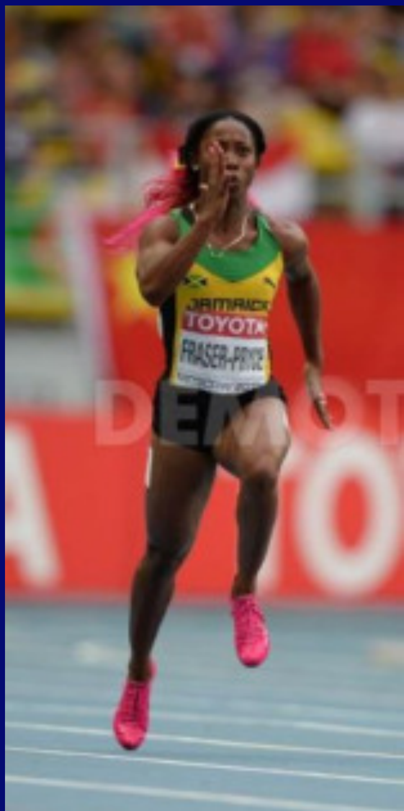
The Science of Speed:
from GAIT MOTION to GROUND FORCE



Gambetta Athletic Improvement Network

Houston, TX
June 13, 2018

Peter Weyand
Glenn Simmons Professor of Applied Physiology & Biomechanics
Southern Methodist University
Dallas, Texas, USA

Vern Gambetta

Dr. Ken Clark

GAIN 2018

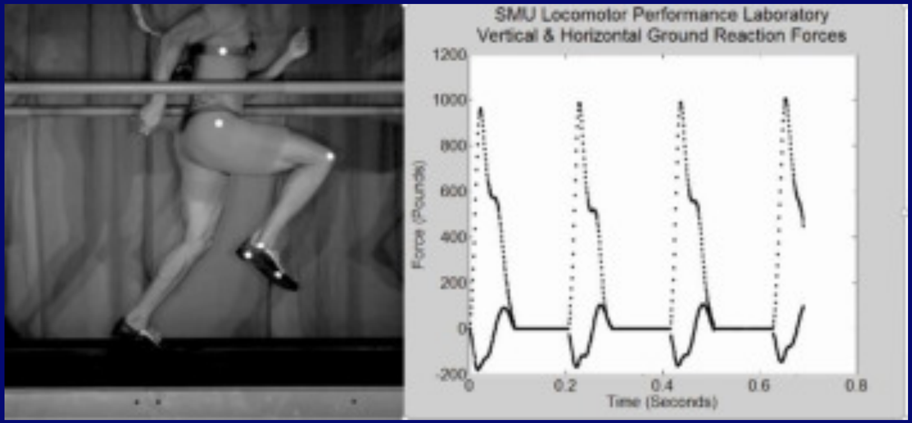
Hopes, Aspirations & 1st Appearances

Vern Gambetta

GAIN 2018

BACK TO BASICS

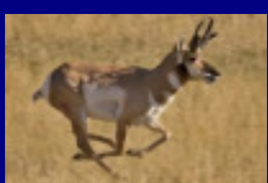
The Science of Speed:
from GAIT MOTION to GROUND FORCE

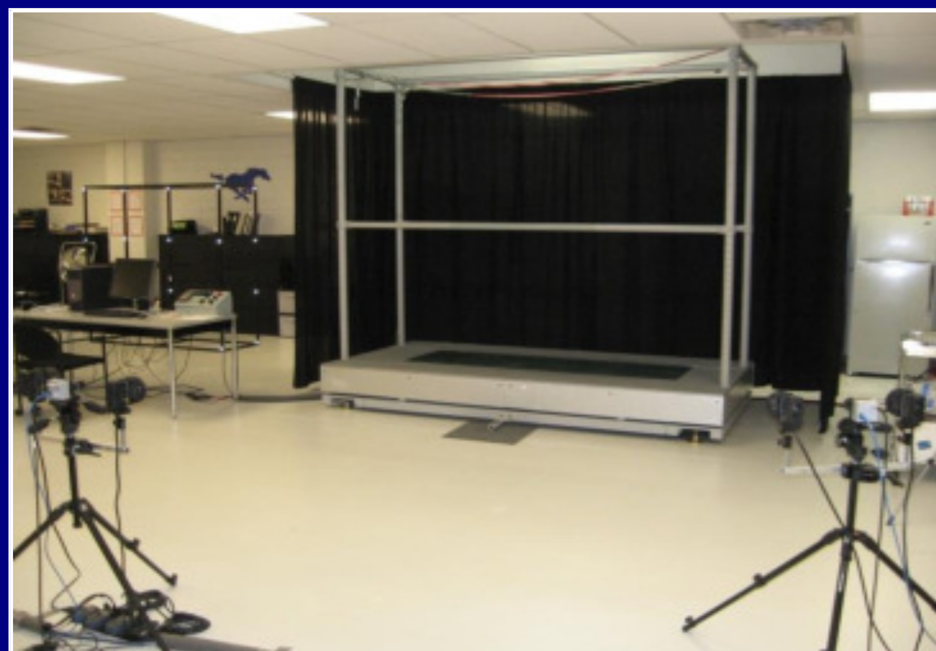


SMU Locomotor Performance Laboratory

YOUTUBE: locomotorlabsmu

TWITTER: *@Dr_Weyand*

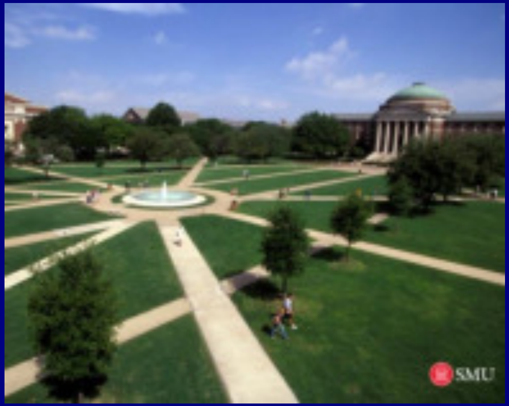




<u>Science Chronology</u>:

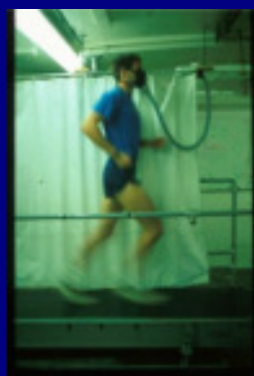
Cowboy Science from Harvard to Heart of Texas

Speed Research:
Background & Origins



Cowboy Science with Ivy League Roots:

Force-Motion-Energy: Locomotion and Movement



Locomotor performance - approaches & perspectives

C. Richard Taylor

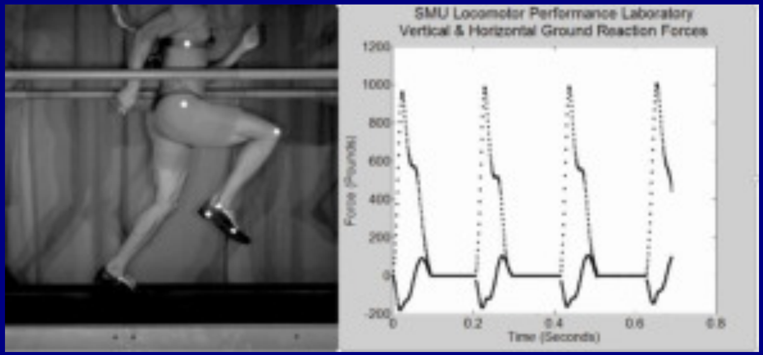
(1940 – 1995)

Chronology, Funding, Talent

SMU/LPL



Harvard U/CFS



Origins of Sprinting Research

Faster top running speeds are achieved with greater ground forces not more rapid leg movements

PETER G. WEYAND, DEBORAH B. STERNLIGHT, MATTHEW J. BELLIZZI, AND SETH WRIGHT
Concord Field Station, Museum of Comparative Zoology, Harvard University, Bedford, Massachusetts 01730

Received 30 March 2000; accepted in final form 14 September 2000

Greyhounds or Humans???

Study Design:

Test slow, medium, fast runners (n=33)


Faster top running speeds are achieved with greater ground forces not more rapid leg movements

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Two Speed Questions

Faster top running speeds are achieved with greater ground forces not more rapid leg movements

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1) What limits running speed?

2) What determines differences in top speed?

Two Speed Questions

Faster top running speeds are achieved with greater ground forces not more rapid leg movements

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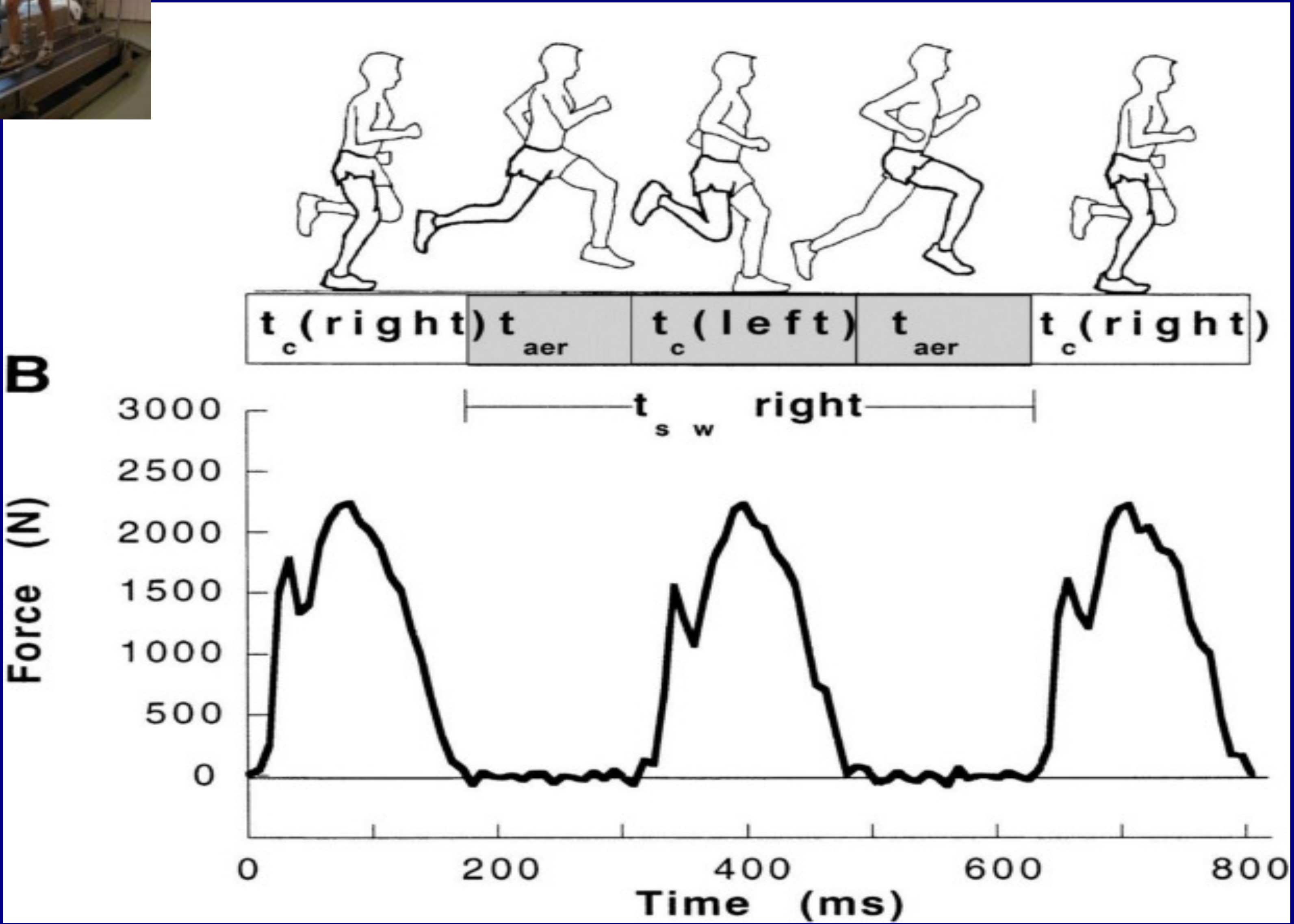
1) What limits running speed?

2) What determines differences in top speed?

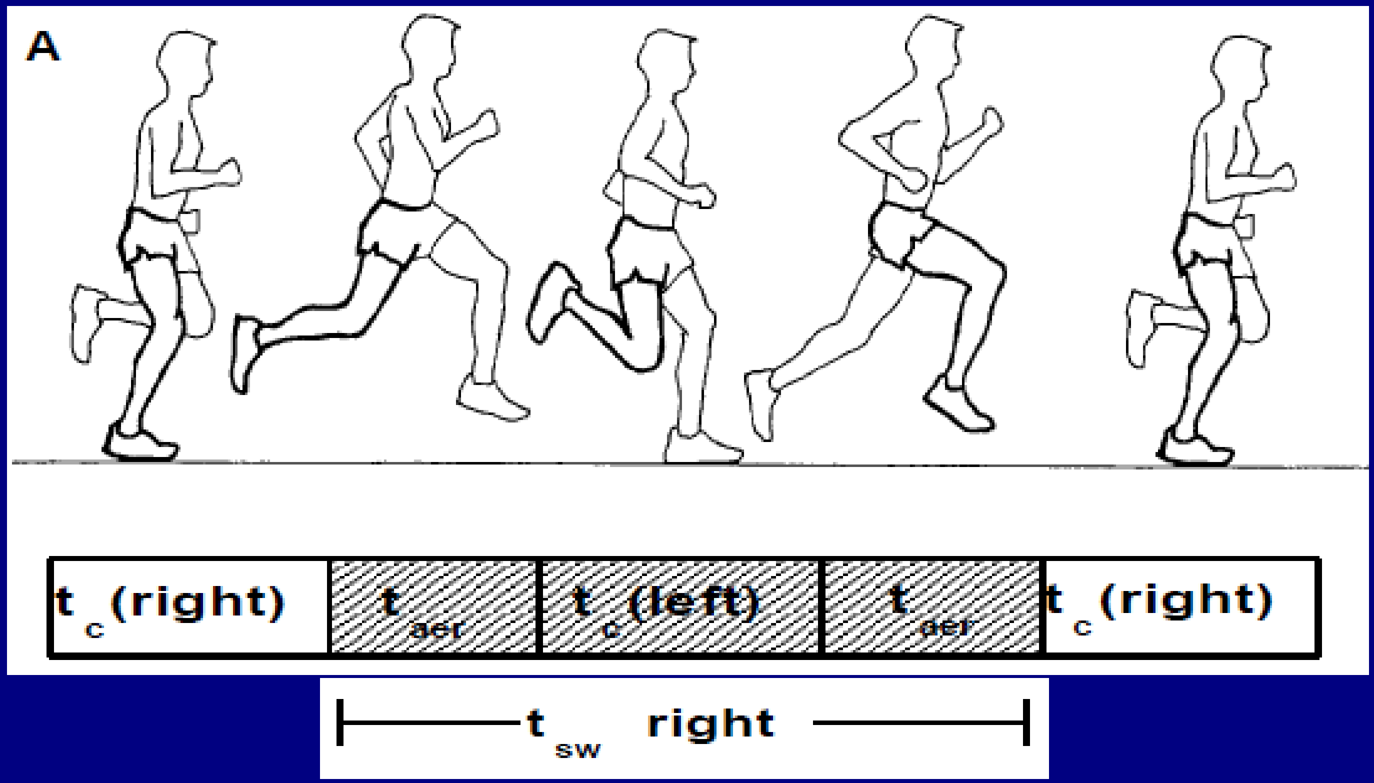
Treadmill Sprint Test *[n=33]*

(> 26 mph)

Force Treadmill Data



Human Running Stride



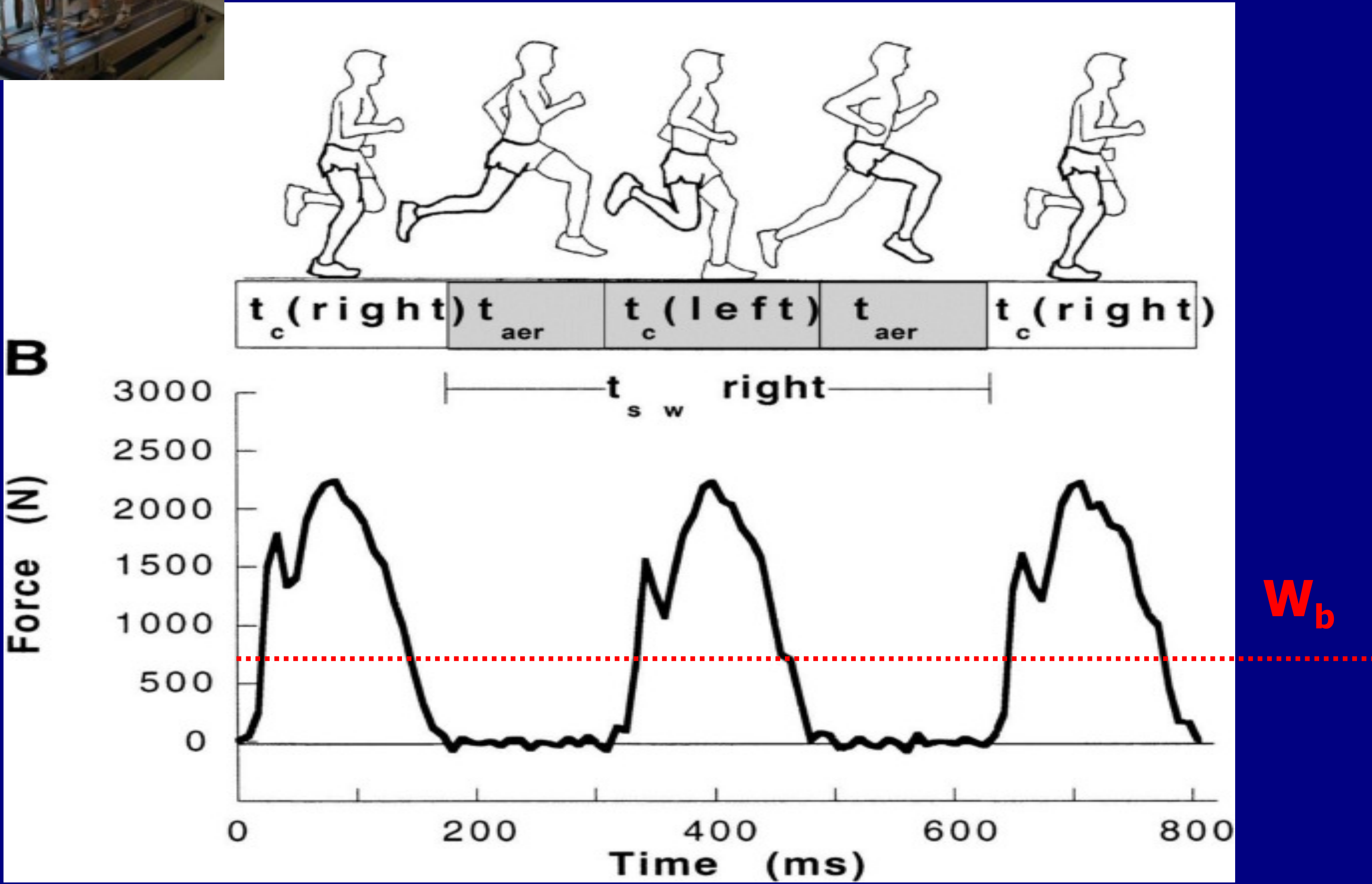
CONTACT (t_c), AERIAL (t_{aer}), SWING (t_{sw})

BASIC CONCEPT

<u>The</u> mechanical requirement of running is:

Applying ground force to support body weight

Force Treadmill Data

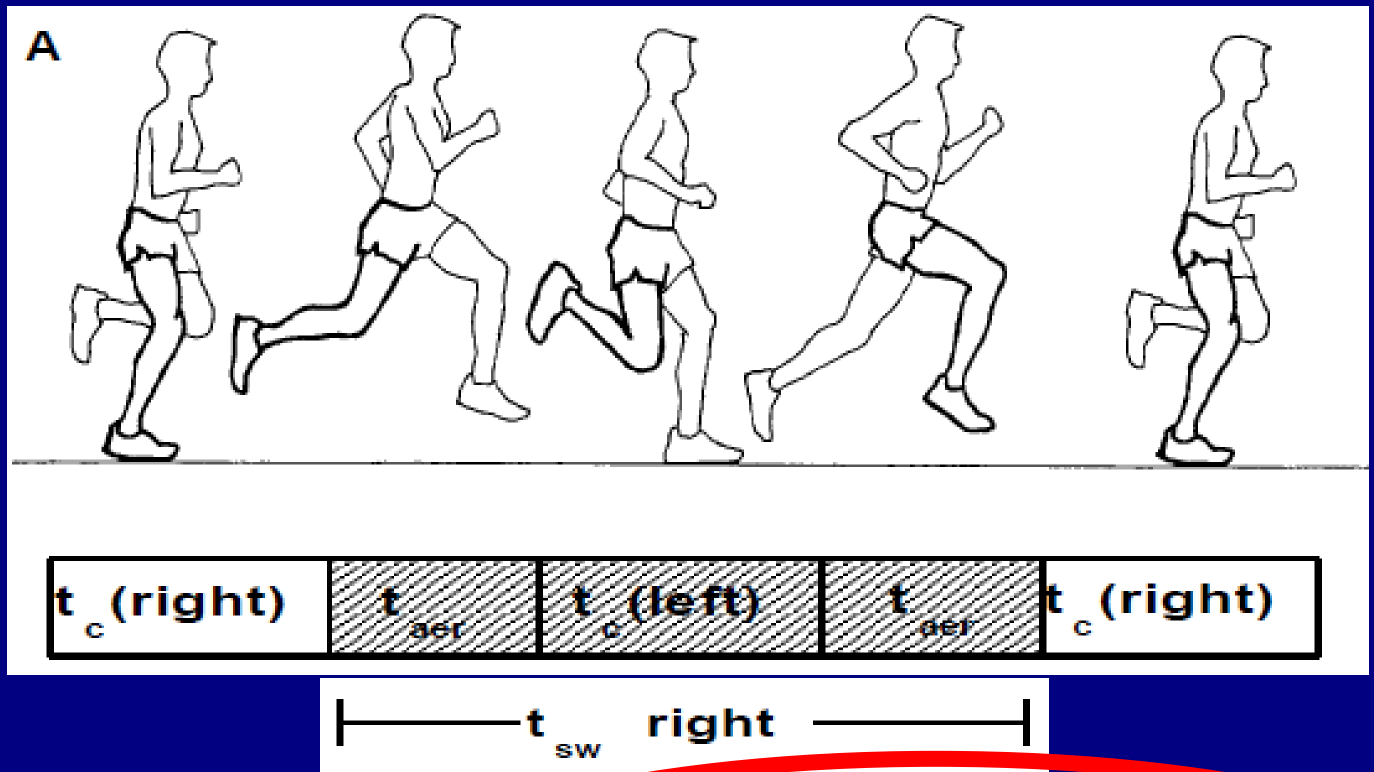


Results

SCIENTIFIC PUNCH LINE #1

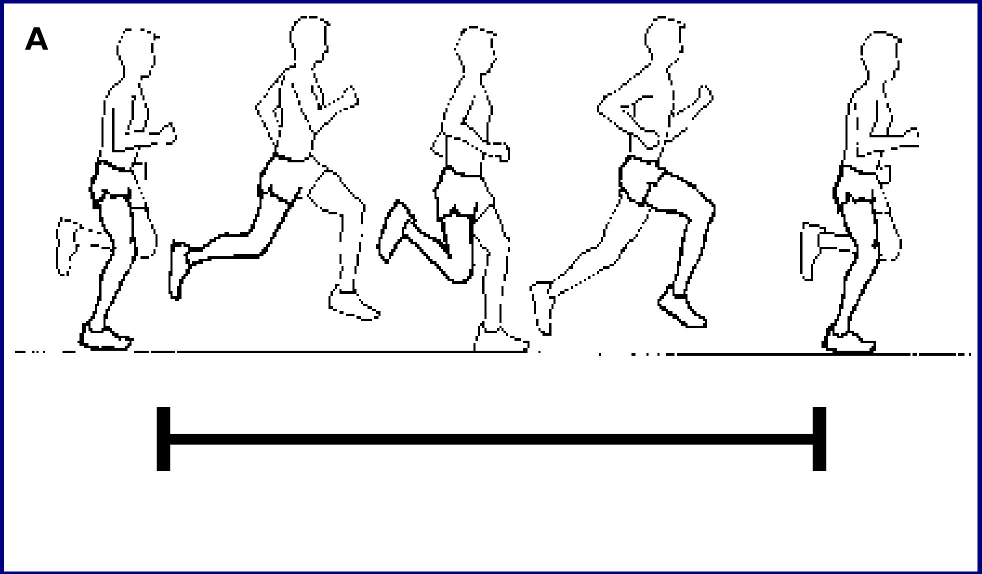
The timing of the human running stride is highly constrained

Human Running Stride



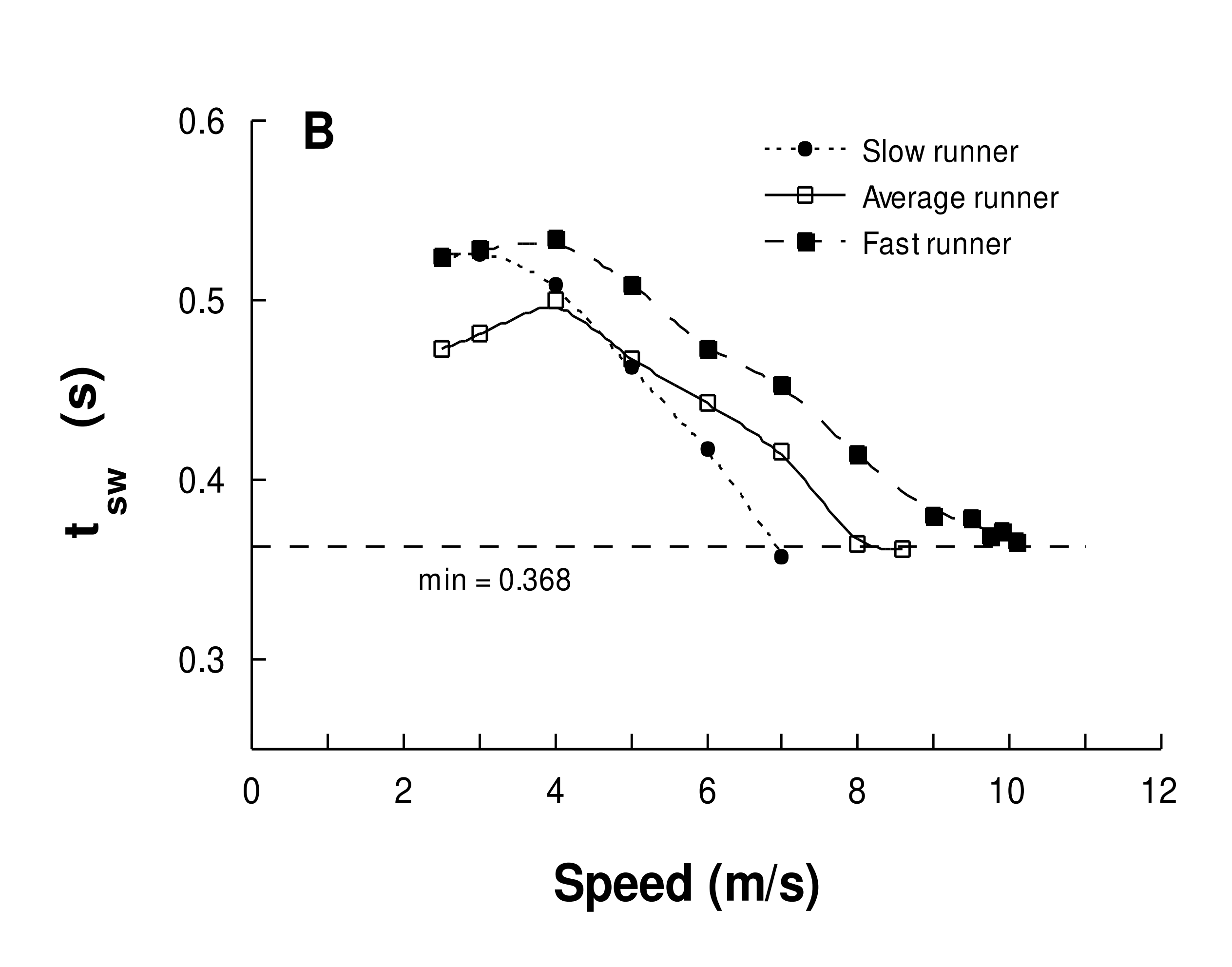
CONTACT (t_c), AERIAL (t_{aer}), SWING (t_{sw})

Swing time
(or limb repositioning time)



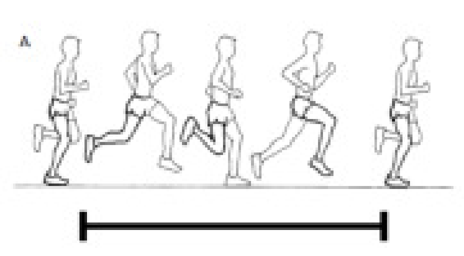
Swing times
across speed

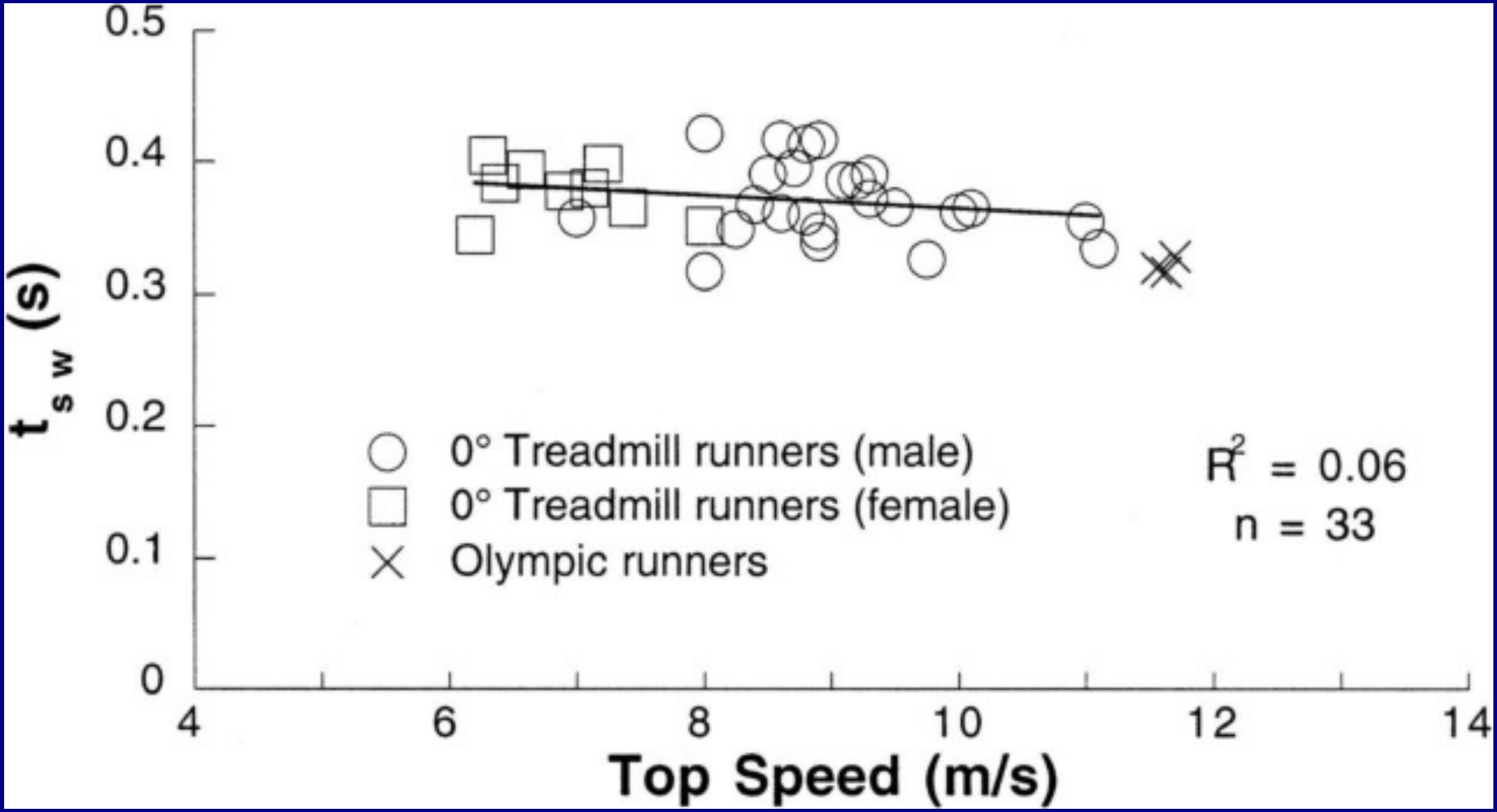
Real Data – Three runners (n=3)



Limb Swing times

at top speed *(n=33)*





Swing times

Sprinter vs. Non-sprinter

Olympic Sprinter
23.0 mph

Athlete Non-Sprinter
19.0 mph

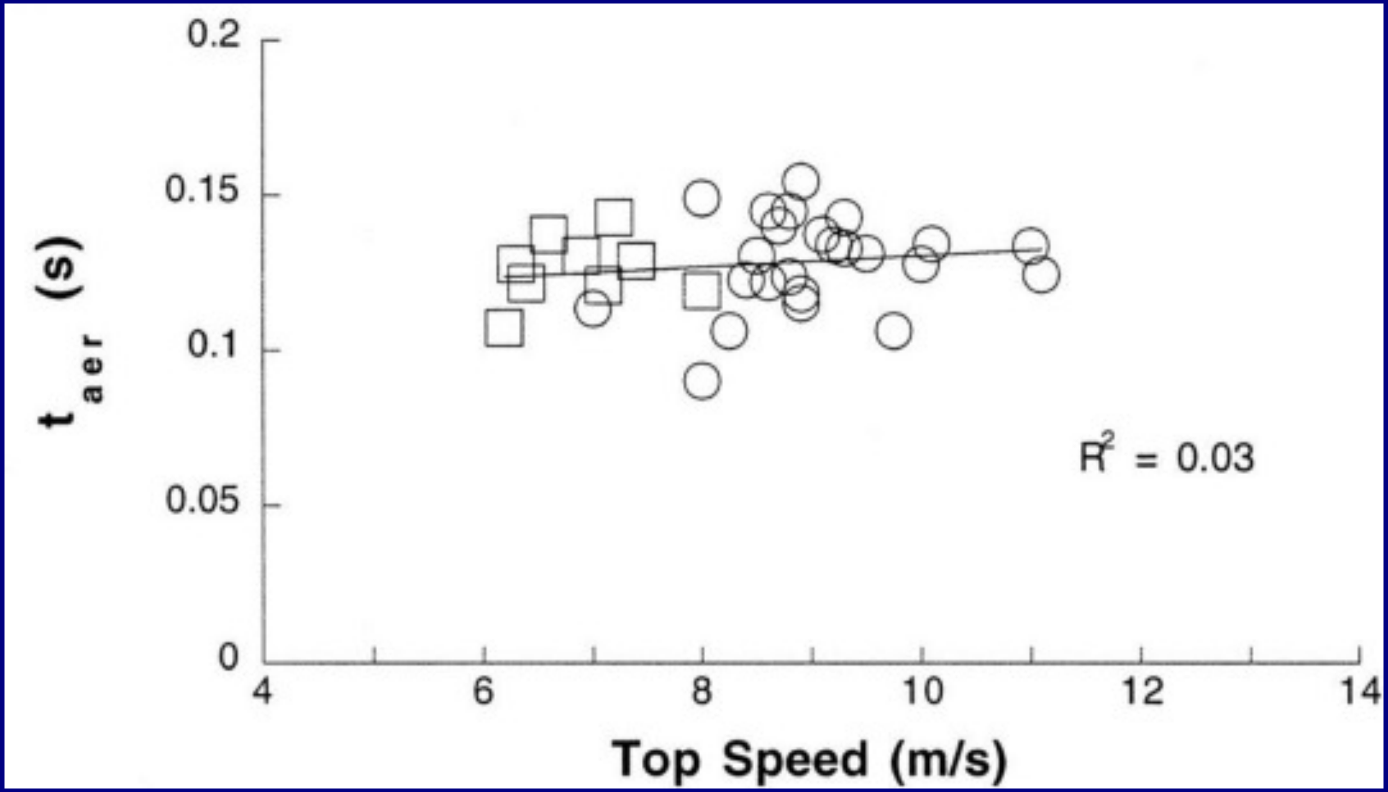
Punch Line #1

SAME SWING TIMES

Usain to slow pokes

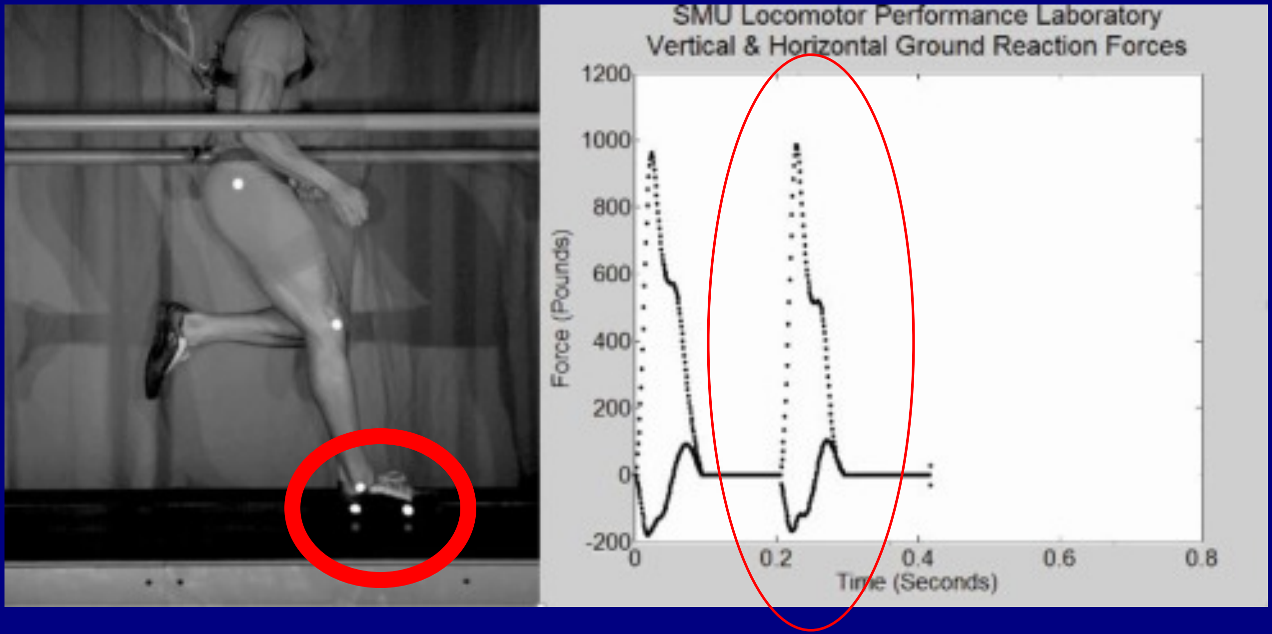
Aerial Time

at top speed (n=33)



If swing times are similar, what confers fast sprint speeds?

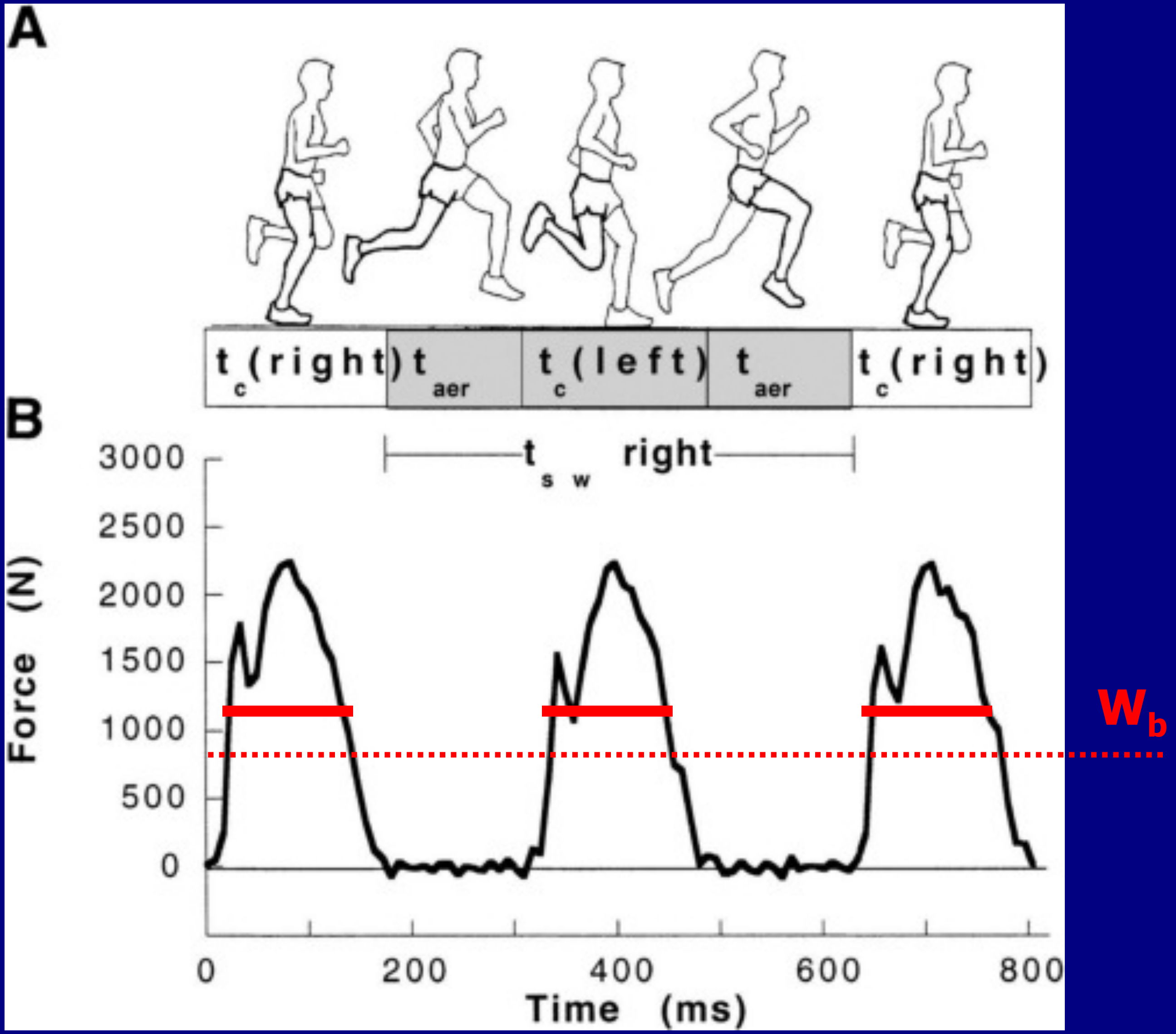
SCIENTIFIC PUNCH LINE #2

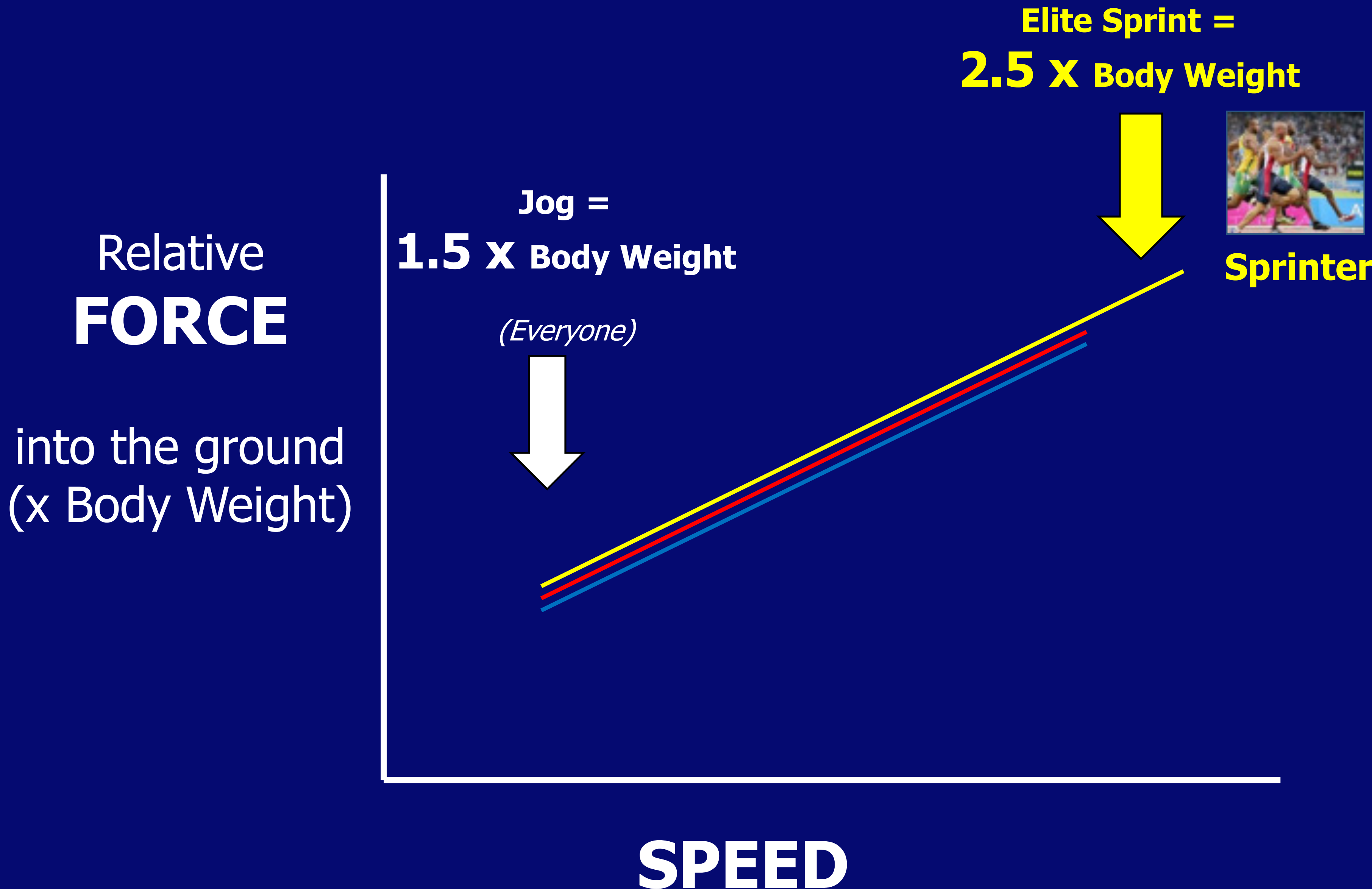


Big ground forces - the how of fast speeds

(Peak 5 x body weight)

Force Treadmill Data




Elite Sprint =
2.5 x Body Weight
Sprinter
Jog =
1.5 x Body Weight
(Everyone)
Relative
FORCE
into the ground
(x Body Weight)
SPEED

Force vs. speed relationship - general

$$\text{Force} = 1.26\ W_b + 0.1\ W_b \bullet \text{Velocity}$$

Faster top running speeds are achieved with greater ground forces not more rapid leg movements

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At top speed:

- different runners

The biological limits to running speed are imposed from the ground up

Peter G. Weyand,[1,2] Rosalind F. Sandell,[1,2] Danille N. L. Prime,[2] and Matthew W. Bundle[3]
[1]Department of Applied Physiology and Wellness, Southern Methodist University, Locomotor Performance Laboratory, Dallas, Texas; [2]Kinesiology Department, Locomotion Laboratory, Rice University, Houston, Texas; and [3]Biomechanics Laboratory, College of Health Sciences, University of Wyoming, Laramie, Wyoming

Across speed:

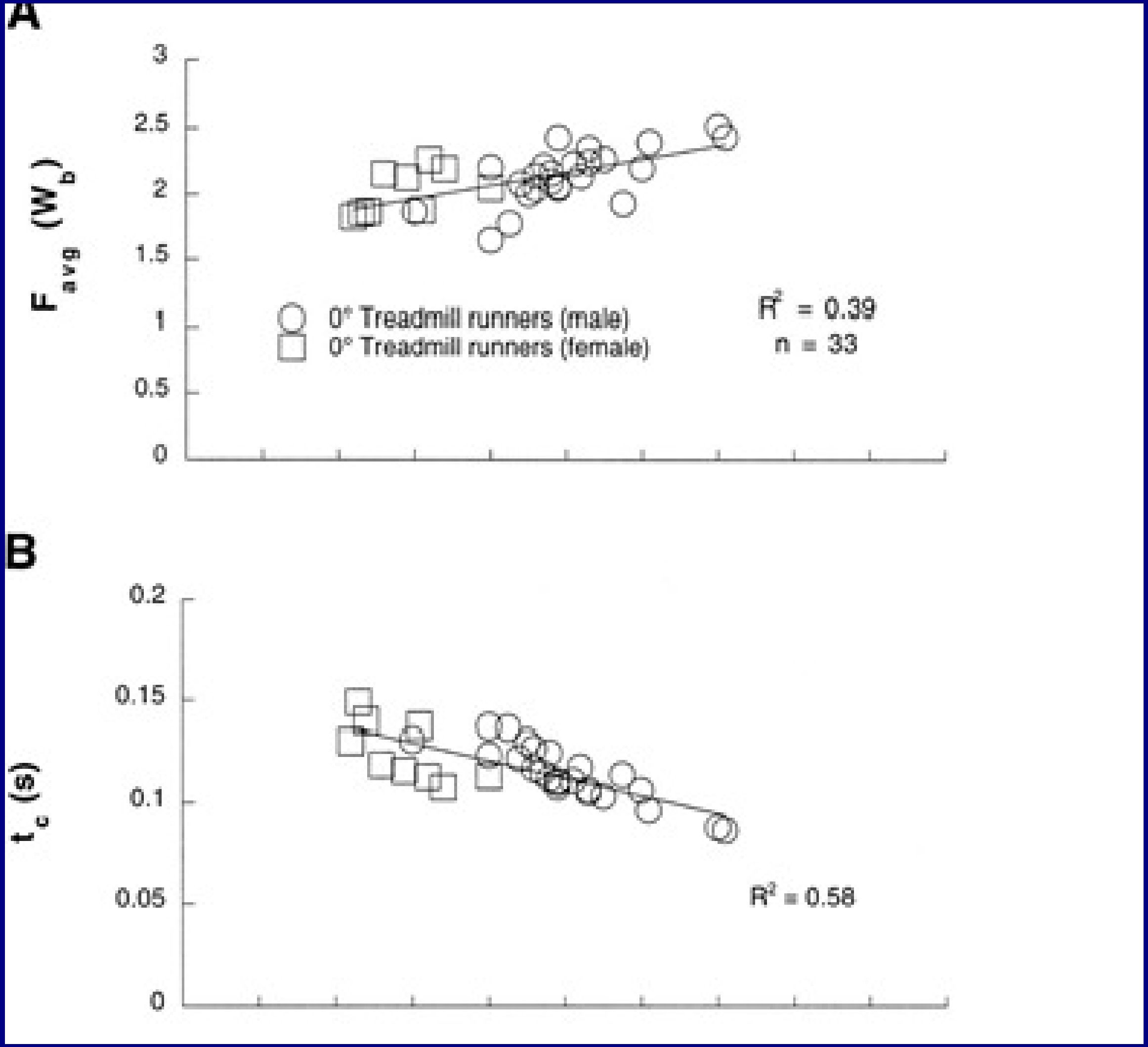
- individual runners

Fast Runners:

1) Apply large ground forces (Force/mass)
2) Have short contact times

Mechanics of ground force application determine speed

Force (W_b)



t_c (s)

Top Speed (m/s)

FAST

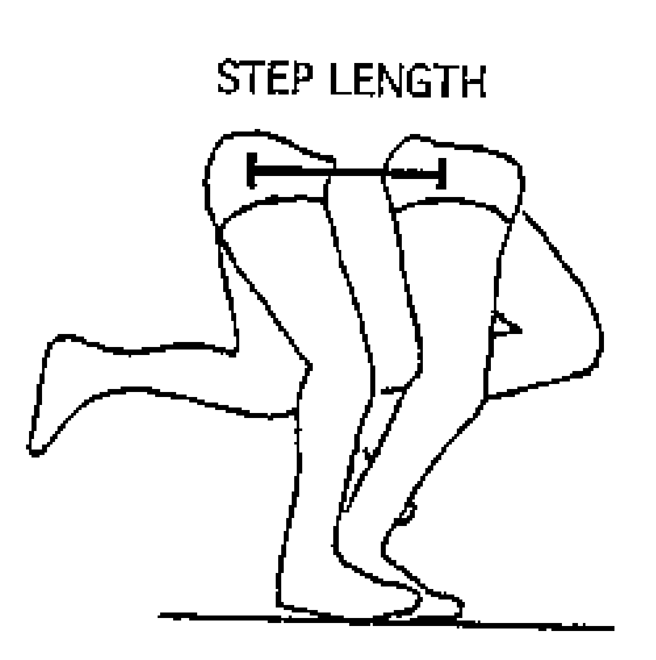
More force

Shorter times of force application

Contact Times ~ <u>must</u> <u>decrease</u> as Speed Increases

<u>Step length</u> (L_c):

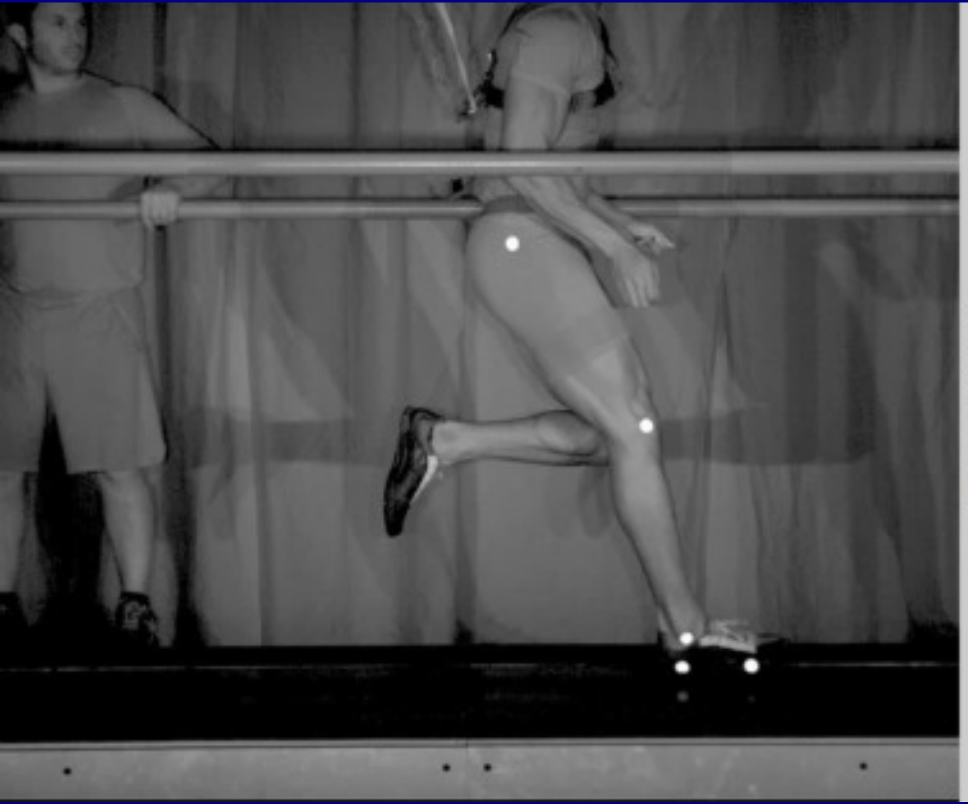
1.0 meter

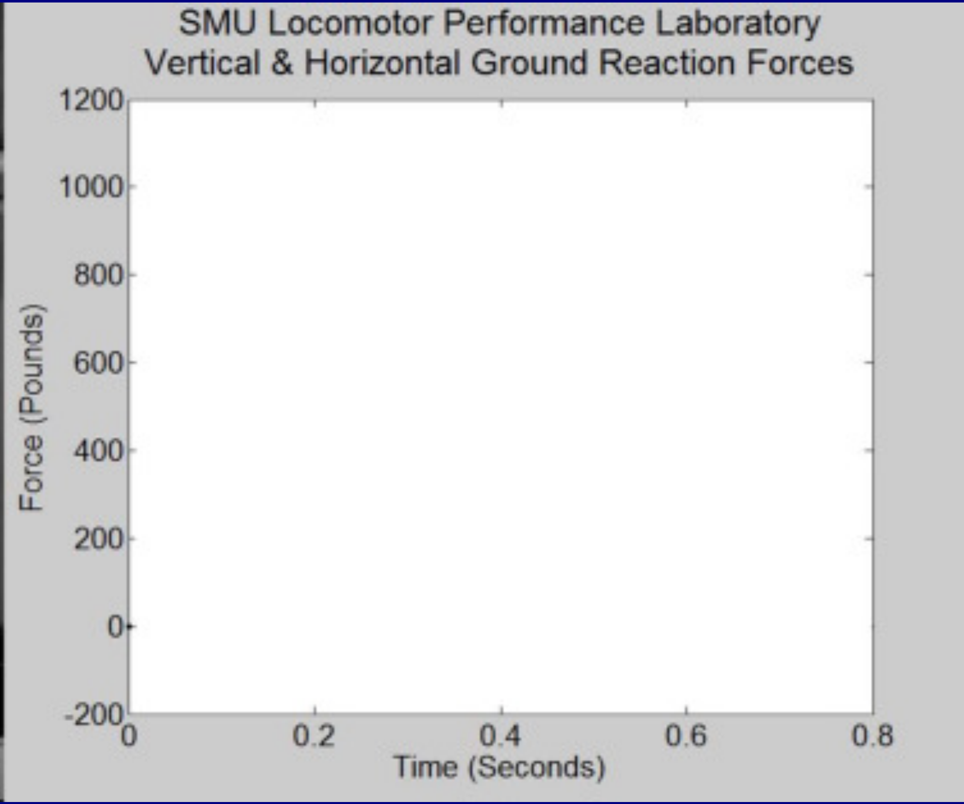


Speed (m/s)	Contact Time (s)
1.0	1.00
2.0	0.50
4.0	0.25
10.0	0.10

L_c changes little from moderate to top sprint speeds

Sprinters hit the ground forcefully *(Force/mass)*

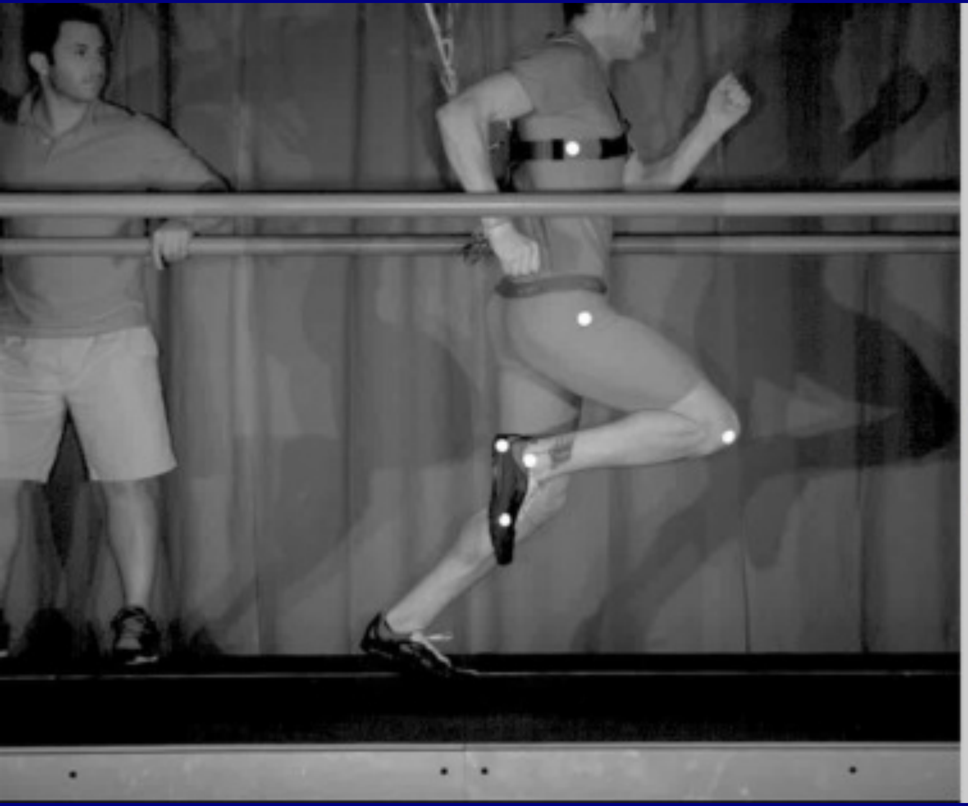


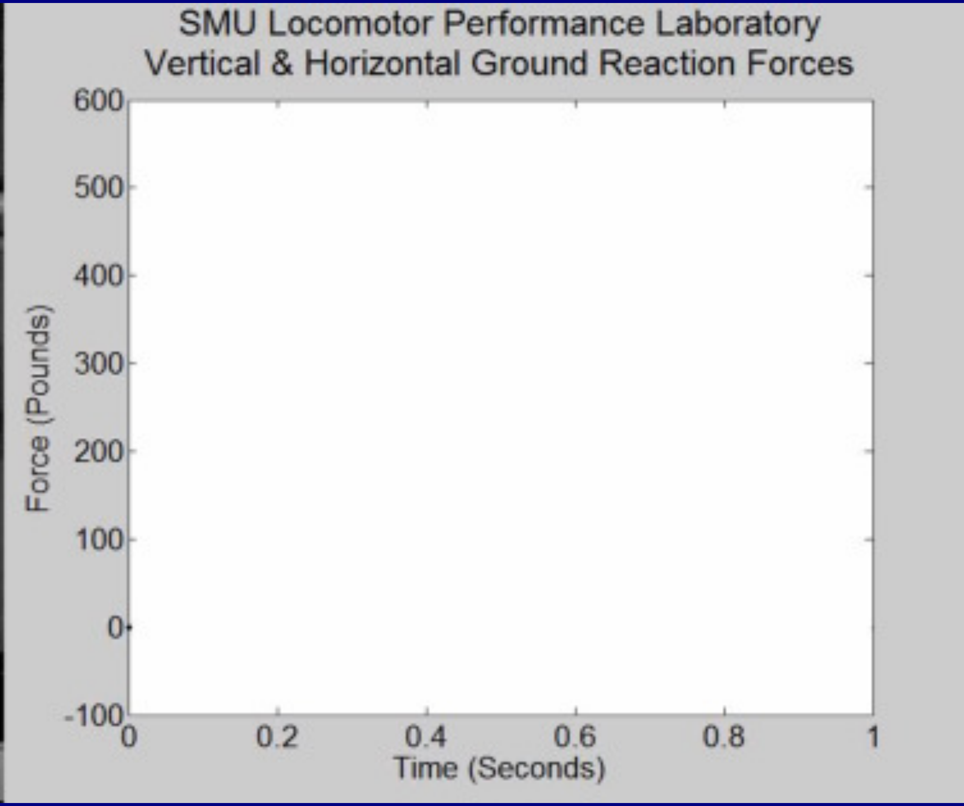


BIG FORCES

Distinct Waveform Shape

Middle Distance Runner





Less force/mass

PART 3

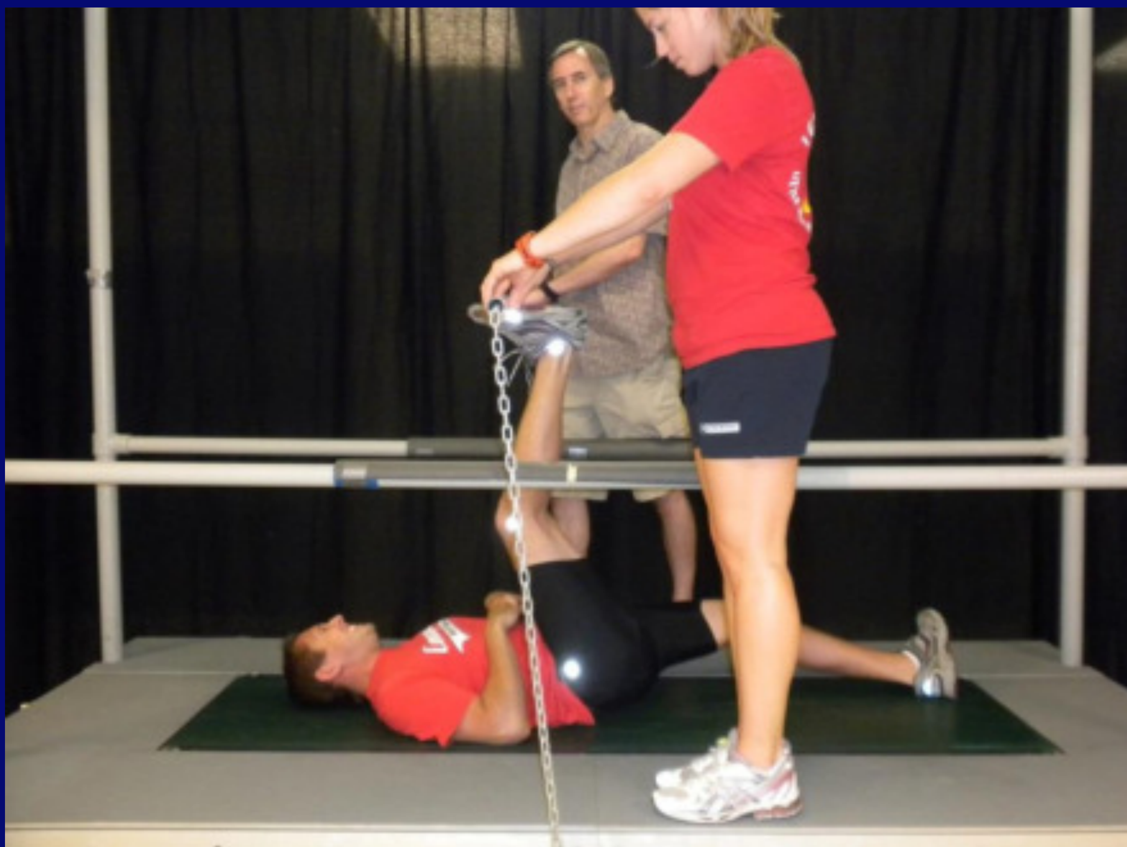
How do faster runners hit the ground more forcefully?

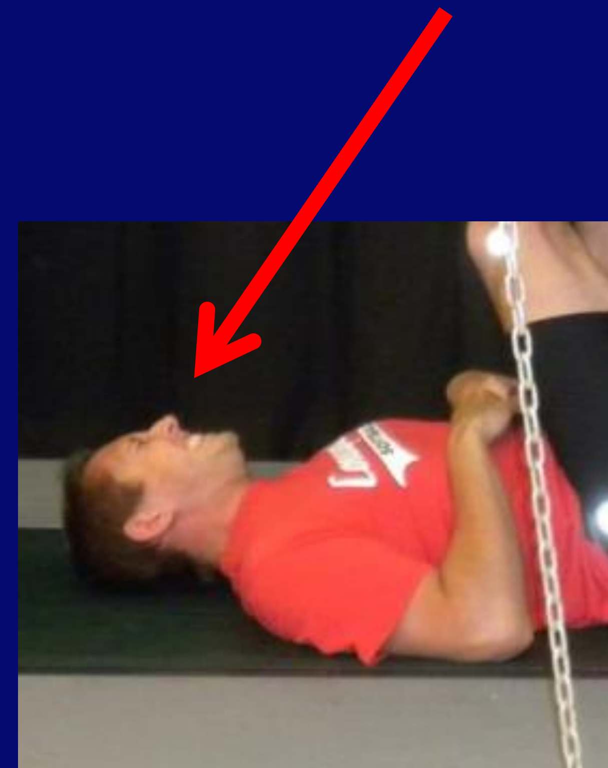
What is THE SECRET?

DEBATE:
What is THE SECRET?

Limb strength or running form?

Strength or Gait Mechanics?





How do the Fastest Runners Hit the Ground More Forcefully?

Limb Motion-Force

Ken Clark, Ph.D.
Doctoral Student

THEY ATTACK THE GROUND

Motion to force mechanism

Larry Ryan, Ph.D.
Physicist

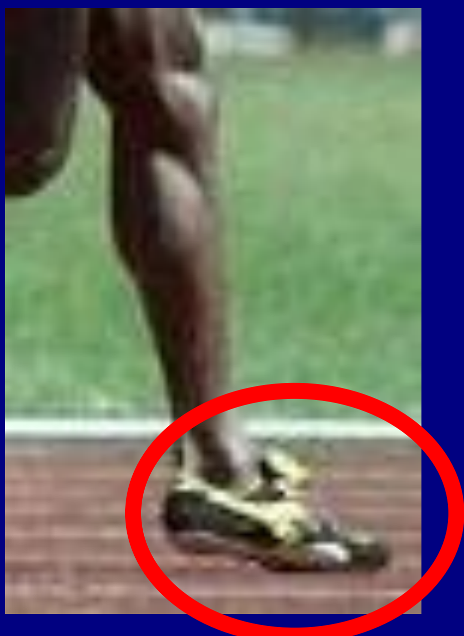
Same time, different motion

Sprinter vs. Non-sprinter

Olympic Sprinter
23.0 mph

Athlete Non-Sprinter
19.0 mph

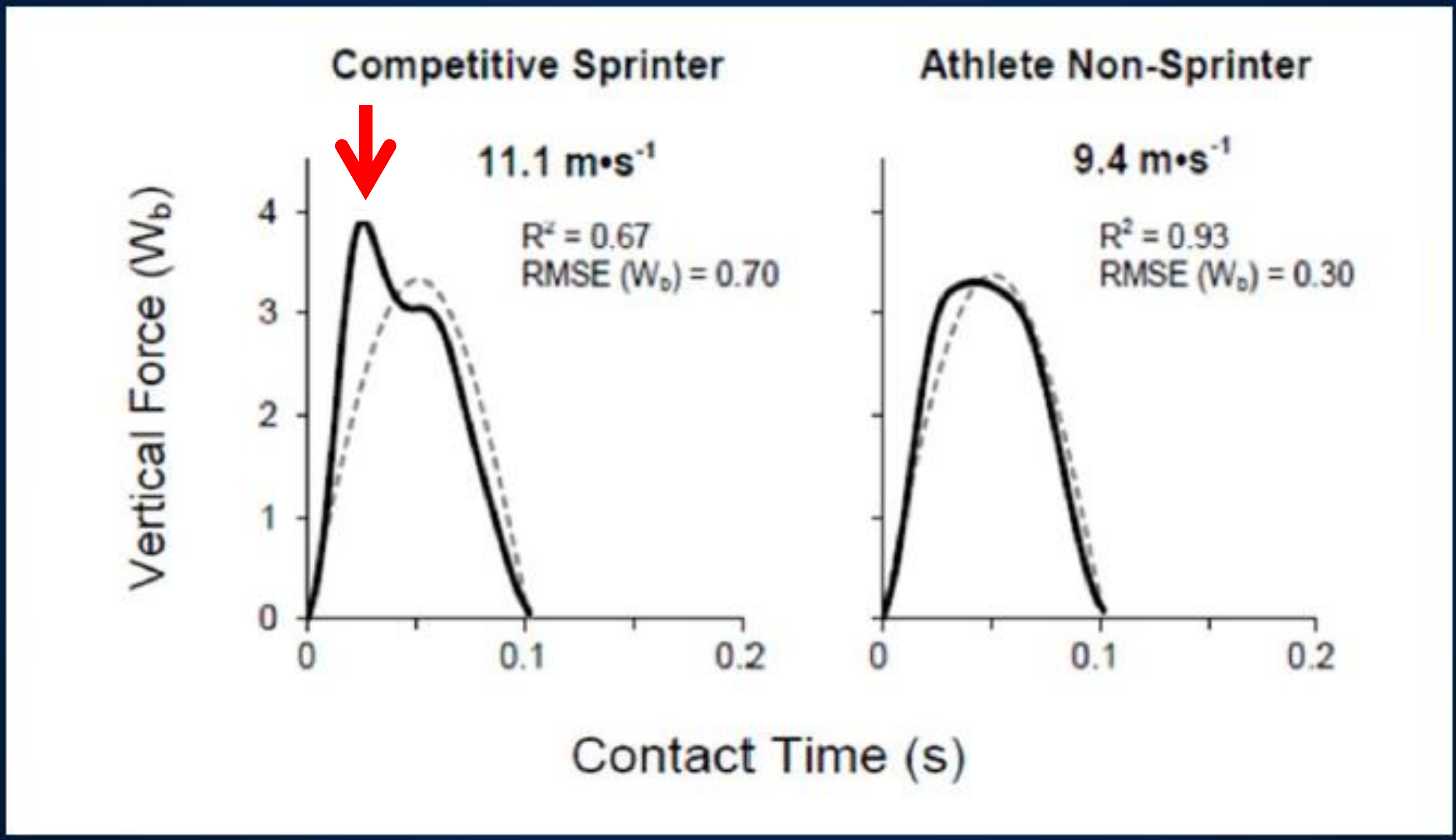
SCIENTIFIC PUNCH LINE #3



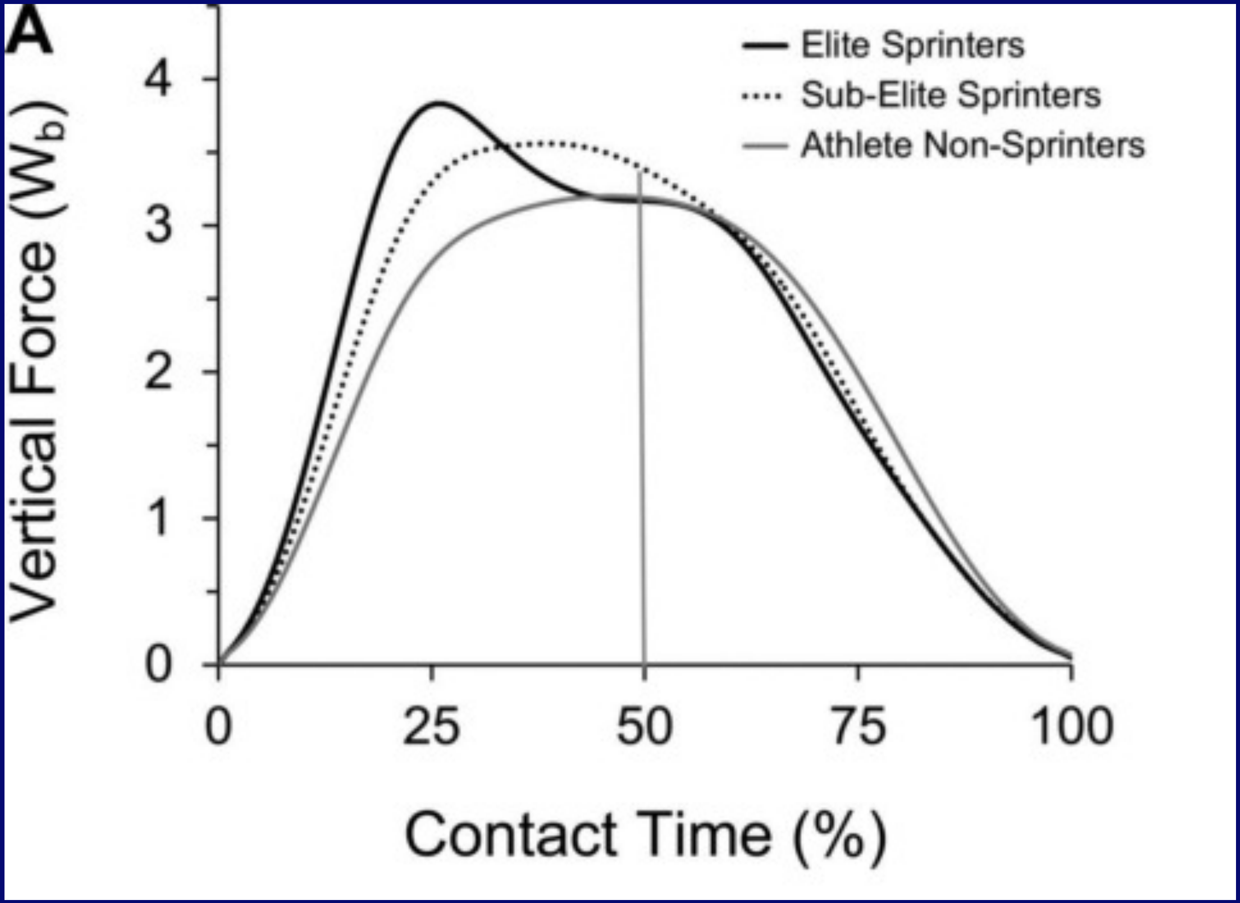
- **FAST LEG VELOCITY**
- **QUICK STOP**

Big forces from: big deceleration on impact

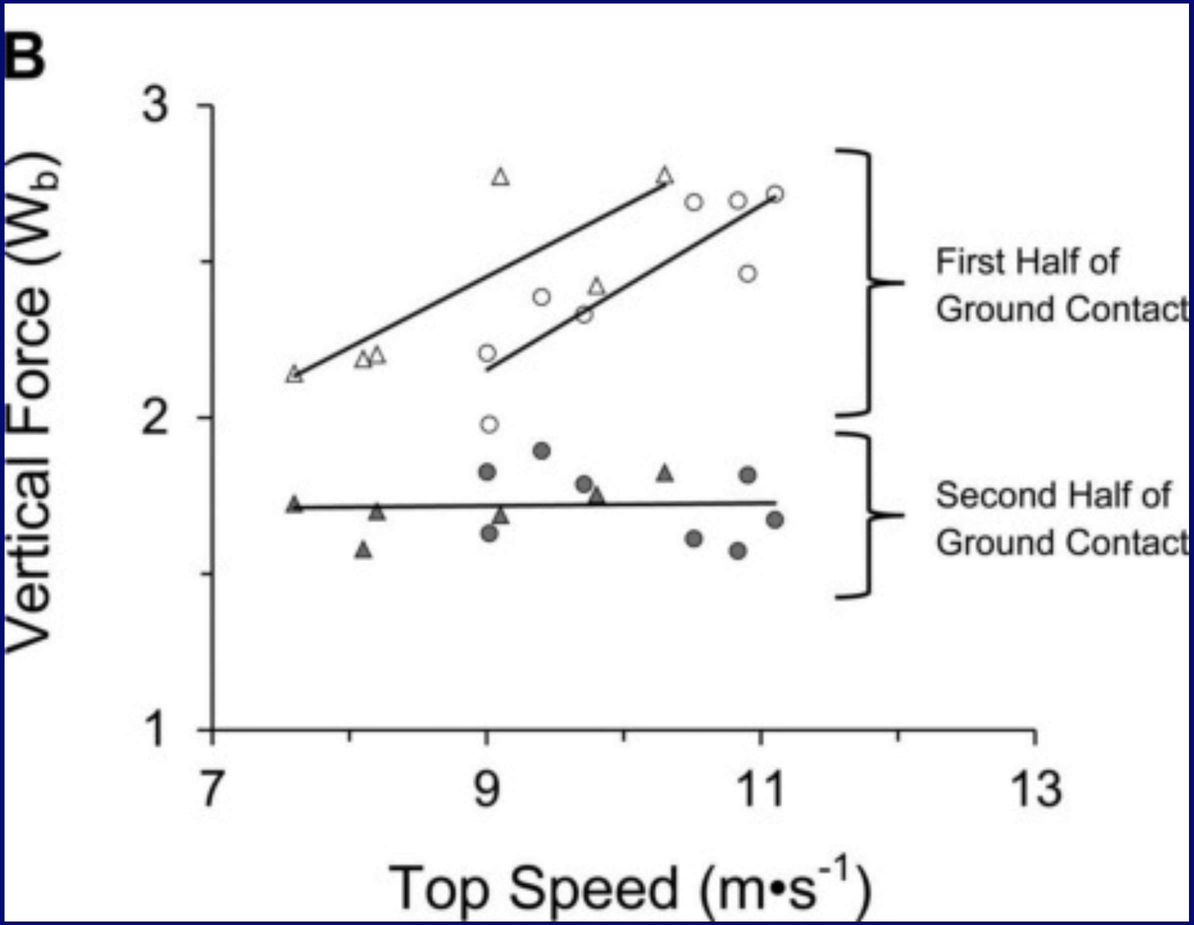
Force-Time Waveforms
Illustrate the Secret to Big Ground Forces



Elite vs. Sub-elite Males
TOP SPEED



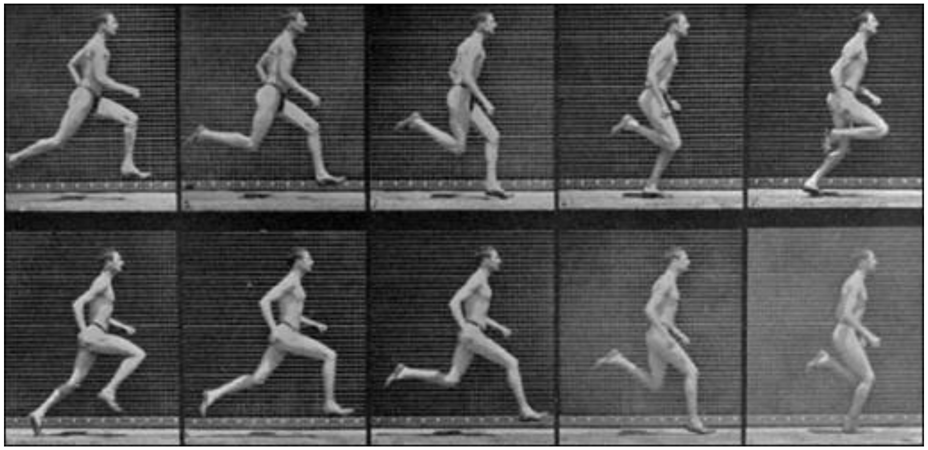
Fourteen Athletic Subjects: Top Speed Forces



Lower-Limb:
Two Critical Actions – <u>Punch Analogy</u>

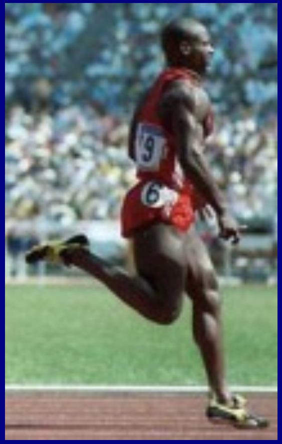
1. Drive it Fast
2. Stop it quick

Musculoskeletal Biology & Physics → Speed



<u>Convergence</u> on a Single Solution

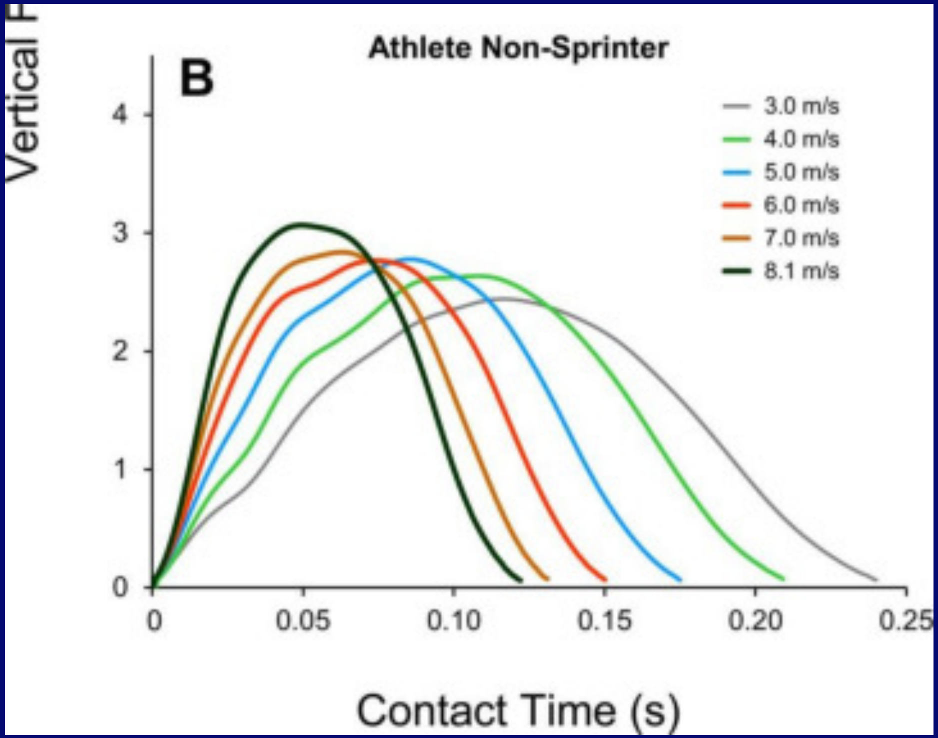


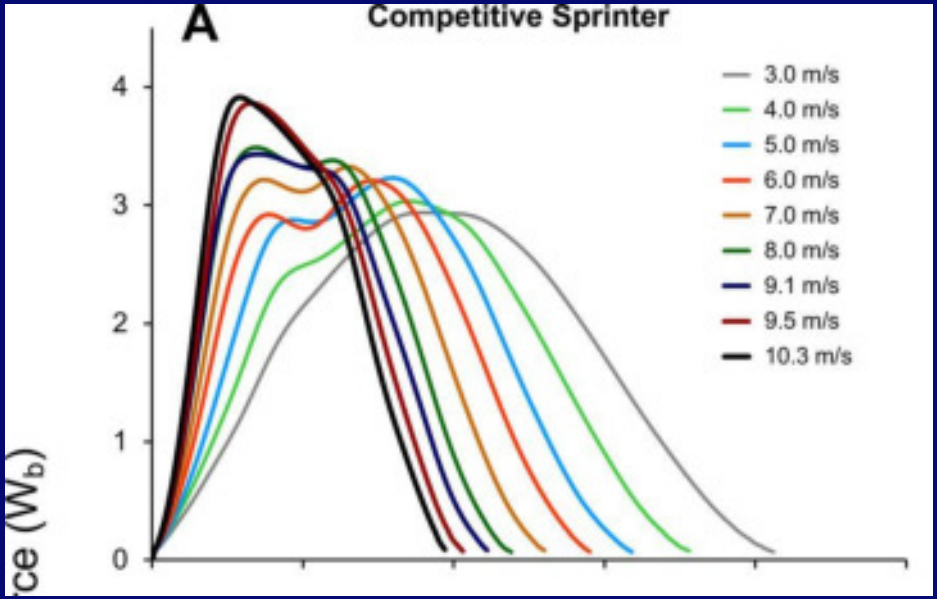


Gait Modification for Speed

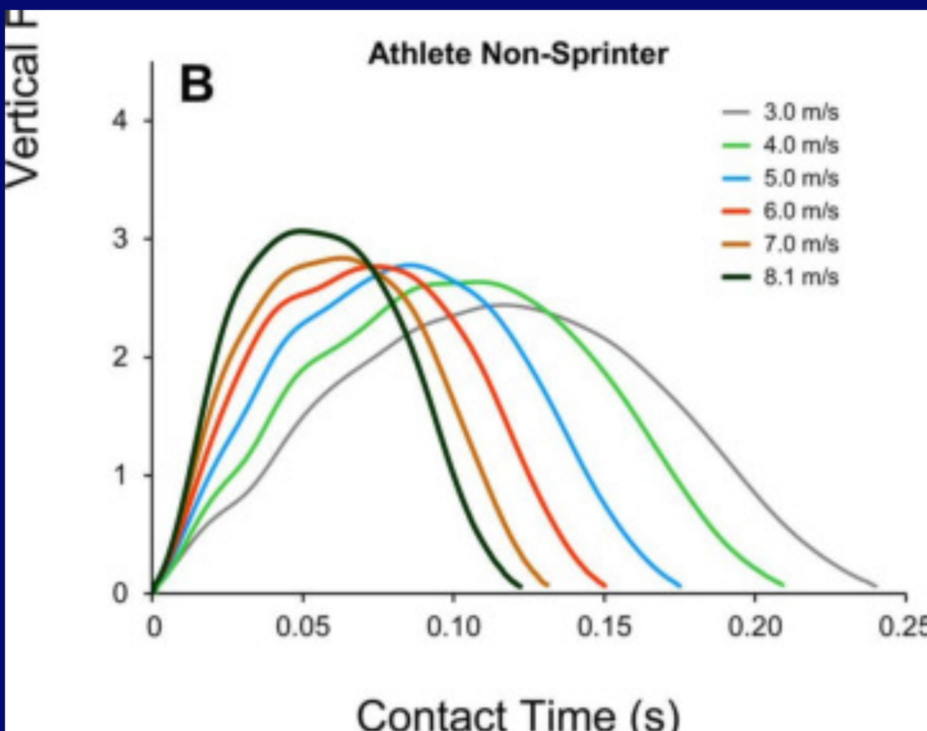
Sprinters Attack the Ground:

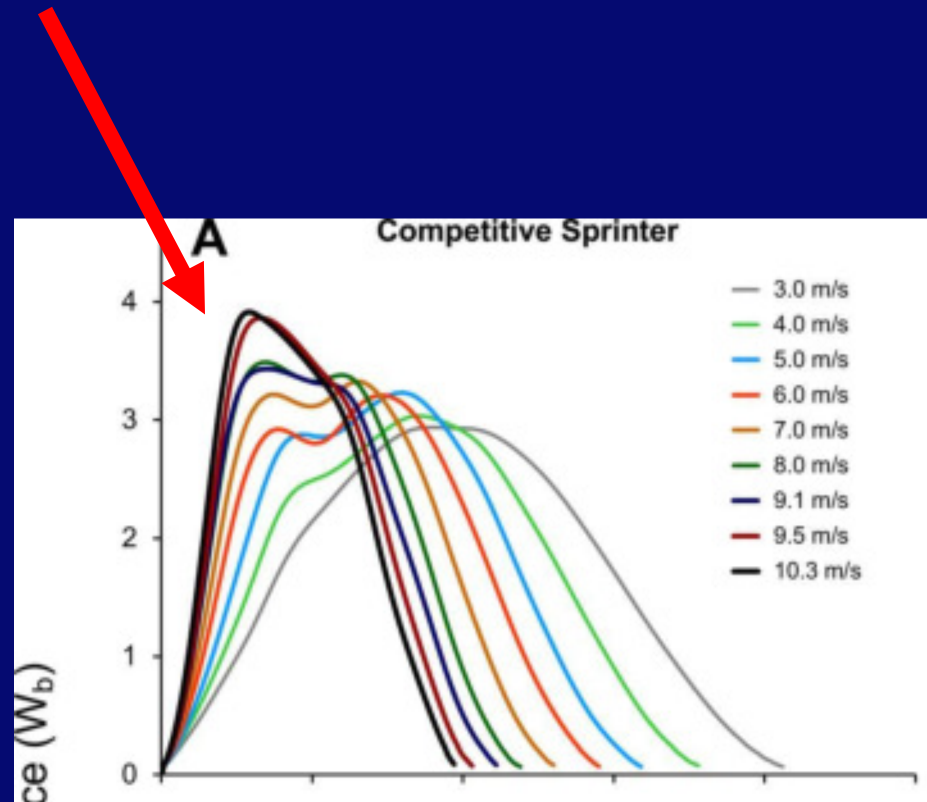
Force-time patterns at different speeds





Sprinters Attack the Ground





Chair demo

Shoe demo

Same time, different motion

Sprinter vs. Non-sprinter

Olympic Sprinter
23.0 mph

Athlete Non-Sprinter
19.0 mph

Two-Mass Model:
The general link: motion and force during running

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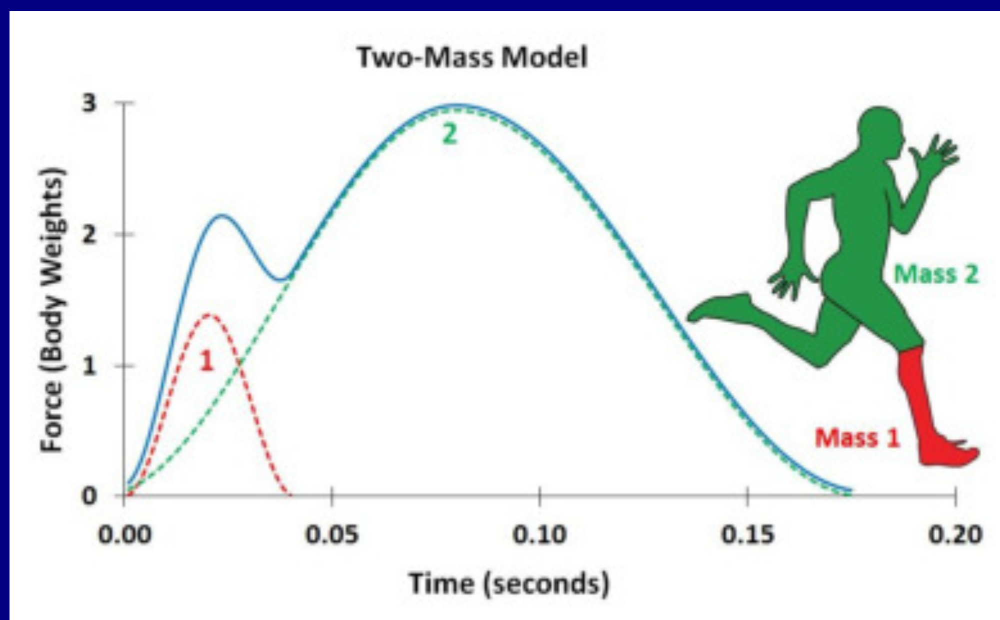
RESEARCH ARTICLE

A general relationship links gait mechanics and running ground reaction forces

Kenneth P. Clark[1,2], Laurence J. Ryan[1] and Peter G. Weyand[1,*]



Three Inputs: 1) Contact time, 2) aerial time, 3) ankle motion

Two-mass Model:
Attacking the Ground

Two-Mass Model: The general link: motion and force during running

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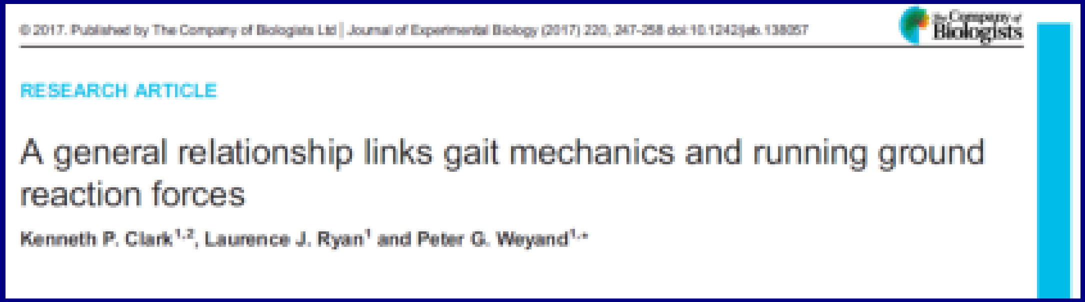
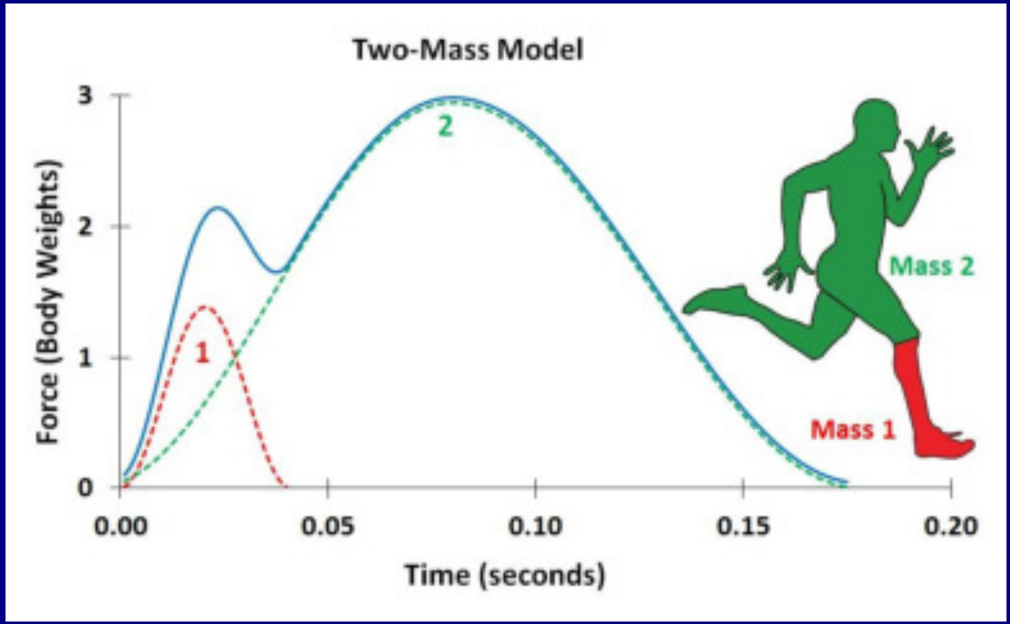




Three Inputs: 1) Contact time, 2) aerial time, 3) ankle motion

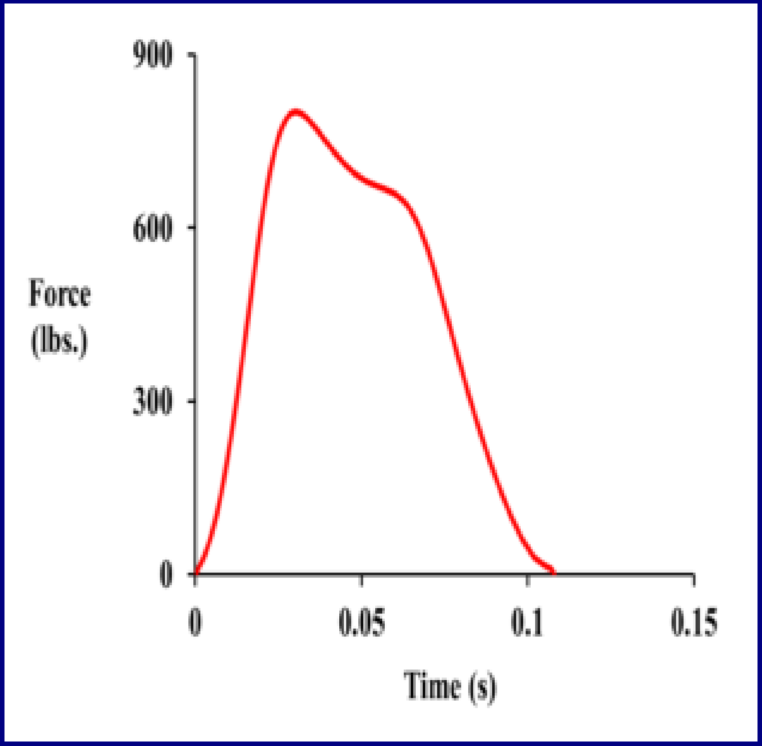
Motion to Force Applications: Two-Mass Model

MOTION

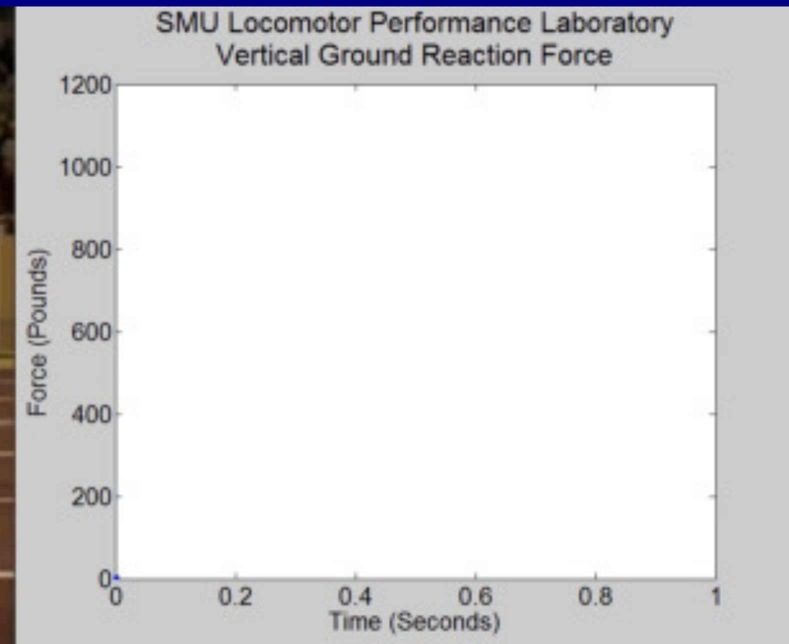
FORCE

Video

Sensors



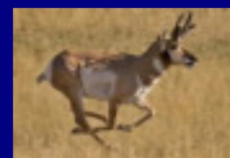
So What?



From Motion to Force

(contact time, aerial time, ankle velocity)

SPRINT PERFORMANCE CONCLUSIONS



1) Top Speed <u>swing</u> & <u>aerial</u> times: *NOT DIFF*

2) Faster athletes: *GREATER FORCE/MASS*

3) Big ground forces: IMPACT DECELERATION