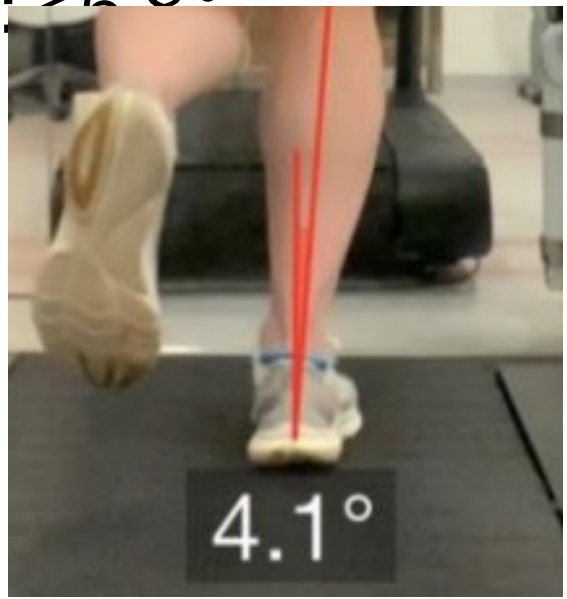
# HSS Running Program

Your foot mechanics:

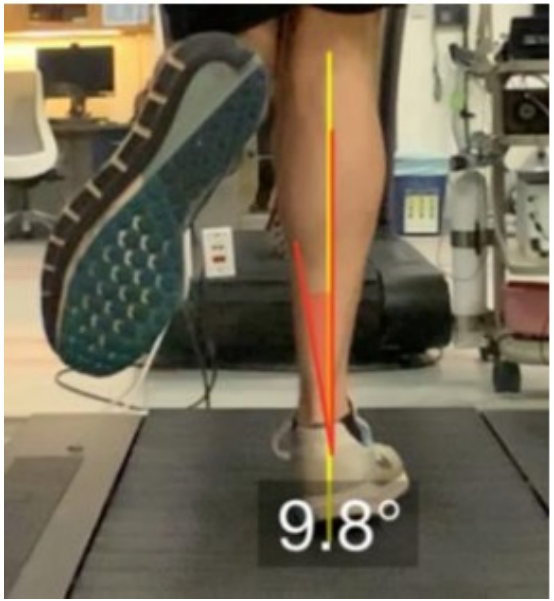


# Mid Stance: Pronation

- Goal: <6.8°




Appropriate




Excessive



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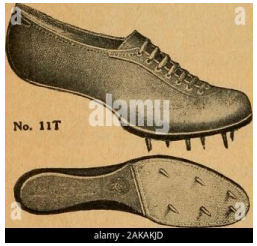
# 1949 – The First Marathon Shoe

# The history of running shoe technology

- The first shoe specifically designed for running was developed by Spalding Company in 1852
  - Made of kangaroo leather and had 6 spikes
- In 1917, Keds made shoe with rubber soles and cloth upper called Plimsoll
  - They were much more comfortable
  - They were quieter hence the name sneakers
- In 1936, Adolf Dassler is credited with the modern running shoe
  - His shoes were used by Olympians such a Jessie Owens
  - He later founded Adidas in 1948




# The modern Running shoes

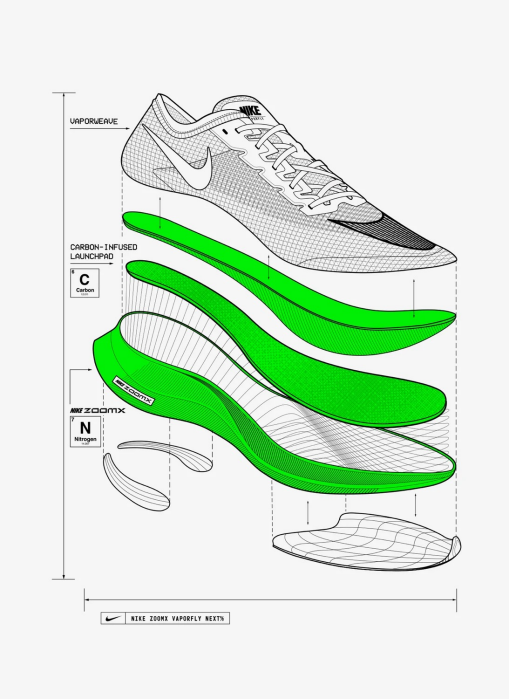
- In 1960s, the rubberized midsole was introduced by Bowerman and Knight
  - Later formed Nike 1971
- 1970, removable spike were first introduced
- 1974, Nike introduced the Waffle shoe designed to have runner land of their heel
- In 1975, Brooks incorporated Ethlyene vinyl acetate, an air-infused foam
- 1976 Brooks introduced Vantage to control pronation
- 1987 Nike created heel cushioning bubble technology
- In 2005, Nike Free and Vibram FivFingers brought in the minimalist/barefoot running movement

# Common Running Shoes Technology Terms

- Upper – everything that sit on top of the sole
- Outsole – layer of foam on the bottom of the shoe that makes contact with the surface
- Midsole – layer of foam that connect the upper to the outsole
- Heel to toe drop, the difference between the height of the heel box vs the toe box
    - High toe drop >10mm
    - Moderate 5-9mm
    - Low <4mm

# Where are we now

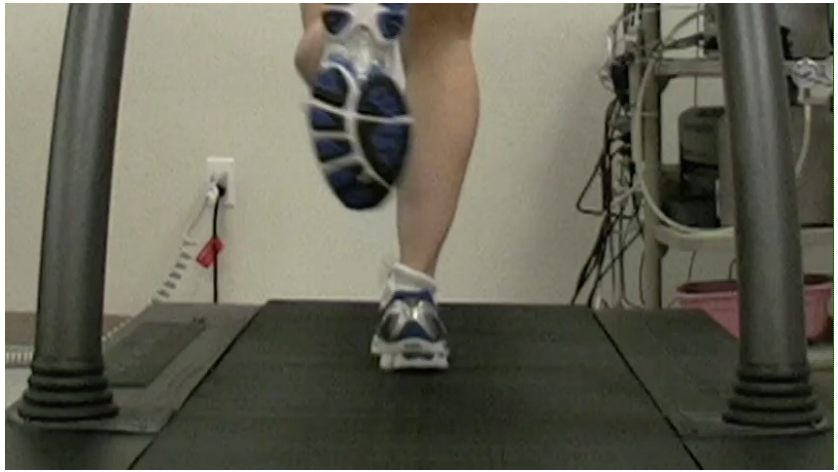
- The main focus for the decade has been trying to create material that is more shock absorbing with more recoil that is lighter
- In 2013, Adidas introduced their Boost technology which replaces EVA with a thermoplastic polyurethane midsole, made of thousands of energy returning capsules
    - Most running shoe companies have developed shoes with a lighter, more responsive foam than EVA
- Nike Vaporfly (2019) combines a carbon fiber plate with a new recoiling foam, PEBA with a thicker heel to create a spring loading effect “Supershoe”
    - 4% more efficient in competitive marathon runners
    - 50 g lighter than traditional competitors
    - All the latest record breaking runs in the marathon



# Running/Walking With Right Shoes?

Bad Feet

Good Feet



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# Shoe Wear and Run Mechanics

To compare the vertical ground-reaction force and ankle kinematics between maximal and traditional shoes before and after a 6-week acclimation period to the maximal shoe.

There is increasing enthusiasm in the "cushioned

A 6-W aximal

Runni Change

Runni

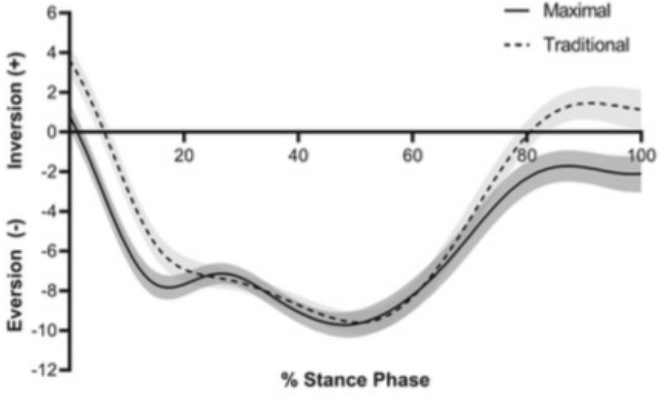


**Figure 2.** Ensemble curves for inversion (+) and eversion (–) in each shoe condition, in degrees. Error bars represent ±1 SE.

Hannigan J et al, AJSM, 2019

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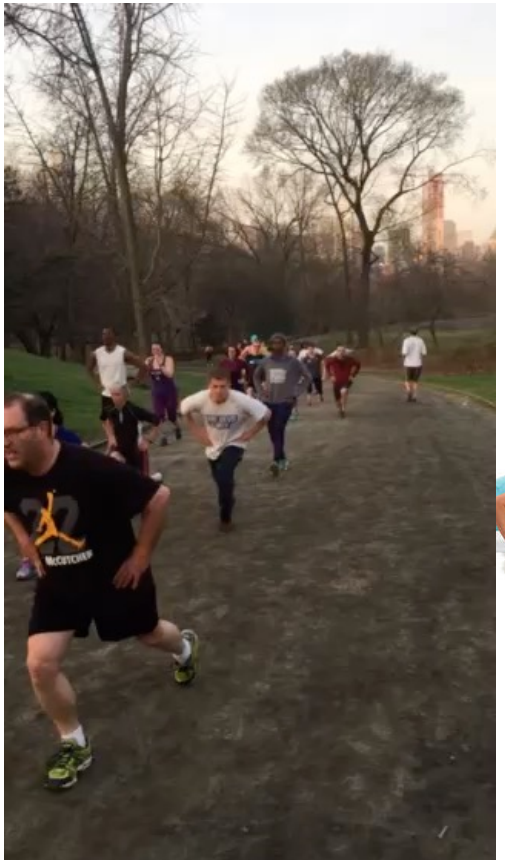
# What Are the Things We Can Alter?

- Kinetic Chain
- Foot Mechanics
- Stride Mechanics
- Training Plans
- Nutritional Issues
- Total Body Strength

# Strength Training for Running

- Economy of movement
- Improved form with training, racing
- Reduction in joint loading force
- Plyometric based training = plyometric based activity

*Fatouris et al, 2000,* Vissing et al, 2008



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# Putting it All Together For Our Patient

Rapid injury diagnosis

Once injury is diagnosed, assess causative factors:

- Foot mechanics
- Stride mechanics
- Training program
- Nutrition
- Mental Health

# Conclusions

- Running is awesome!
- The medical community has an interest in encouraging healthy running
- Further research is needed in the care, treatment, and **prevention** of running injury.