

### HIGH PERFORMANCE CONFERENCE

**MADRID 2025** 

Biomechanical profiling of athletes to improve performance and reduce injury

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### Introduction

### There are several Talent Hubs across England, which provide support to elite and developing athletes across the range of athletics events.

- The talent pathway partners are London Marathon Events, TASS, British Athletics and Sport England.
- At Leeds Beckett University, we provide sport science support as well as training facilities and coaching for athletes in the north of England.
- We also support sporting organisations such as British Triathlon and athletes from other nations.
- This support includes physiology, nutrition, psychology and biomechanics.





### 1500m Race Simulations – Jakob Ingebrigtsen

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#### FIGURE 8

Simulated speed for Ingebrigtsen for his race in Munich (blue line), with the final value of VO<sub>2</sub> increased by 5% (green line), with anaerobic energy  $e^0$  increased by 5% (red line), and with the maximal force  $f_M$  increased by 10% (black line).

### **Biomechanics of Running**



## Impulse

- The product of force and time is called impulse (the change in momentum).
- During running and race walking, minimising braking impulses is important because it reduces the need for larger propulsive impulses.
- Generating large propulsive impulses results in greater acceleration but cannot be maintained for long periods.



# **Underlying Factors**

- All running performances are determined by the magnitude and direction of the ground reaction forces applied during each step.
- The more force applied, the faster the athlete will run. Larger forces depend on maximal muscle strength, muscle contractility and the athlete's mass.
- For optimal performance, athletes need to maintain a large enough impulse but without it being either excessive (early fatigue) or wasteful (poor economy).



# **Underlying Factors**

Which of the variables in grey could and / or should we try to change?

### Success Requires



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Stride frequency

Stride cycle time

Maximum running

velocity

Stride length

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# **Running Economy**



- Running biomechanics can explain 4–12% of the between-individual variation in running economy when considered in isolation (van Hooren et al., 2024).
- Better running economy has been associated with greater leg stiffness (Dutto and Smith, 2002) because of a better use of elastic energy.
- Leg stiffness is primarily determined by muscle activation strategies, not by passive muscle-tendon unit properties (van Hooren et al., 2024).
- This is because it is affected by how the knee's motion is coordinated during midstance.

### What is Leg Stiffness?

- Leg stiffness is a measure of how much the leg's effective length decreases (e.g., because of knee flexion) relative to peak vertical force.
- It is often abbreviated to k<sub>leg</sub> and its unit is N/mm (or a variant of).
- Are stiffer legs better or worse for endurance performance? *It depends*.





2017 World Championship Marathons (last lap) – British athletes

### Men's 1500m – Benefits of Reduced Leg Stiffness



### Spatiotemporal Variables – Men's 1500m

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 Data are taken from 8 of the 12 finalists in the men's 1500m final (World Championships, 2017).

	Lap 2 (650 m)	Lap 3 (1050 m)	Lap 4 (1450 m)
Speed (km/h)	25.84 (± 0.52)	25.55 (± 0.76)	26.32 (± 1.36)
Step length (m)	2.18 (± 0.14)	2.15 (± 0.13)	2.13 (± 0.08)
Cadence (Hz)	3.30 (± 0.16)	3.30 (± 0.18)	3.43 (± 0.22)
Foot ahead (m)	0.36 (± 0.04)	0.35 (± 0.04)	0.35 (± 0.04)
Foot behind (m)	0.59 (± 0.04)	0.59 (± 0.05)	0.60 (± 0.05)
Flight distance (m)	1.10 (± 0.07)	1.09 (± 0.06)	1.05 (± 0.06)
Foot movement (m)	0.13 (± 0.01)	0.13 (± 0.01)	0.13 (± 0.01)

Hanley et al., 2023

### Spatiotemporal Variables – Women's 800m



### **Duty Factor in Endurance Running**

- Duty factor is a simple but effective measure used in running analysis. It is calculated using contact time and stride time.
- Duty factor gives an indication as to whether an athlete is more dependent on contact time or flight time for running speed.
- Leg stiffness is strongly correlated with duty factor, which is a much easier variable to measure.
- Typically, we would expect successful distance runners to have lower duty factors. It is one of the key biomechanical variables we measure to profile athletes.







### **Athlete Profiling**







https://www.englandathletics.org/news/leeds-talent-hub-supportingolympians-and-future-stars-to-fulfil-their-potential/

# **Athlete Profiling**

### EUROPEAN ATHLETICS HIGH PERFORMANCE CONFERENCE MADRID 2025



Large forces Long contact time Large impulse High duty factor Fatigue quickly Small forces Long contact time Small impulse High duty factor Fatigue slowly





Small forces Short contact time Small impulse Low duty factor Fatigue slowly

Large forces Short contact time Large impulse Low duty factor Fatigue quickly



## **Athlete Profiling**

### EUROPEAN ATHLETICS HIGH PERFORMANCE CONFERENCE MADRID 2025



Large forces Long contact time Large impulse High duty factor Fatigue quickly Small forces Long contact time Small impulse High duty factor Fatigue slowly





Small forces Short contact time Small impulse Low duty factor Fatigue slowly

Large forces Short contact time Large impulse Low duty factor Fatigue quickly



### Athlete Profiling – Football

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#### SPECIALTY SECTION

This article was submitted to Elite Sports and Performance Enhancement, a section of the journal Frontiers in Sports and Active Living Grizzlies and gazelles: Duty factor is an effective measure for categorizing running style in English Premier League soccer players

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# **Athlete Profiling – Running**



- "Aerial" runners
- More reliant on spring-like behaviour
- Less time on the ground for each step
- Low duty factor / high leg stiffness values
- Push harder in an upwards direction
- More vertical movement
- Likely to have better running economy
- Better suited to plyometric training



- "Terrestrial" runners
- More reliant on strength
- Less time in the air for each step
- High duty factor / low leg stiffness values
- Push harder in a forward direction
- Stay low to the ground
- Likely to have better acceleration ability
- Better suited to resistance training



### **Spatiotemporal Variables**

Changes were S: Small; M: Moderate; L: Large; VL: Very large; EL: Extremely large

250 г 2.2 4.5 VL 225 Contact time 2.0 Flight time VL 4.0 VL VL 200 Step length (m) 1.8 Cadence (Hz) Time (ms) VL 175 3.5 1.6 Μ EL VL 150 1.4 S 3.0 125 1.2 2.5 12 20 16 24 30 16 12 20 24 30 Speed (km/h) Speed (km/h) Duty factor: 0.311 0.279 0.258 0.247 0.254

### Duty Factor (@ 24 km/h)



#### **EUROPEAN ATHLETICS** HIGH PERFORMANCE Duty Factor (@ 24 km/h) CONFERENCE **MADRID 2025** 22 20 r = -0.9318 Leg stiffness (norm.) t<sub>stance</sub> DF =2 $t_{stance} + t_{flight}$ 16 Most 14 medals Fastest 12 athlete 10 0.220 0.225 0.230 0.235 0.240 0.245 0.250 0.255 0.260 0.265 0.270 0.275 Duty factor

Athletes with high leg stiffness are bouncier and rely on long flight times to run faster (by having longer steps).

### Knee flexion @ midstance

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High stiffness (17.7) Olympic marathon runner Low stiffness (14.7) Olympic 800m runner

- We expect that those athletes who flex their knees more during midstance will have lower leg stiffness.
- We must consider race specificity when deciding whether to adopt training to increase or decrease leg stiffness.
- One factor that must be accounted for is the risk of injury.

# **Effects of Fatigue**

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 We simulate 1500m racing in female athletes to observe what changes they undertake to be able to maintain fast running speeds despite fatigue.



### Changes in Running Mechanics – Example of Female 1500m Athlete



## Technique Analysis – S&C

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The coaches who work in Strength & Conditioning can use the high-speed videos and data from the treadmill to assess running technique in each athlete and assess for any areas to develop.



Toe-off Max Vertical Late swing Touchdown Mid stance projection

Dane Mitchell & Maj Skok, European Endurance Conference presentation, 2024

### **Practical Applications – MD**











### **Practical Applications – LD**

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### Thank you for your attention!

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Please get in touch if you would like your athletes to take part in any of our ongoing research studies on biomechanics of middle- and long-distance runners: b.hanley@leedsbeckett.ac.uk

### Key takeaways!



- What is one key idea or insight you're taking home from this experience?
- What is something you'd like to implement in your own work or federation?
- What support would you need from European Athletics or other federations to make it happen?

# **GROUP DISTRIBUTION**





- For participating
- For sharing
- For connecting
- For contributing to the European Athletics community
- For building the athletics of the future