TESTING, CÓMO VALORAR EN EL DEPORTE

V. JORNADAS DE ACTUALIZACIÓN EN RENDIMIENTO DEPORTIVO

28 de Septiembre de 2018

Facultad de Educación y Deporte (UPV/EHU). Aula Magna. Portal de Lasarte, 71 - Vitoria-Gasteiz

TESTING ATHLETES: the real challenge

Example with « force » measurements during sprinting

Pr J-B Morin

jbmorin.net

SPORTS PERFORMANCE RESEARCH INSTITUTE, NEW ZEALAND
AN INSTITUTE OF AUT UNIVERSITY

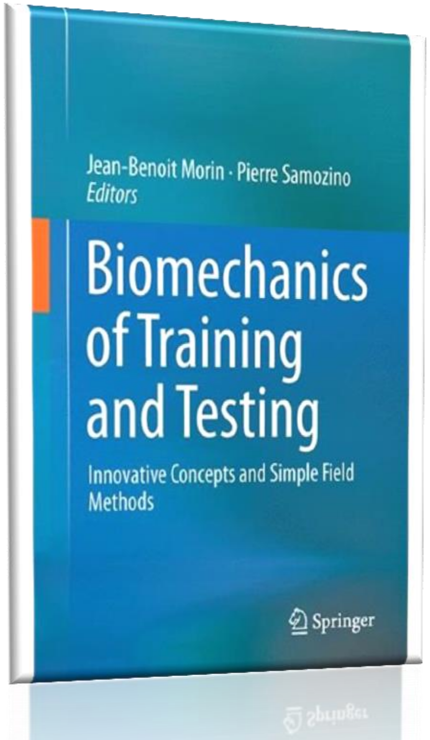
UNIVERSITÉ CÔTE D'AZUR

@jb_morin

Understand - Evaluate - Improve

OUTLINE

- **WHAT FORCE(S): from single cell to in-game data**
- **Studying human sprinting: mission impossible?**
- **From the field to the field....history of methods**
- **Next steps: muscles measurements in-situ?**



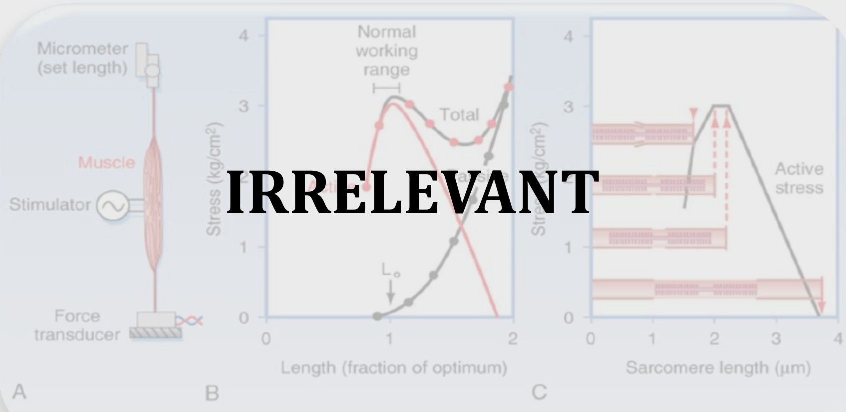
ResearchGate

@jb_morin

MANY DIFFERENT « FORCES »

Not all « forces » are made equal…from single cell to sport contexts

Isolated Muscle-Fiber
In vitro



Koeppen & Stanton: Berne and Levy Physiology, 6th Edition.

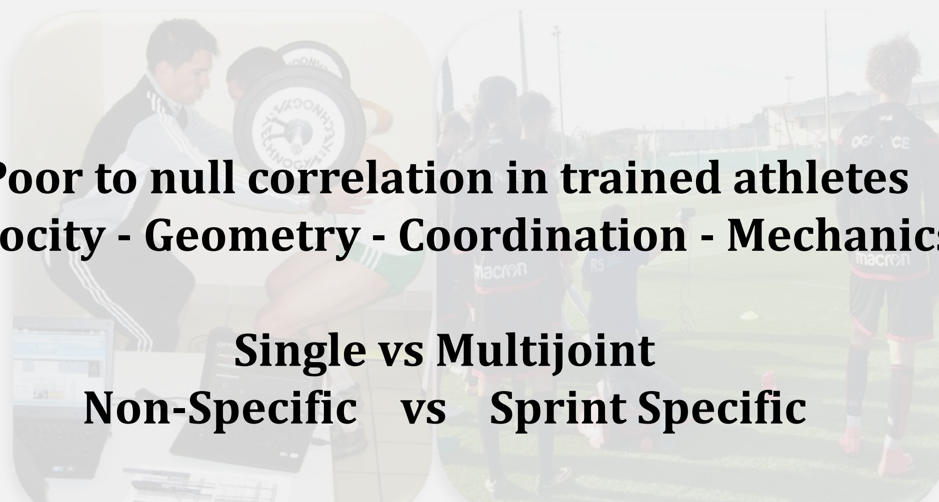
IRRELEVANT

Muscle Group Single Joint
In vivo I

DIFFERENT

INFO

Global Jump & Sprint Movements
In vivo II



Poor to null correlation in trained athletes
Velocity - Geometry - Coordination - Mechanics

Single vs Multijoint
Non-Specific vs Sprint Specific

In-Game Output
In Situ

IMPOSSIBLE

MISSION: Impossible ?

1 second….12-m

WHY SHOULD WE STUDY « FORCE » DURING SPRINTING?

Understand

Performance
determinants

Improve

Performance
Training
Injury Management

Historical perspective

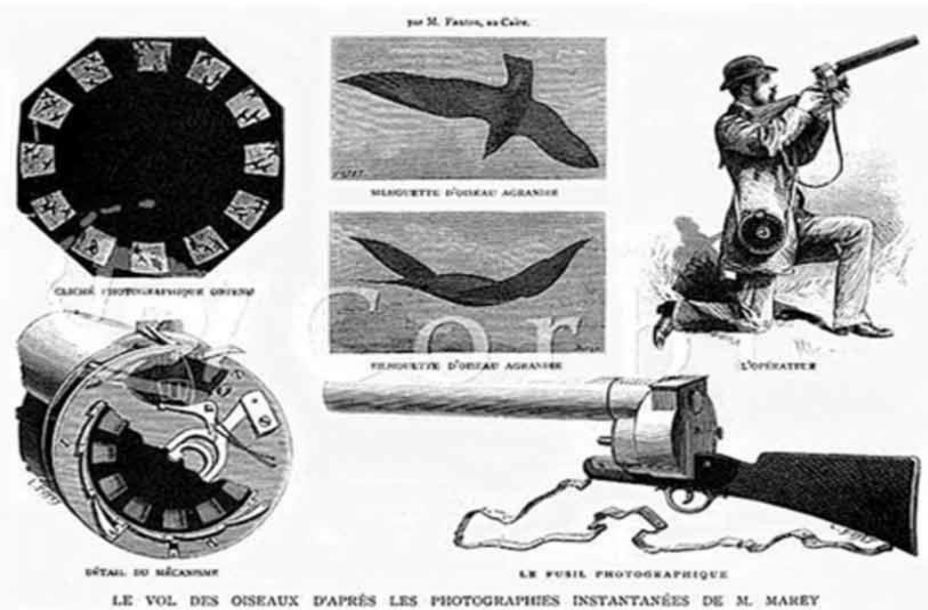

FROM THE FIELD…
TO THE LAB…
TO THE FIELD…

Experimental Challenge

E-J Marey, 1882

Chronophotographic "gun", *24 frames per second*

First « Kinematics » ✓



EXPERIMENTAL CHALLENGE

1927: AV.. Hill, K. Furusawa

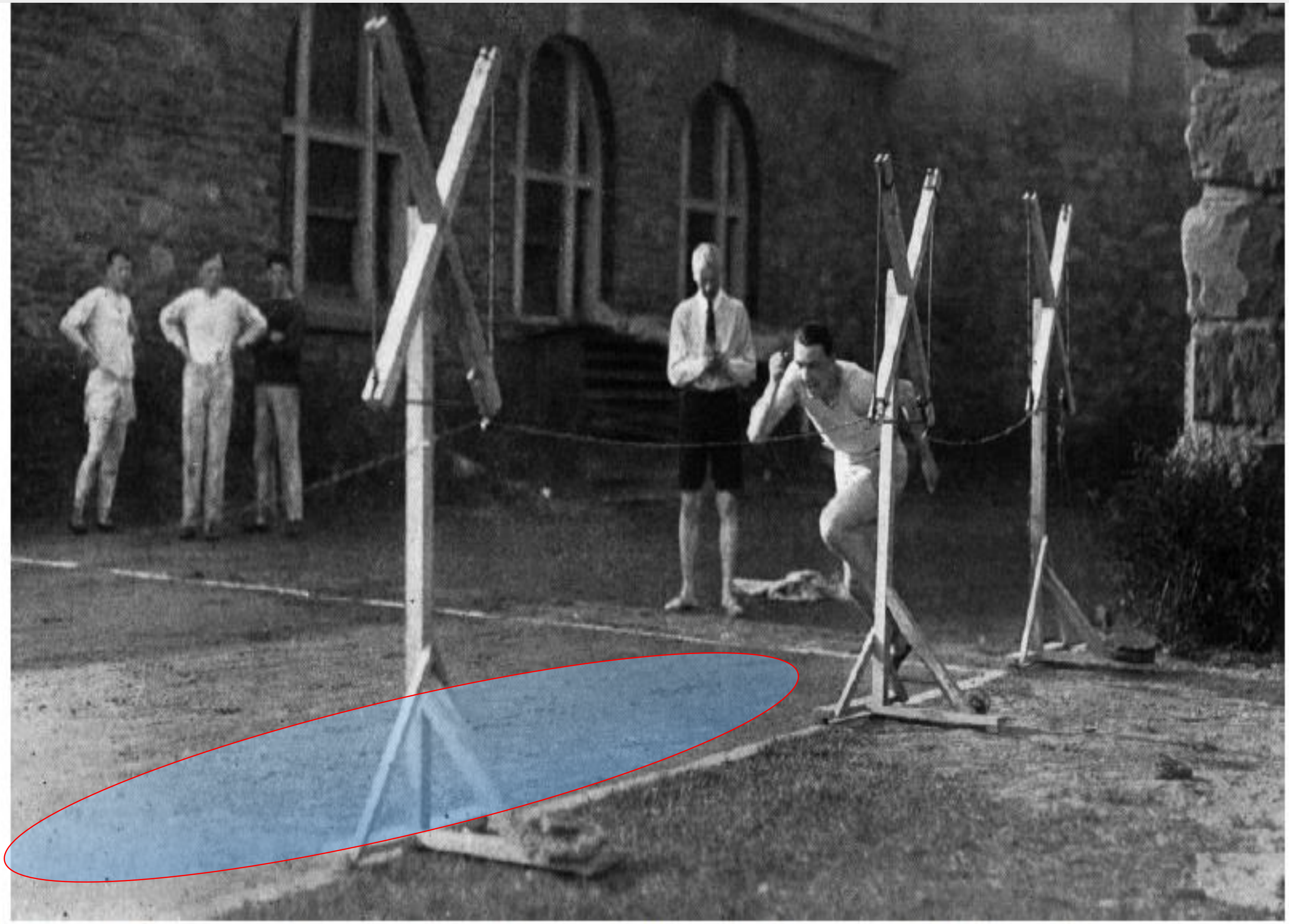
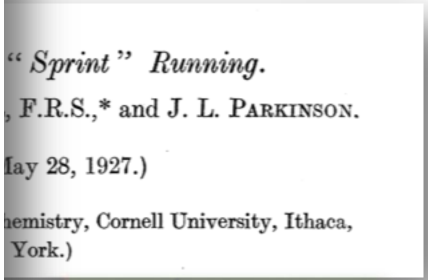


Fig. 12. Testing the acceleration of sprinters at Cornell University, Ithaca, NY, in the spring of 1927, when Hill was completing the George Fisher Baker lectureship in chemistry. The large coils of wire were used to detect a magnet worn by the runner as he sprinted past them. Velocity and acceleration were calculated by knowing the distance between the wire coils. From Hill's *Muscular Movement in Man* (55).

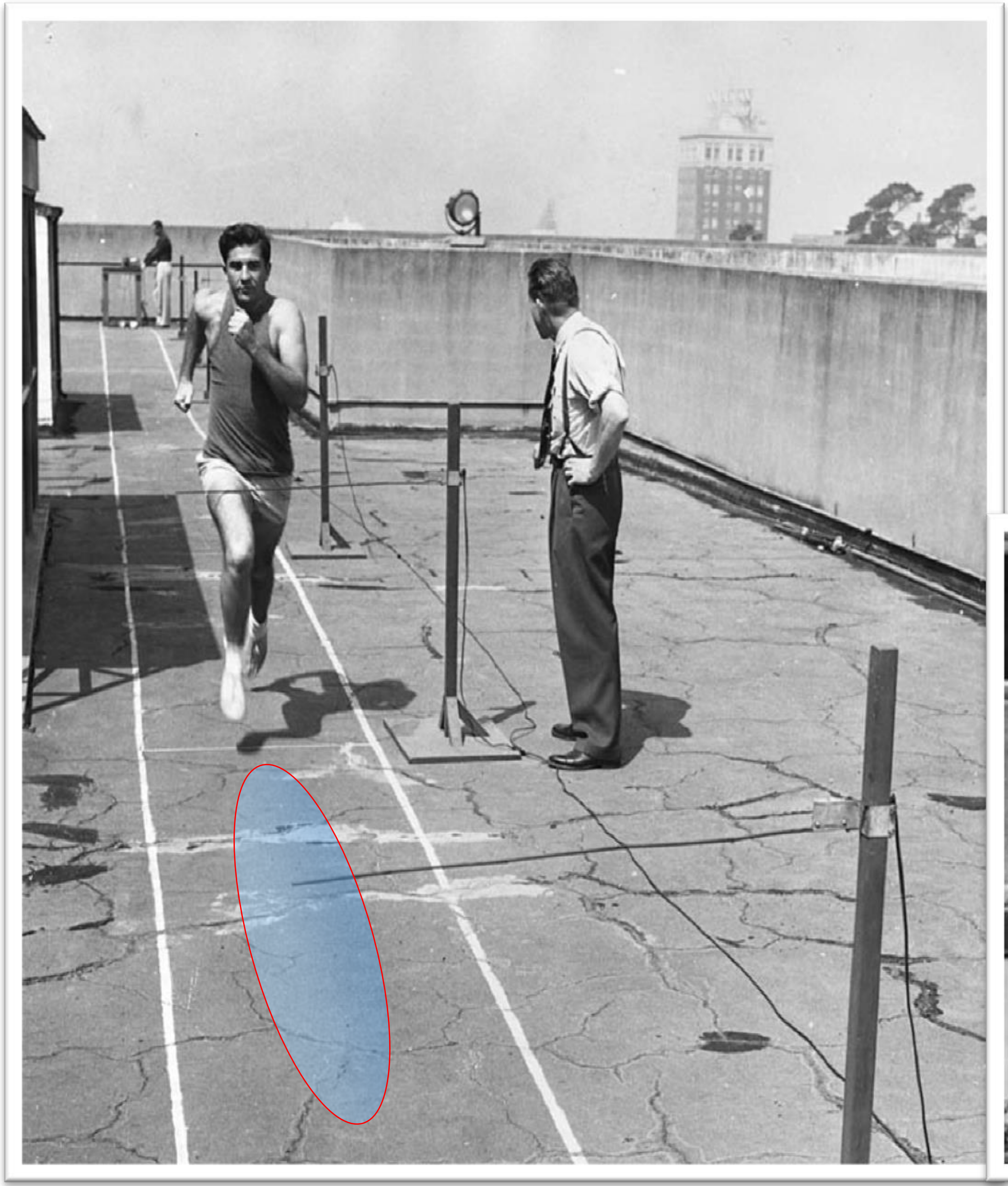


" Sprint " Running.
, F.R.S.,* and J. L. PARKINSON.
lay 28, 1927.)
hemistry, Cornell University, Ithaca,
York.)

« Kinematics » ✓

Kinetics ✗

EXPERIMENTAL CHALLENGE



1950's, F. Henry

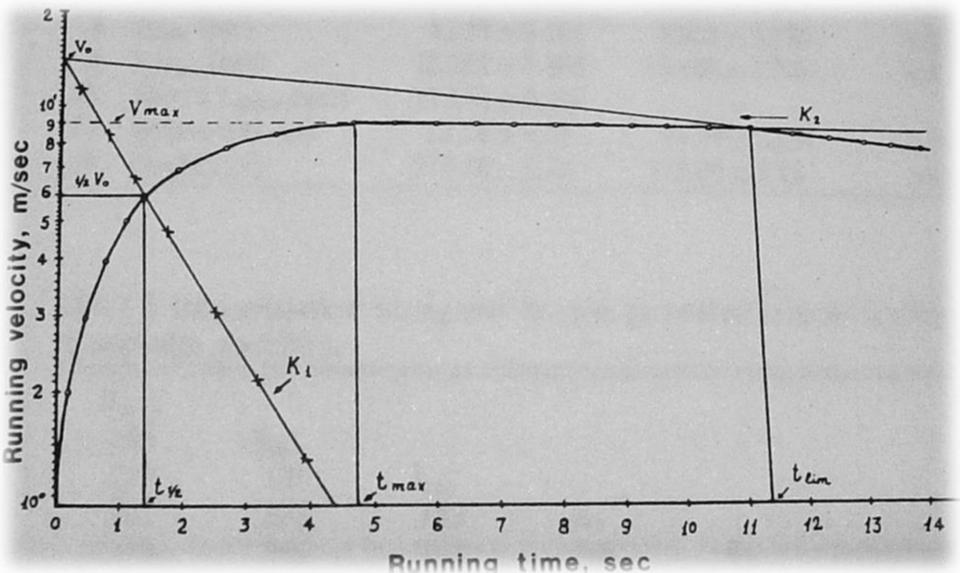
Kinematics ✓

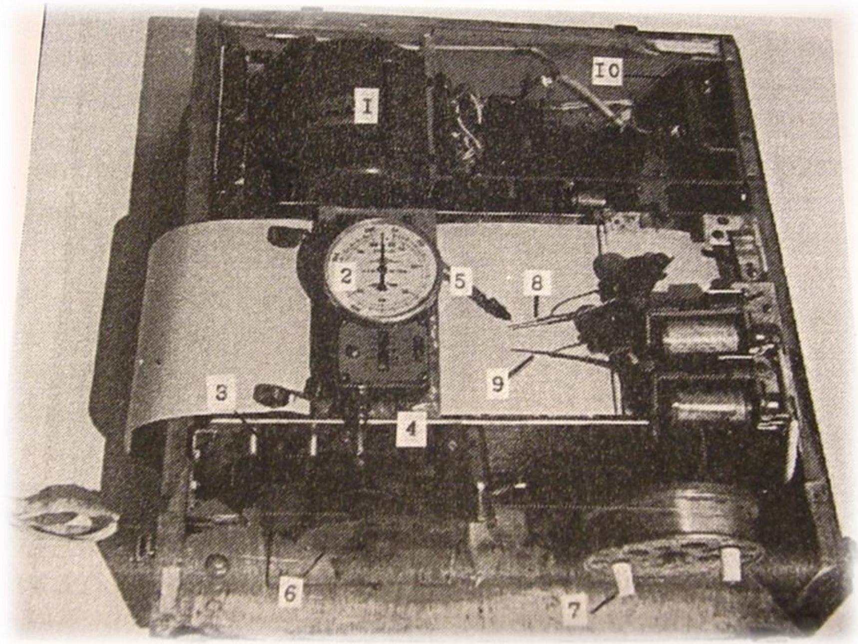
Kinetics ✗

Experimental Challenge

« Velocity-Time curves »

1979: N. Volkov





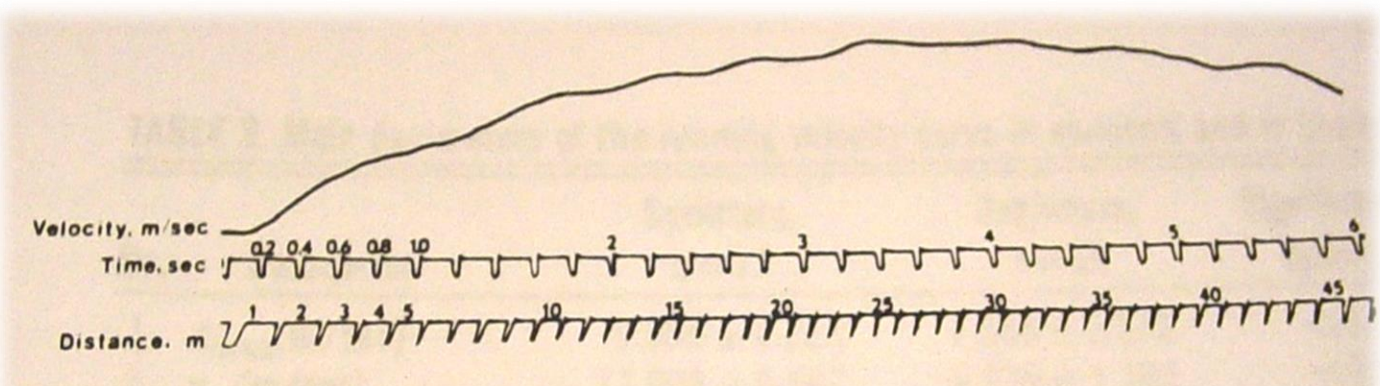


Figure 2–Speedogram of sprint running.

Kinematics ✓

Kinetics ✗

Experimental Challenge

Kinetics

2-3 steps

1971: first “steps” by Cavagna et al.

J. Physiol. (1971), 217, pp. 709–721 709
With 5 text-figures
Printed in Great Britain

THE MECHANICS OF SPRINT RUNNING

By GIOVANNI A. CAVAGNA, L. KOMAREK and STEFANIA MAZZOLENI

From the Istituto di Fisiologia Umana dell'Università di Milano e Centro di Studio per la Fisiologia del Lavoro Muscolare del C.N.R., Milano, Italy

(*Received 3 May 1971*)

METHODS

Procedure and apparatus. The experiments were made on three male subjects 19–22 yr old, the body weight being 66–70 kg and the height 1·72–1·76 m. The subjects were trained sprinters; they ran in an indoor track 56 m long. A strain-gauge platform (4 × 0·5 m), sensitive to the forward and the vertical component of the push exerted by the foot was inserted, with its surface at the level of the floor, 30 m from the beginning of the corridor. The subjects did several runs on different days starting at various distances from the platform; they always exerted their maximum effort. Care was taken to avoid fatigue. Two photocell sights were placed 3 m apart at the platform level to measure the speed of the trunk. To prevent skidding the subjects wore gym shoes.

The platform has a natural frequency of 42 c/s in the forward and 30 c/s in the vertical direction. The maximum difference of its electrical response to a given force applied on different points of its surface is 10 % for the vertical and 12 % for the forward direction. The platform was tested up to 250 kg in the vertical and up to 100 kg in the forward direction and found to give a linear response within an average error of 5 and 7 % respectively.

Elaboration of the data. In this study the measurements were limited to the work necessary to move the centre of gravity of the body in forward direction, W_f: in fact in this direction only the speed of the body relative to the ground increases, thus possibly affecting the power of the muscles propelling the body forward. The work done against gravity, W_v, was measured occasionally for the first second from the start only (Fig. 1*a*).

The force exerted by the foot on the platform in the direction of the run is:

$$F = m.a + \text{Forces of friction} \quad (1)$$

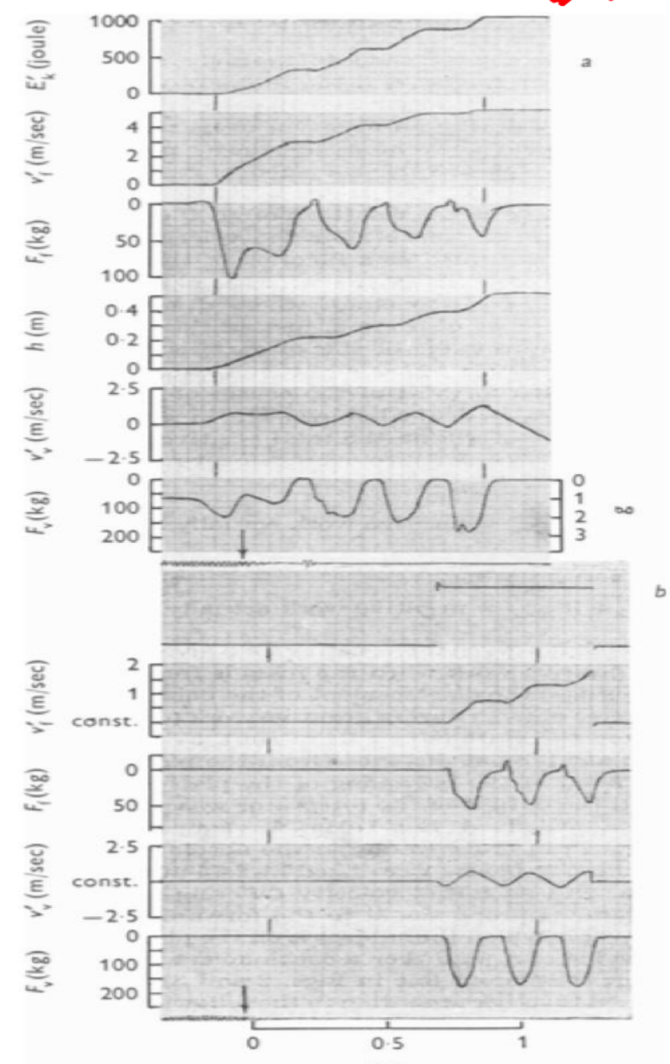


Fig. 1. For legend see opposite page.

TREADMILLS

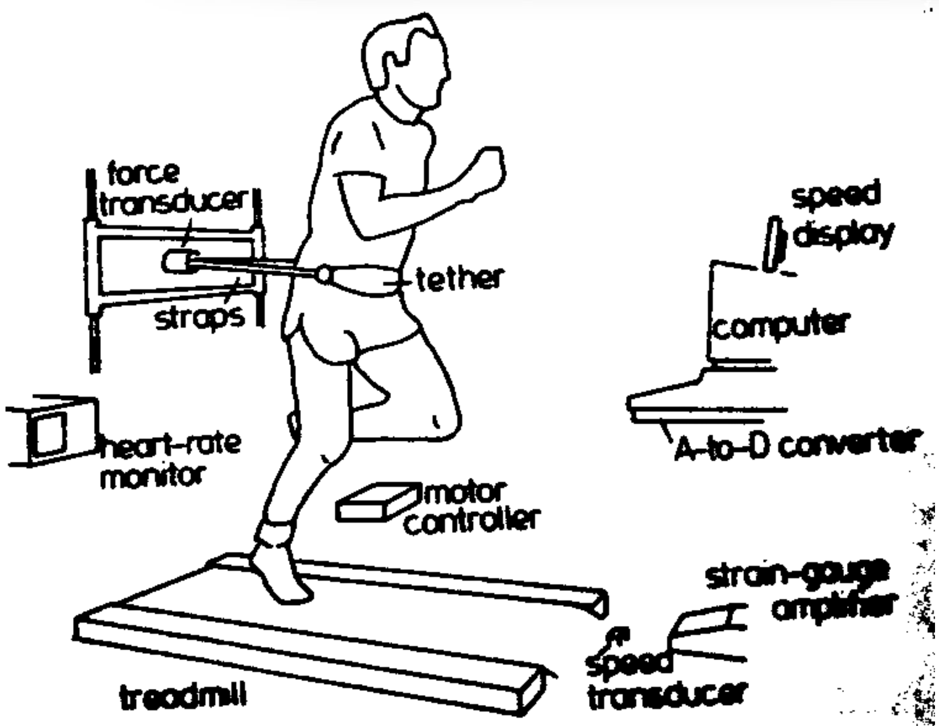
1987: H. Lakomy

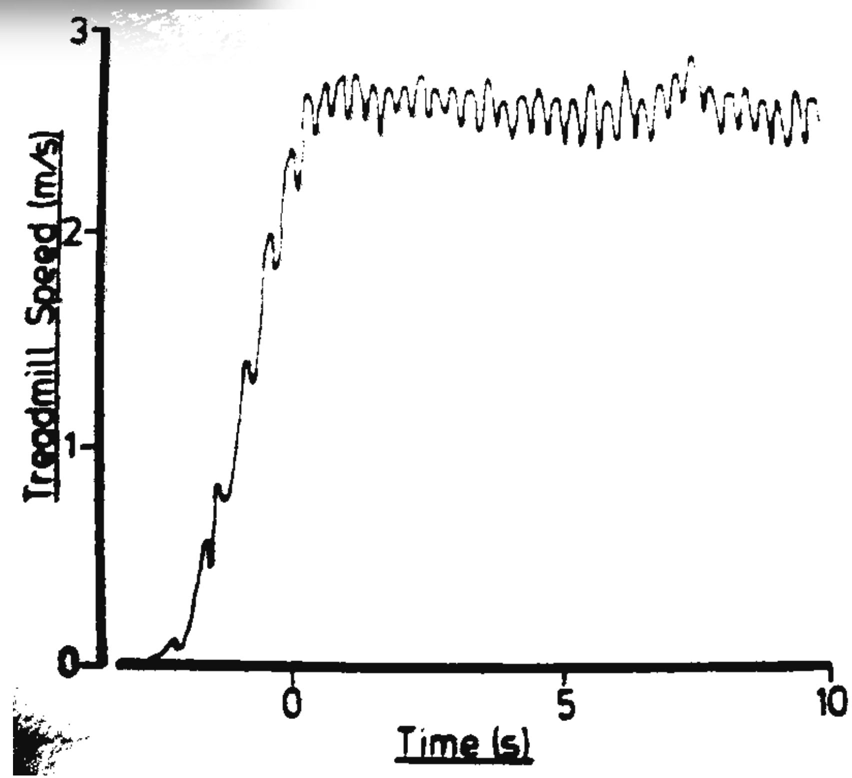
ERGONOMICS, 1987, VOL. 30, NO. 4, 627–637

The use of a non-motorized treadmill for analysing sprint performance

H. K. A. LAKOMY

Department of P. E. & Sport Science, University of Technology, Loughborough, Leics. LE11 3TU, England





TREADMILLS

2000 - …: P. Weyand and K. Clark

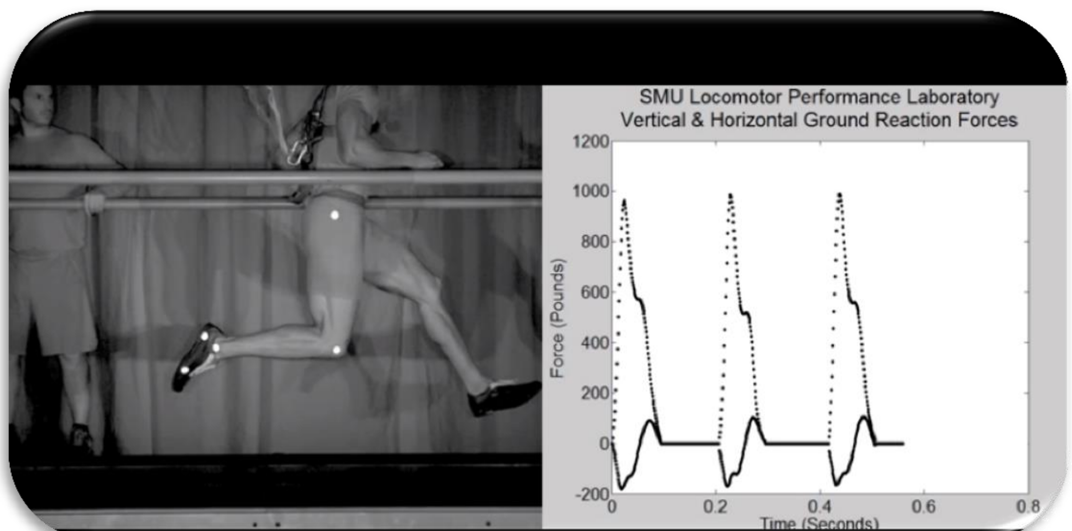
11.5 m/s !

J Appl Physiol
89: 1991–1999, 2000.

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



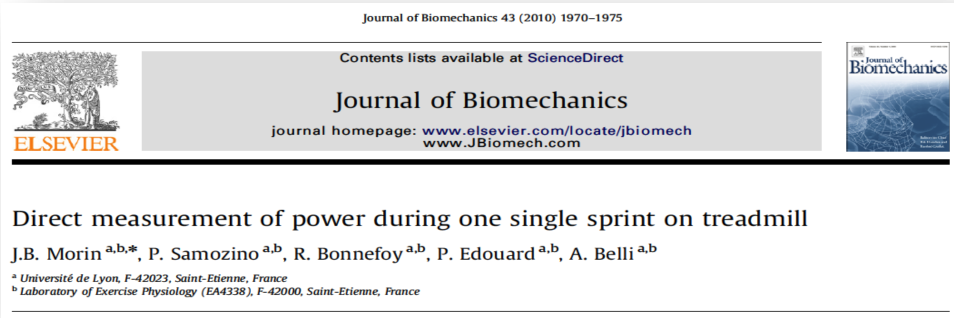
Kinetics ✓

Top Speed ✓

Acceleration ✗

TREADMILLS

2010: JB. Morin


Journal of Biomechanics 43 (2010) 1970–1975

Contents lists available at ScienceDirect

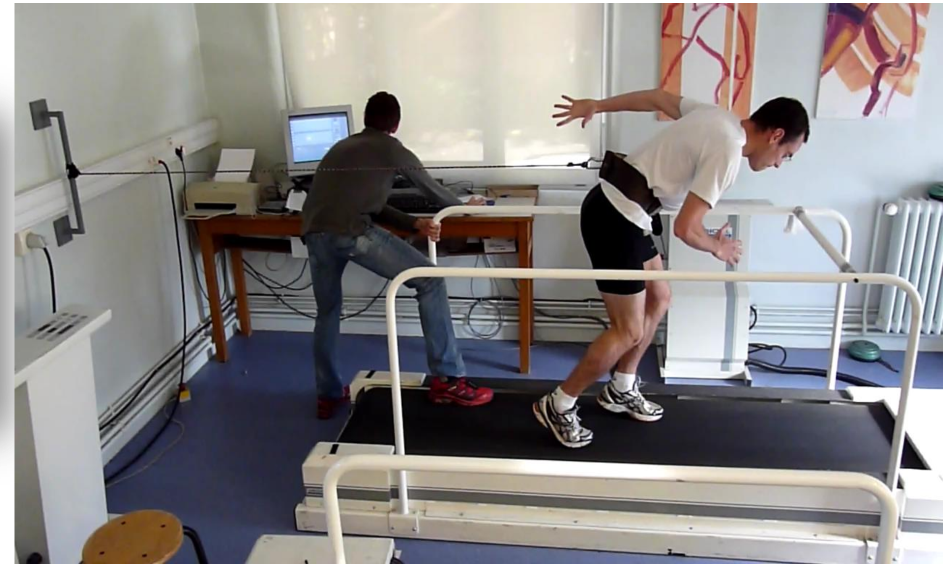
Journal of Biomechanics

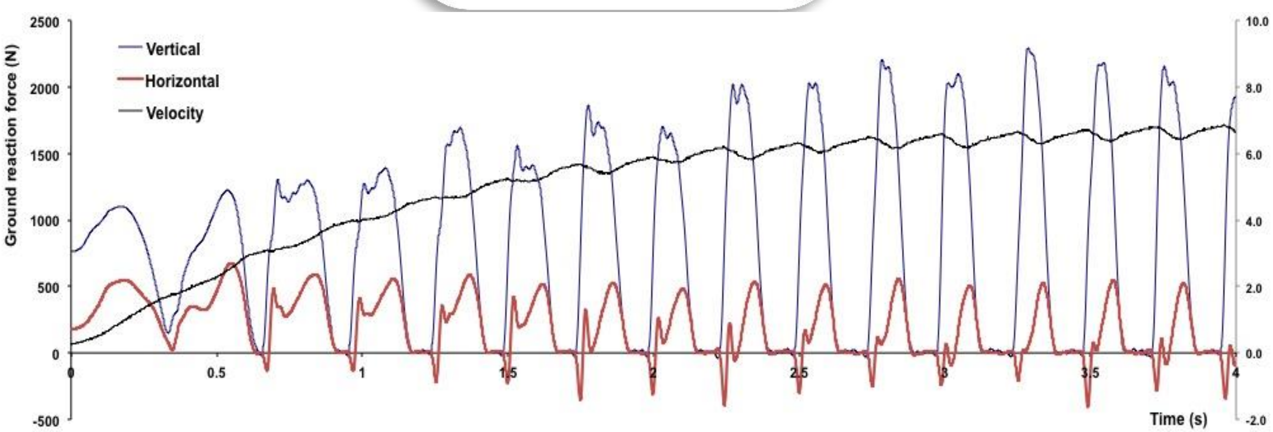
journal homepage: www.elsevier.com/locate/jbiomech
www.JBiomech.com

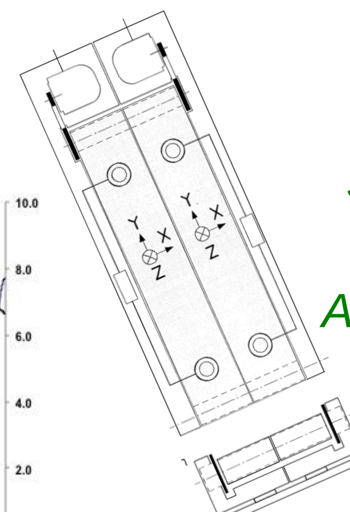
Direct measurement of power during one single sprint on treadmill

J.B. Morin [a,b,*], P. Samozino [a,b], R. Bonnefoy [a,b], P. Edouard [a,b], A. Belli [a,b]

[a] Université de Lyon, F-42023, Saint-Etienne, France
[b] Laboratory of Exercise Physiology (EA4338), F-42000, Saint-Etienne, France







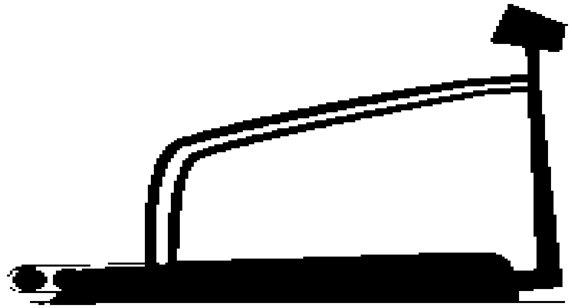
3D Kinetics ✓

Acceleration ✓

Morin et al., J Biomech, 2010 *Girard et al. J Appl Biomech, 2015*

Treadmill Data = Treadmill Conclusions?

2015: G. Rabita



Scand J Med Sci Sports 2015: ••*:* ••*–*••
doi: 10.1111/sms.12389

SCANDINAVIAN JOURNAL OF
MEDICINE & SCIENCE
IN SPORTS

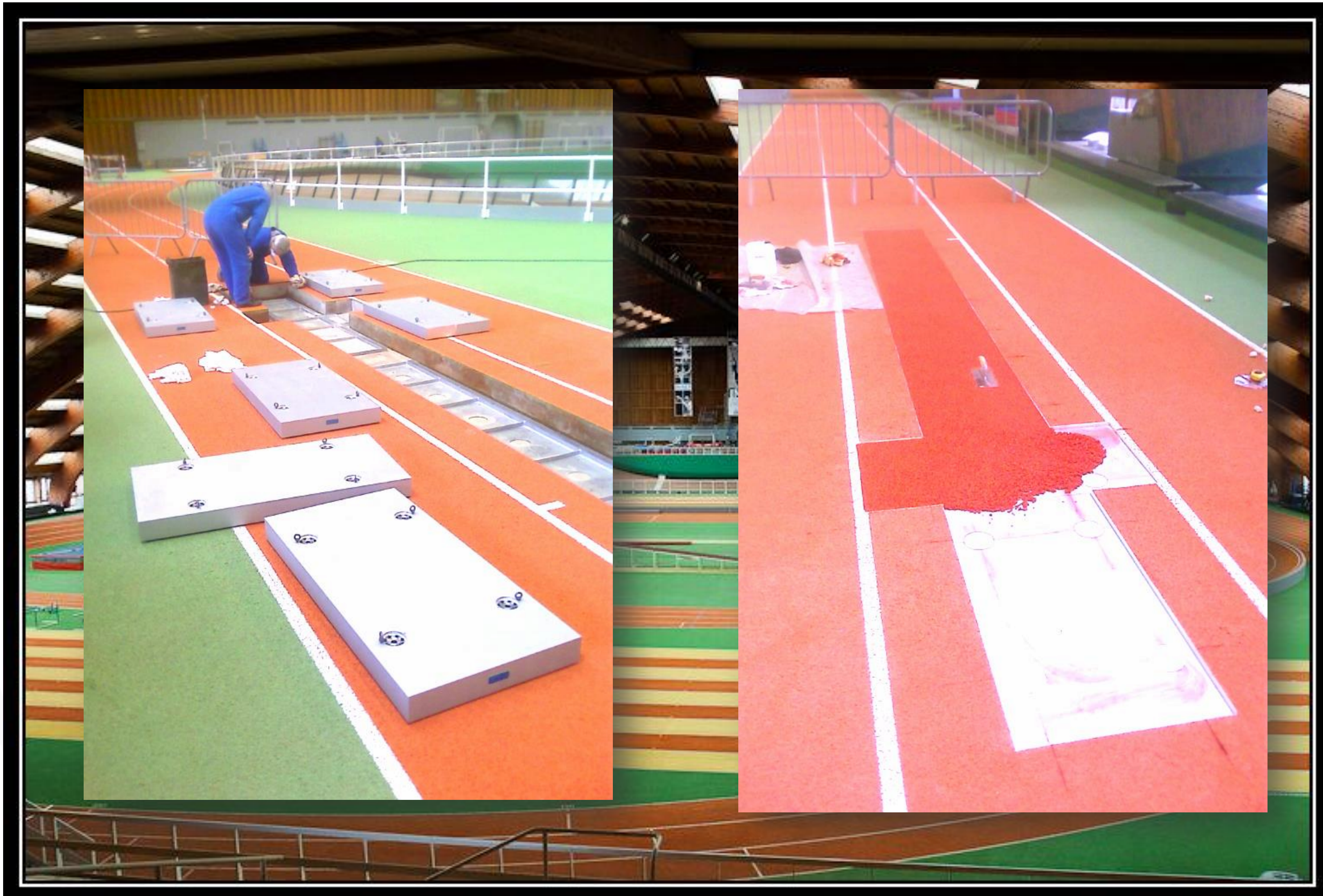
Sprint mechanics in world-class athletes: a new insight into the limits of human locomotion

G. Rabita[1], S. Dorel[2], J. Slawinski[3], E. Sàez-de-Villarreal[4], A. Couturier[1], P. Samozino[5], J-B. Morin[6]

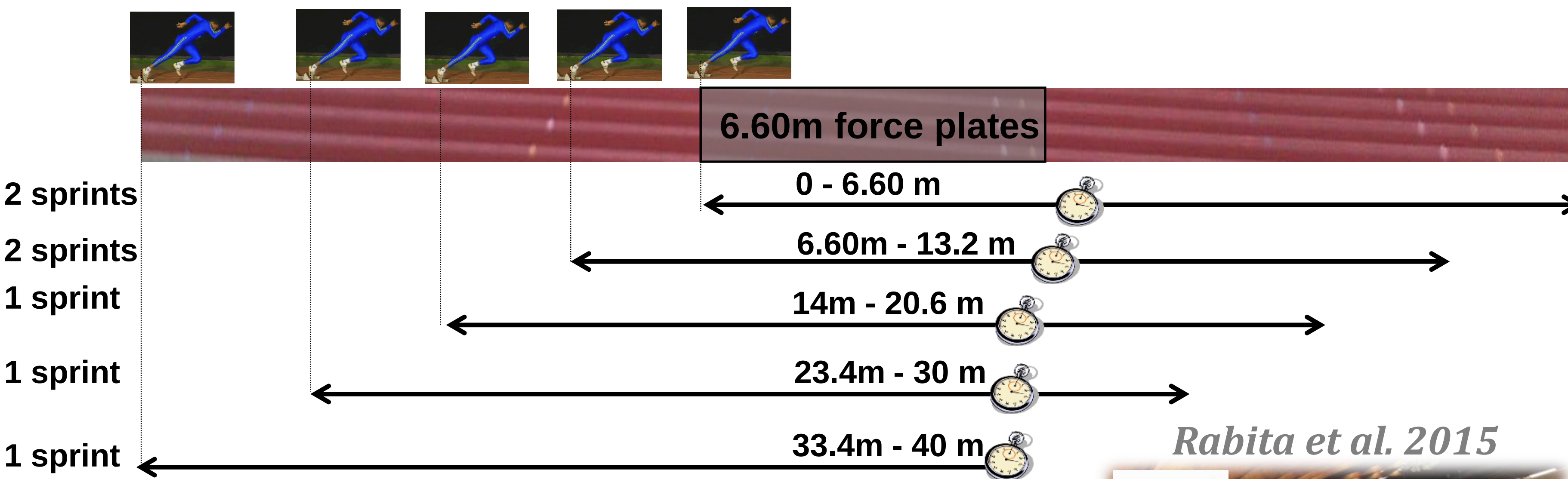
[1]Research Department, National Institute of Sport, INSEP, Paris, France, [2]Laboratory "Movement, Interactions, Performance" (EA 4334), University of Nantes, Nantes, France, [3]Research Center in Sport and Movement (EA 2931), University of Paris Ouest Nanterre La Défense, Paris, France, [4]Faculty of Sports, University Pablo de Olavide, Seville, Spain, [5]Laboratory of Exercise Physiology (EA 4338), University of Savoie, Le Bourget-du-Lac, France, [6]Laboratory of Human Motricity, Education Sport and Health (EA 6309), University of Nice Sophia Antipolis, Nice, France
Corresponding author: Giuseppe Rabita, PhD, Research Department, National Institute of Sport, INSEP, 11 Avenue du Tremblay, 75012 Paris, France. Tel: +33 (0)1 41 74 44 71, Fax: +33 (0)1 41 74 43 35, E-mail: giuseppe.rabita@insep.fr

Accepted for publication 13 November 2014

INSEP
Terre de Champions



- INSEP-Paris: 3D GRF for **18 steps over 40-m sprints**
- **9 Elite and sub-elite sprinters** (2 sub-10 s)

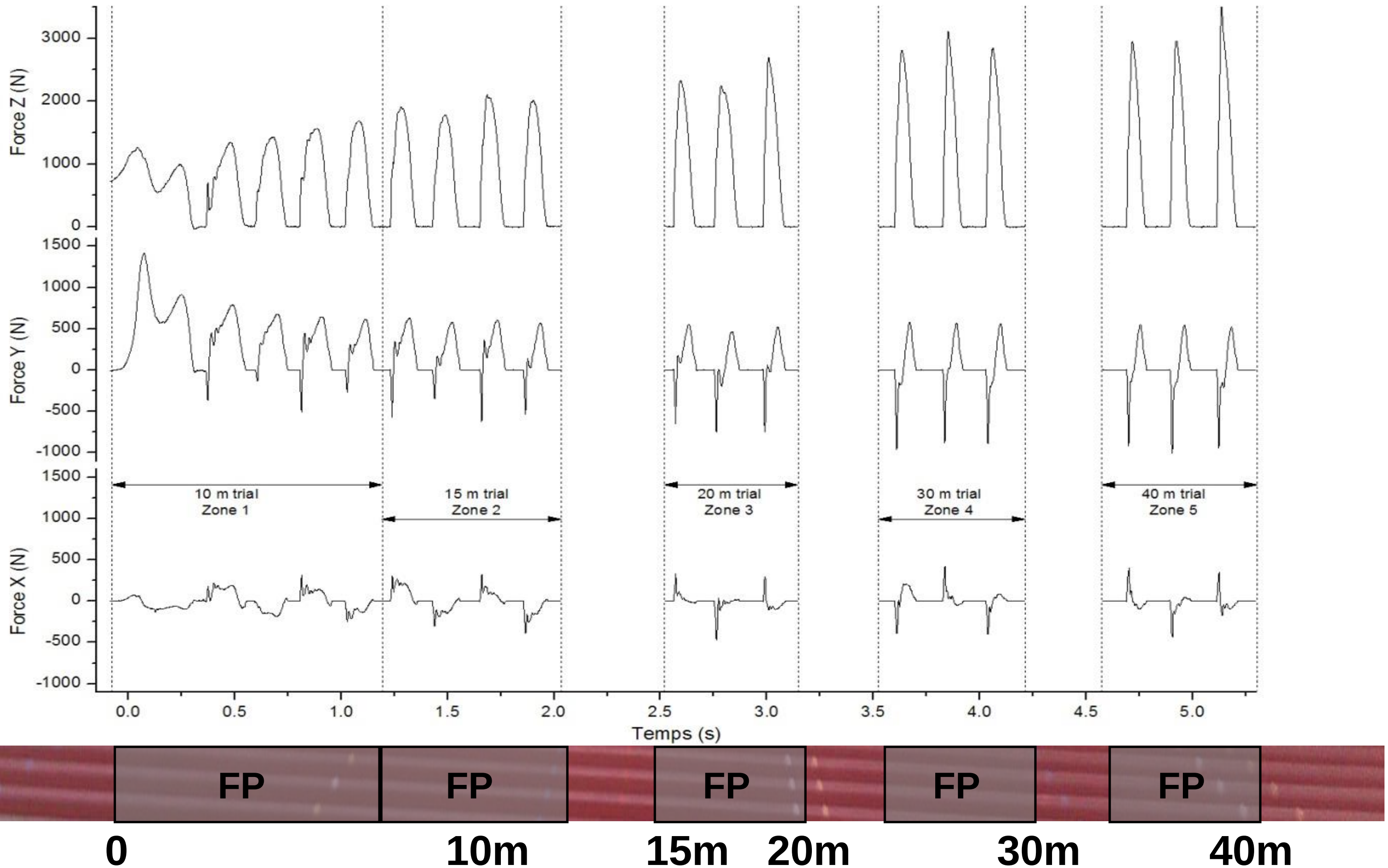


Very high reproducibility…

Rabita et al. 2015

~~Treadmill Data = Treadmill~~ Conclusions?

- INSEP-Paris: 3D GRF for **18 steps over 40-m sprints**
- **9 Elite and sub-elite sprinters** (2 sub-10 s)

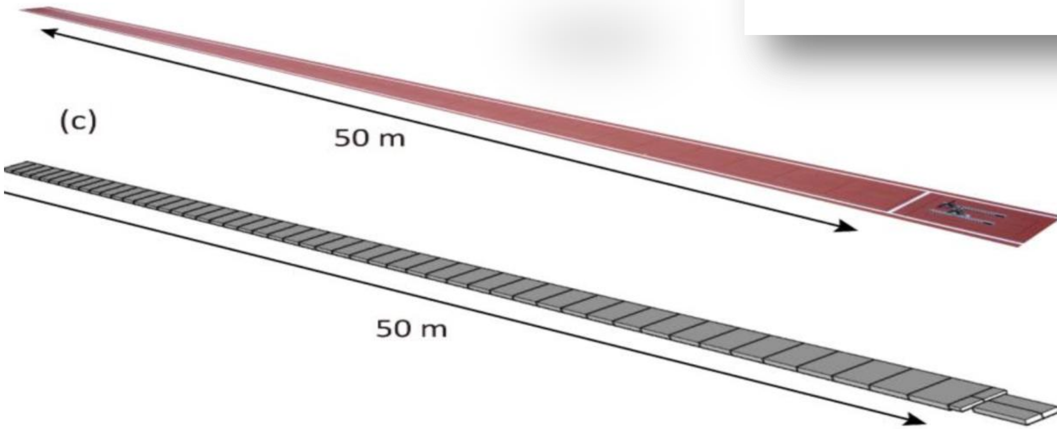


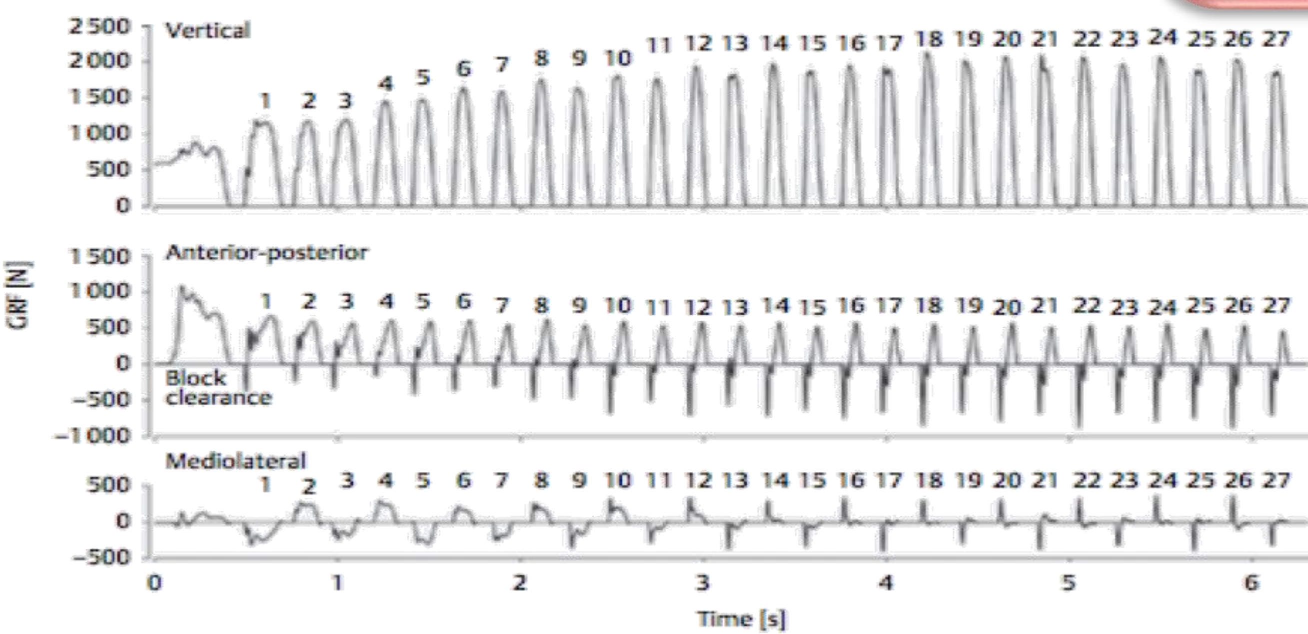
2017: R. Nagahara


Training & Testing

Thieme

Association of Step Width with Accelerated Sprinting Performance and Ground Reaction Force





2017-2018: Groundbreaking analyses

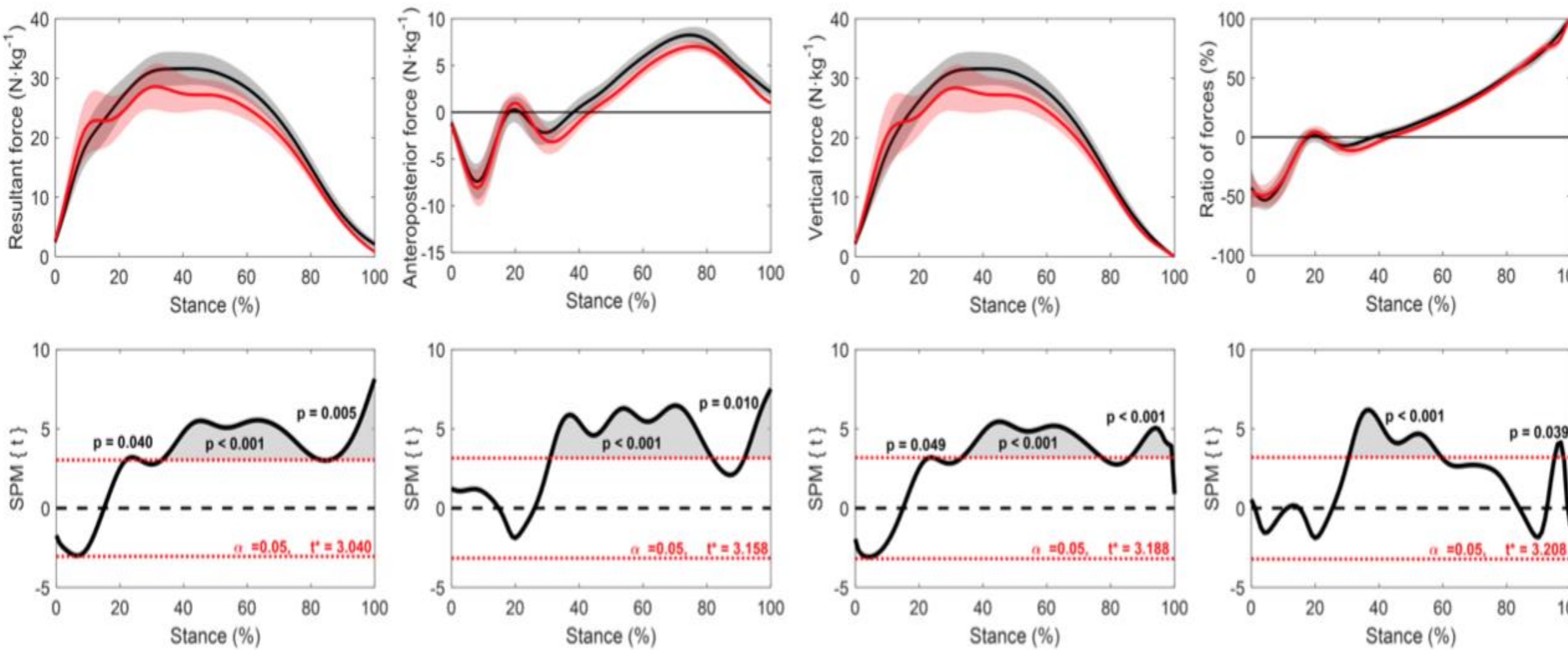
How sprinters accelerate beyond the velocity plateau of soccer players: waveform analysis of ground reaction forces

Steffi L. Colyer[1,2], Ryu Nagahara[3], Yohei Takai[3] and Aki I.T. Salo[1,2]

Colyer, Nagahara, Salo

SPM (Statistical Parametric Mapping): INTRA-STANCE !

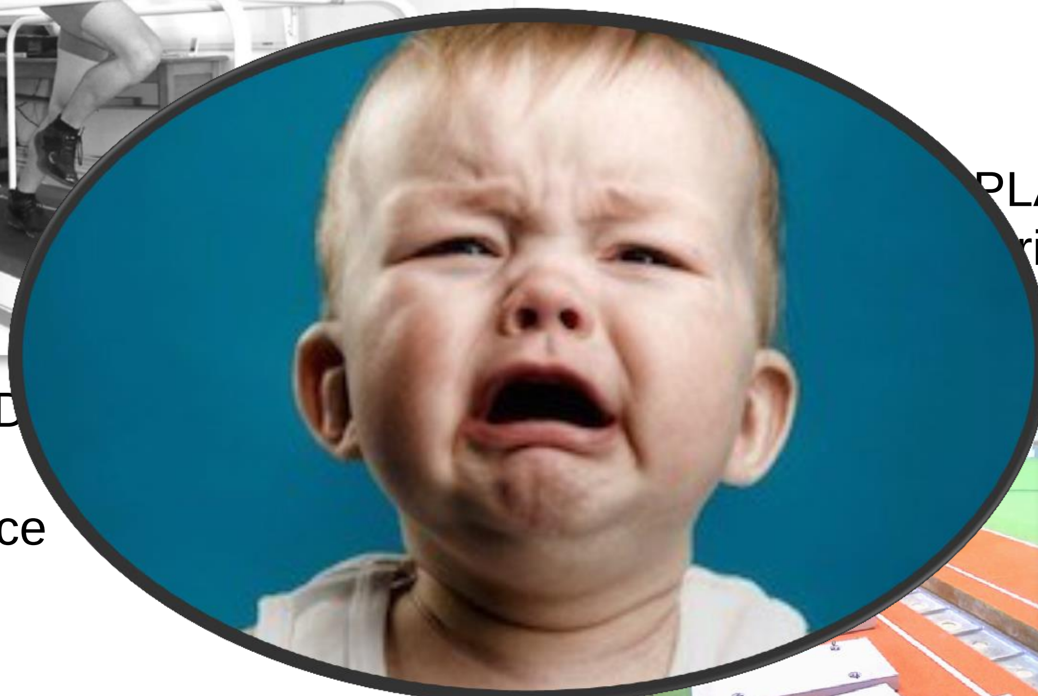
Soccer vs Sprinters



SJMSS Sept 2018

In summary: Two (im)possibilities

INSTRUMENTED
TREADMILL
St-Etienne, France
Doha, Qatar



PLATES
ris, France
pan (50m+)

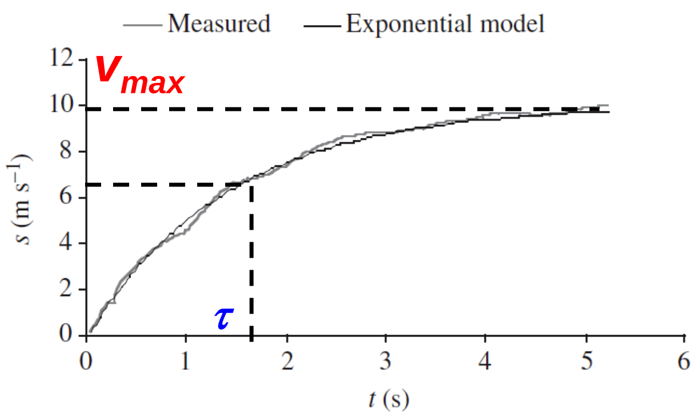
2016: P. Samozino

Scand J Med Sci Sports 2015: ••: ••–••
doi: 10.1111/sms.12490

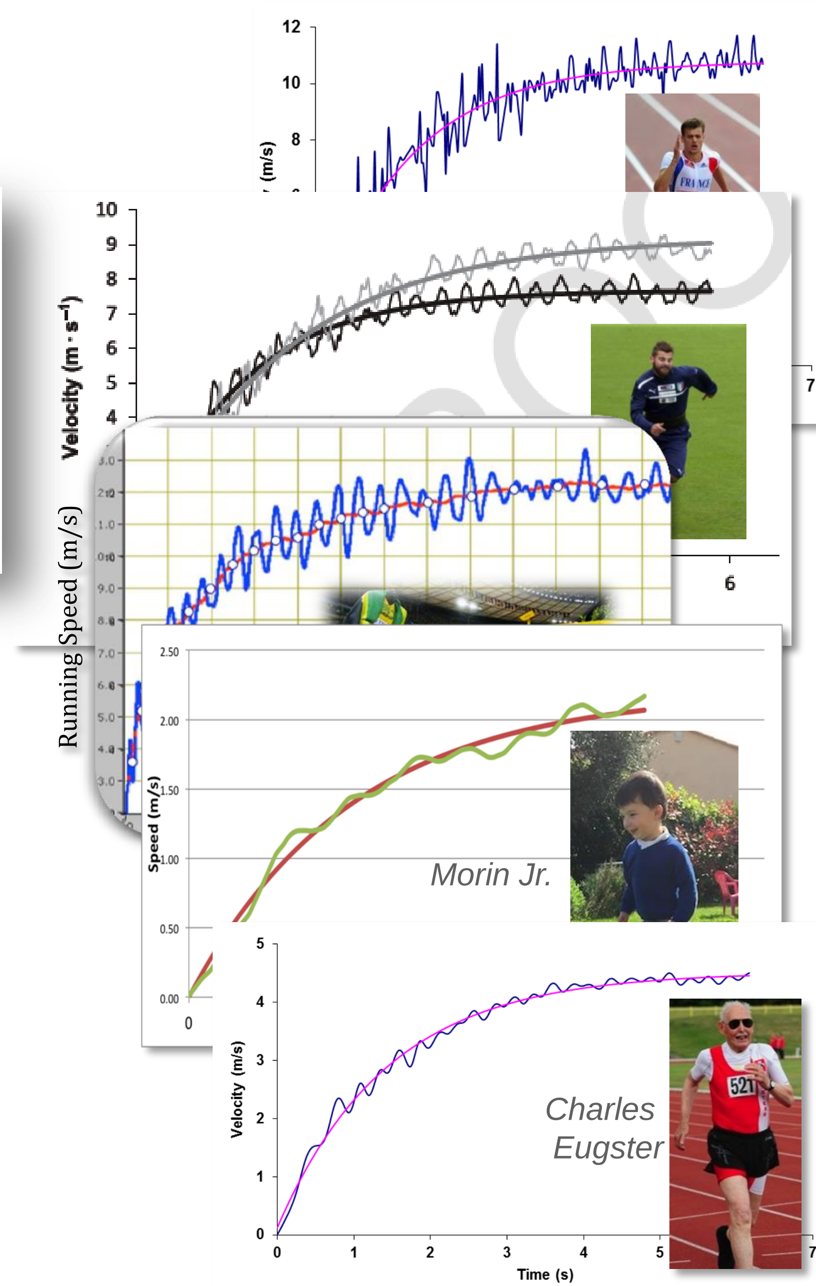
SCANDINAVIAN JOURNAL OF MEDICINE & SCIENCE IN SPORTS

A simple method for measuring power, force, velocity properties, and mechanical effectiveness in sprint running

P. Samozino[1], G. Rabita[2], S. Dorel[3], J. Slawinski[4], N. Peyrot[5], E. Saez de Villarreal[6], J.-B. Morin[7]

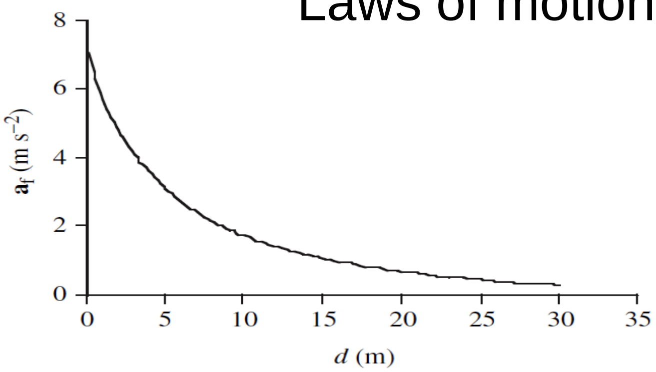


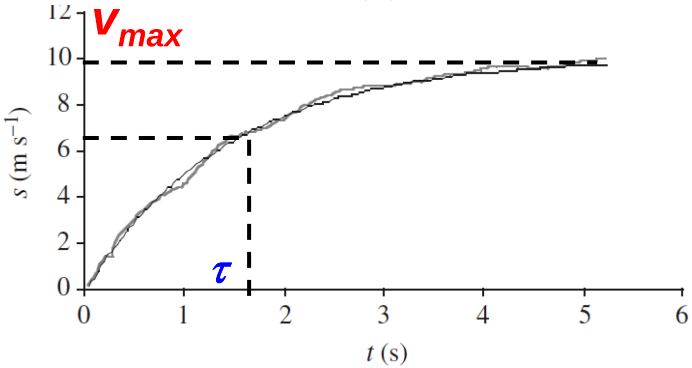
$$v(t) = v_{max}.(1-e^{(-t/\tau)})$$

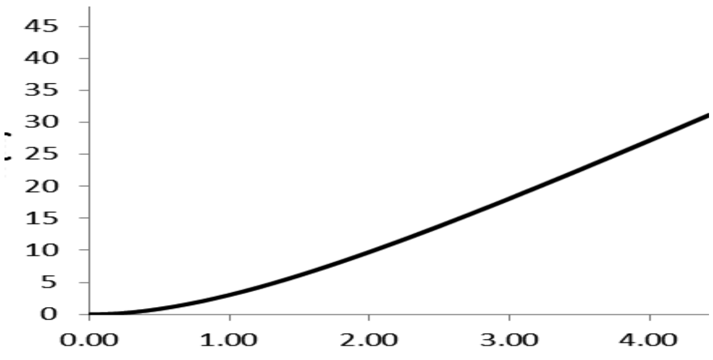


di Prampero et al., 2015

Laws of motion (Newton)...



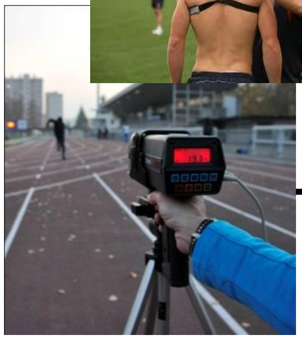




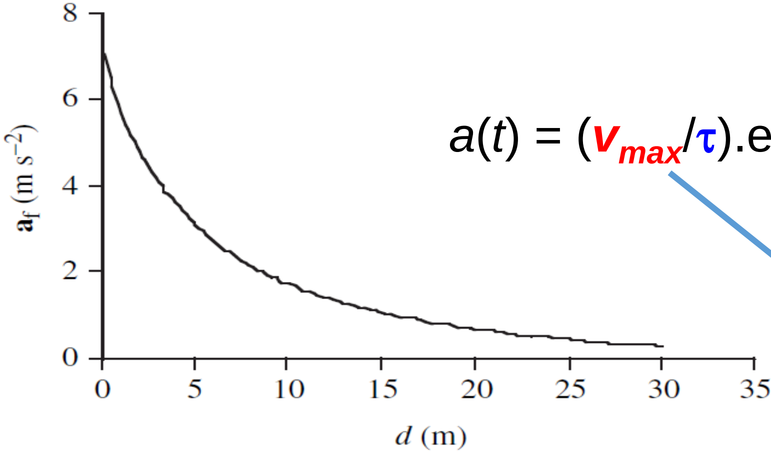
$$a(t) = (v_{max}/\tau).e^{(-t/\tau)}$$

$$v(t) = v_{max}.(1-e^{(-t/\tau)})$$

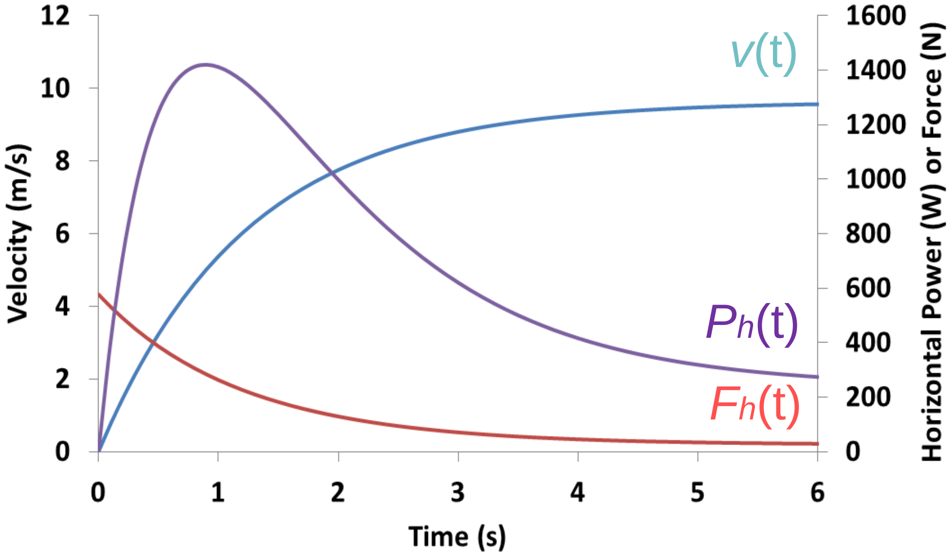
$$x(t) = v_{max}.(t + \tau.e^{(-t/\tau)}) - v_{max}.\tau$$



OR



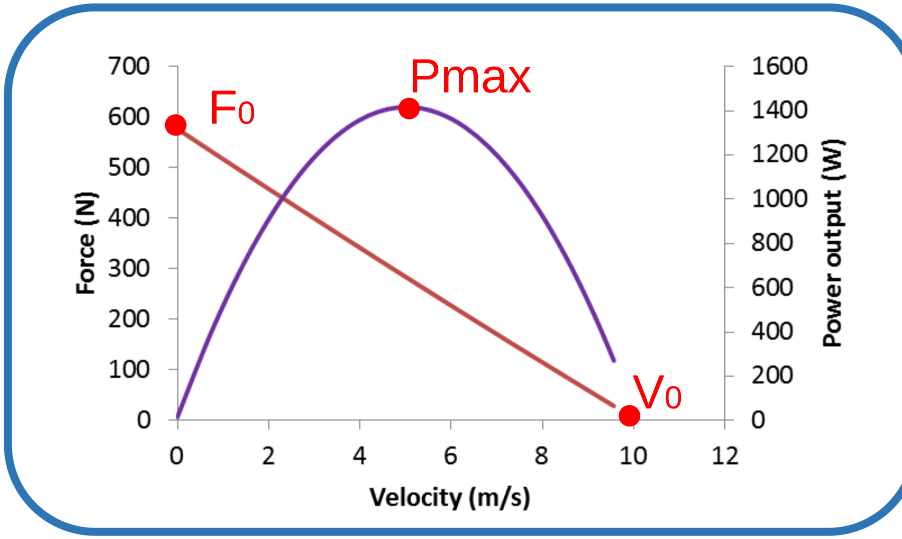
$$a(t) = (v_{max}/\tau).e^{(-t/\tau)}$$



$$F_h(t) = m.a(t) + \boxed{F_{air}}$$

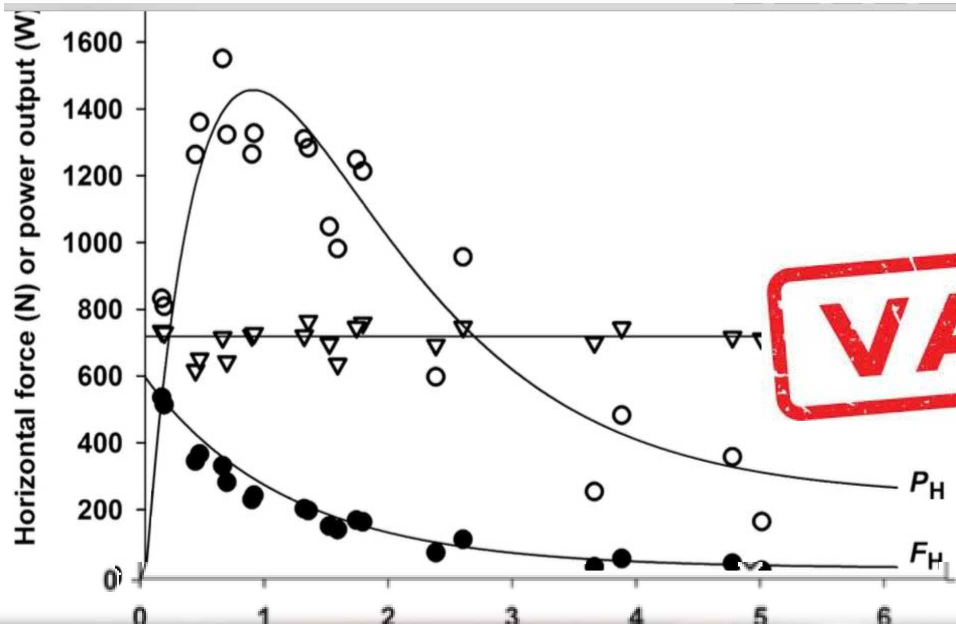
Estimated from height, mass and air charact.

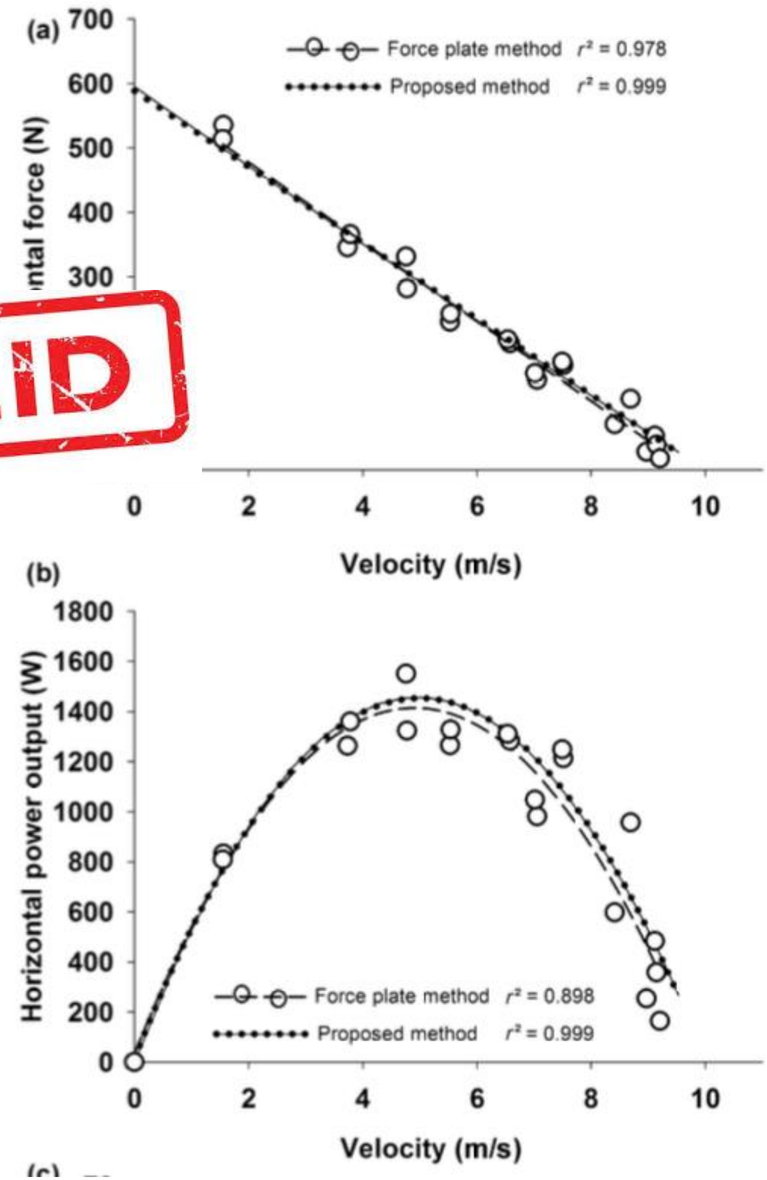
$$P_h(t) = F_h(t) \,.\, v(t)$$



Validity ??

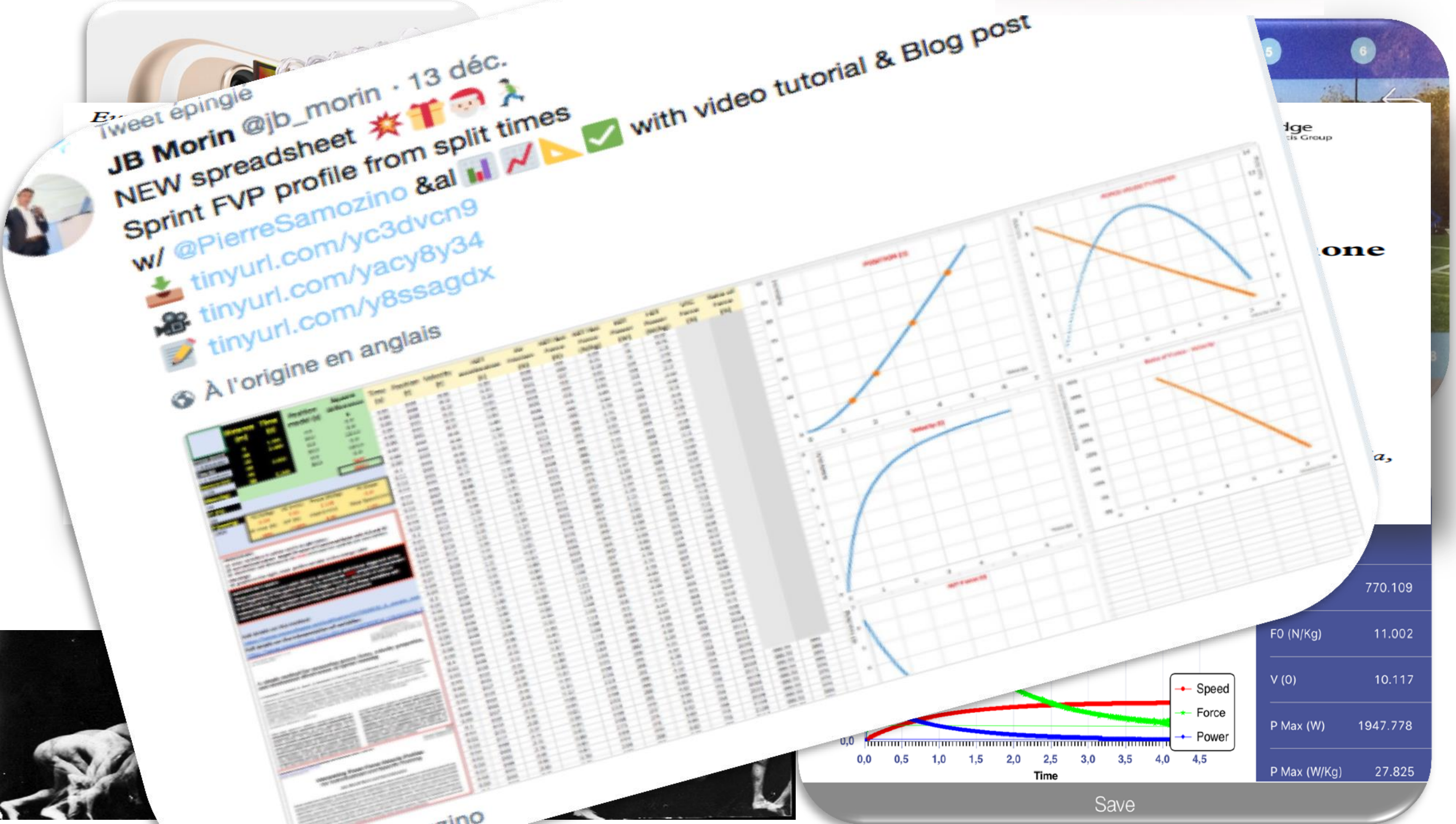
Force plate data vs Simple method

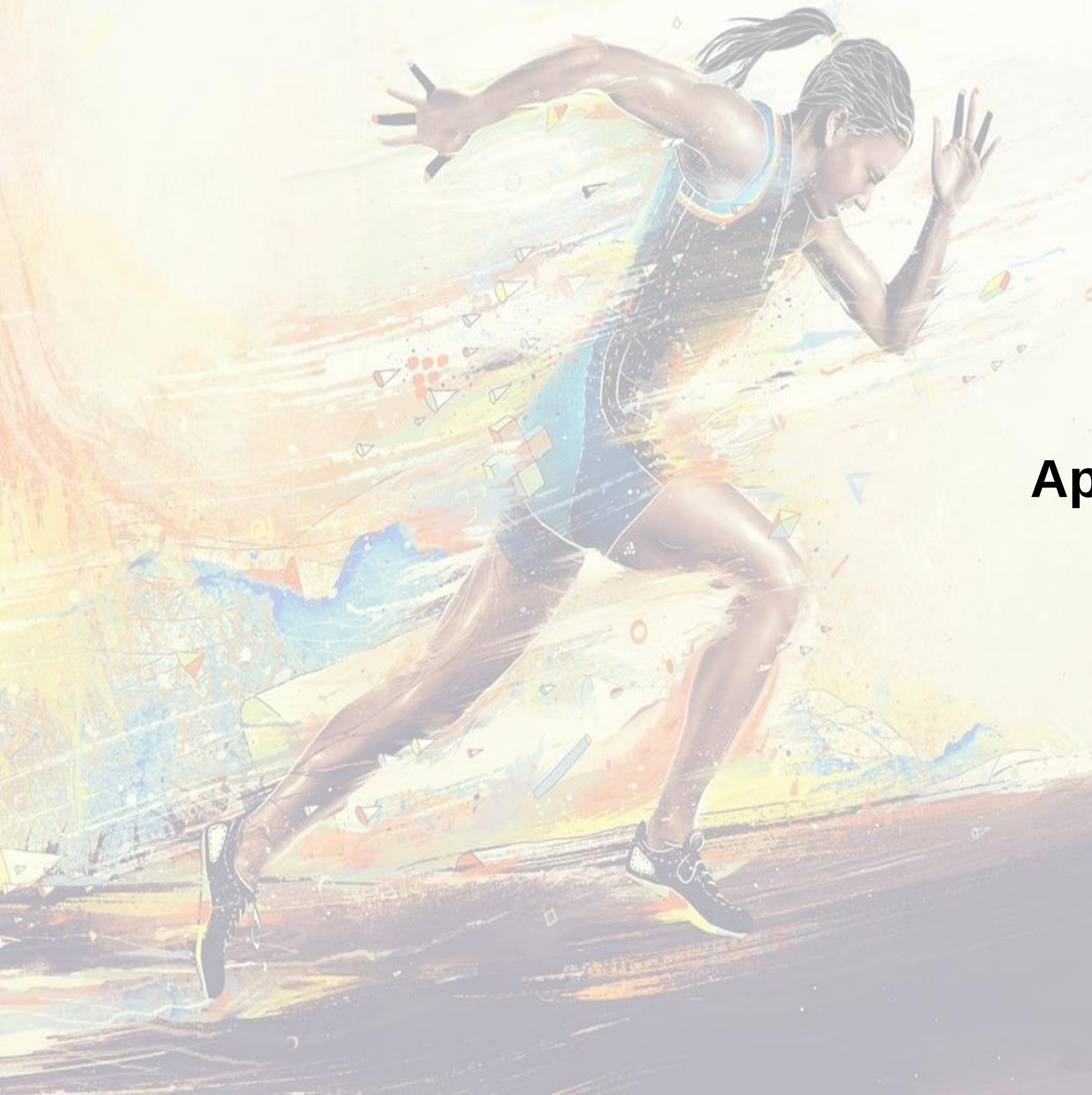




SIMPLER THAN SIMPLE...

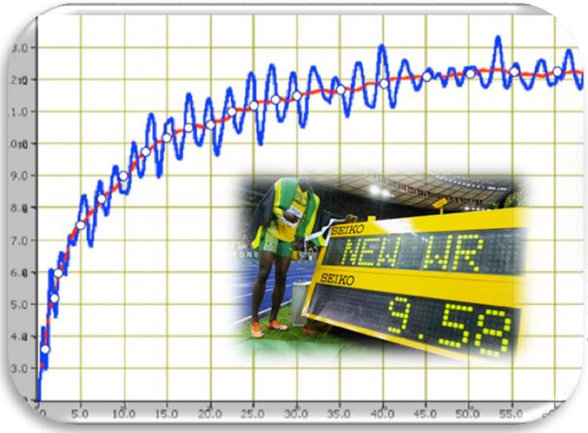
2016: P. Jiménez-Reyes





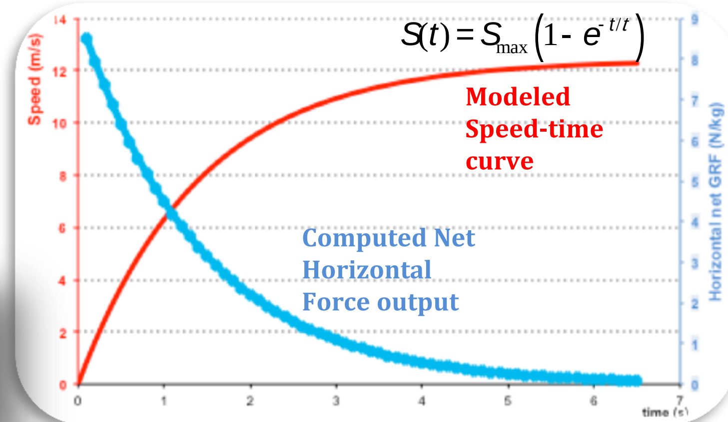
Applications ?

FORCE-VELOCITY-POWER outputs of Usain Bolt's World Record



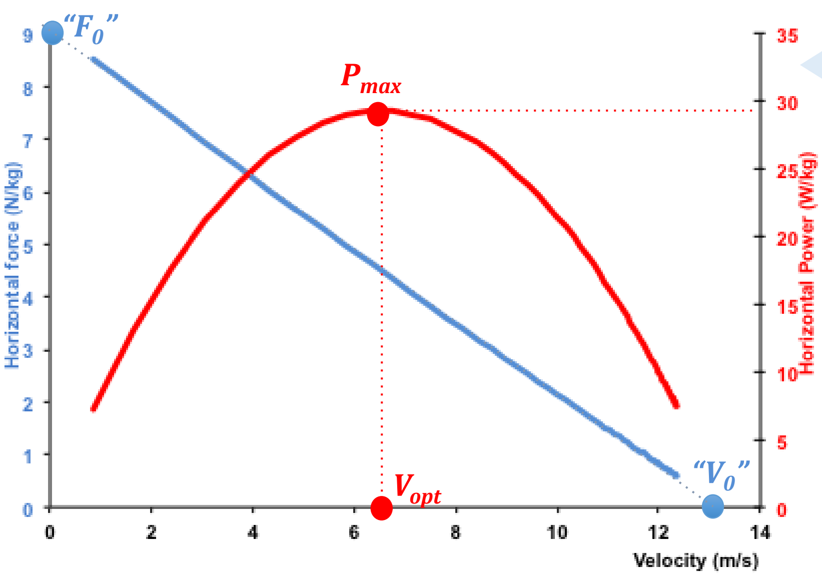
Field Measurements In competition conditions

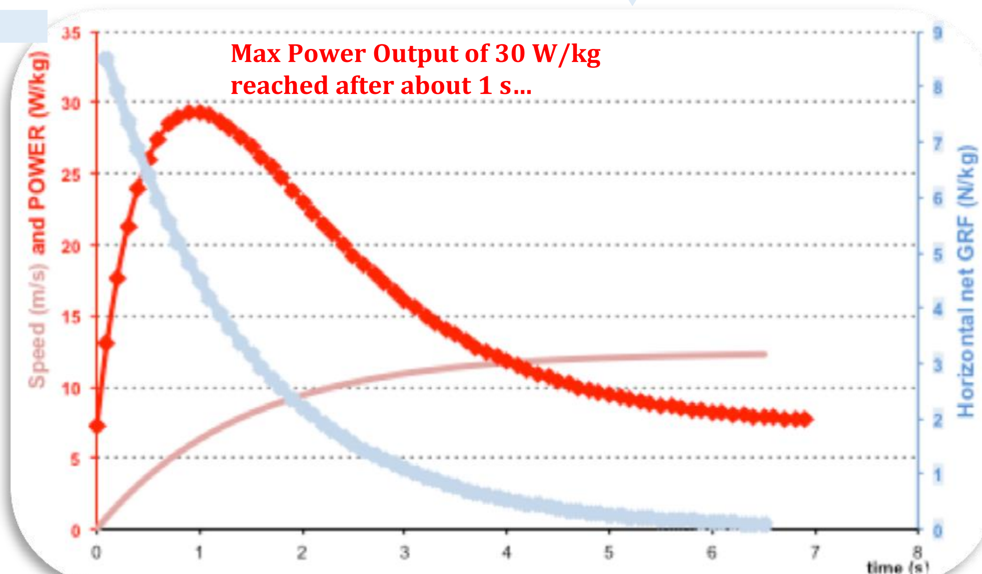
Computing



Power = Force x Speed...

<u>Specific, Field Sprint</u> Force-Velocity-Power profile





The KEY: long-term monitoring

Physical qualities evaluated during the acceleration						Mechanical effectiveness			Performa		
Vmax theoretical V0 (m/s)	Fmax theoretical F0 (N)	Fmax theoretical F0 (N/kg)	Pmax (W)	Max Horizontal Power Pmax (W/kg)	Force-Velocity profile	mean RF on 10m	RFpeak	DRF	Time @ 5 m (s)	Time @ 10 m (s)	Time @ 20 m (s)
9.38	673	6.68	1566	15.5	-71.8	29%	48%	-0.065	1.42	2.15	3.43
8.79	787	7.81	1717	17.0	-89.5	30%	54%	-0.079	1.34	2.07	3.35
9.42	731	6.44	1707	15.1	-77.6	29%	48%	-0.062	1.44	2.18	3.46
9.32	761	6.71	1762	15.5	-81.7	28%	48%	-0.065	1.41	2.18	3.42
8.86	645	7.17							1.40	2.13	3.44
8.90	669	7.43							1.35	2.12	3.40
8.04	790	6.38							1.48	2.31	
9.34	733	7.65							1.34	2.07	3.29
8.19	834	8.45							1.31	2.08	3.39
8.30	517	5.47							1.57	2.40	3.84
9.33	590	7.48							1.37	2.07	3.32
9.46	568	7.20							1.38	2.11	3.36
8.91	673	7.38							1.37	2.11	3.39
8.70	694	7.80							1.34	2.08	3.39
9.35	613	6.89							1.40	2.14	
8.49	815	7.53							1.36	2.13	3.44
8.69	785	8.63							1.31	2.01	3.29
8.66	828	9.11							1.26	1.99	3.24
9.10	778	7.56							1.34	2.08	3.36
9.04	814	7.91							1.33	2.07	3.31
8.69	758	8.43							1.29	2.03	3.31
8.77	755	8.39							1.31	2.05	3.30
9.14	567	5.81							1.52	2.32	3.63
10.15	621	6.75							1.39	2.12	3.34
8.60	585	6.44							1.46	2.26	3.60
8.41	665	7.33							1.40	2.17	3.48
9.18	650	6.64							1.43	2.20	3.48
8.99	682	7.40							1.36	2.13	3.37
9.14	714	7.75	1621	17.6	-78.2	30%	52%	-0.076	1.33	2.07	3.32
8.59	796	7.32	1699	15.6	-92.7	28%	50%	-0.077	1.40	2.14	3.45
8.81	718	6.60	1572	14.4	-81.5	27%	46%	-0.068	1.46	2.22	3.54
9.92	550	6.39	1352	15.7	-55.4	31%	50%	-0.058	1.44	2.18	3.43
9.14	586	6.17	1330	14.0	-64.1	27%	46%	-0.061	1.48	2.24	3.56
8.96	695	7.25	1543	16.1	-78.0	28%	49%	-0.073	1.39	2.14	3.42
0.46	91	0.84	181	1.8	12.4	2%	4%	0.01	0.07	0.09	0.12
5%	13%	12%	12%	11%	16%	6%	8%	13%	5%	4%	4%
8.04	517	5.47	1065	11.3	-101.8	22%	38%	-0.09	1.26	1.99	3.24
10.15	834	9.11	1828	19.6	-55.4	31%	58%	-0.06	1.57	2.40	3.84

NFL Draft Performance

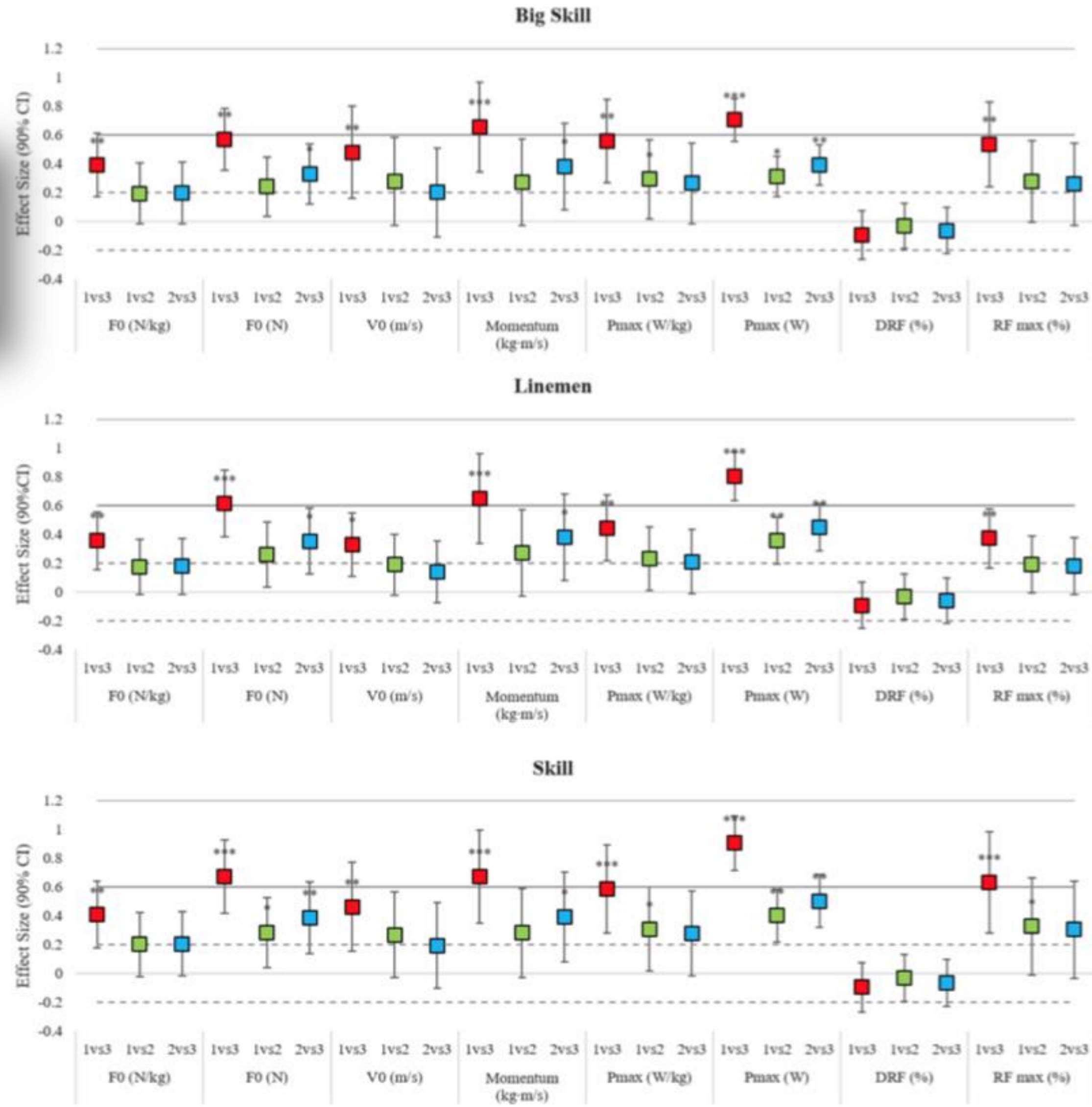

Sprint acceleration mechanical profiling for the NFL draft

Sprint acceleration mechanical profiling for the NFL draft

Jace A. Delaney [1], Travis M. Olson [2] and Jean-Benoit Morin [3]

[1] University of Oregon Athletics Department, University of Oregon, Eugene, Oregon, 97401, [2] Independent Researcher, Portland, Oregon, 97225, and [3] Université Côte d'Azur, LAMHESS, Nice, France

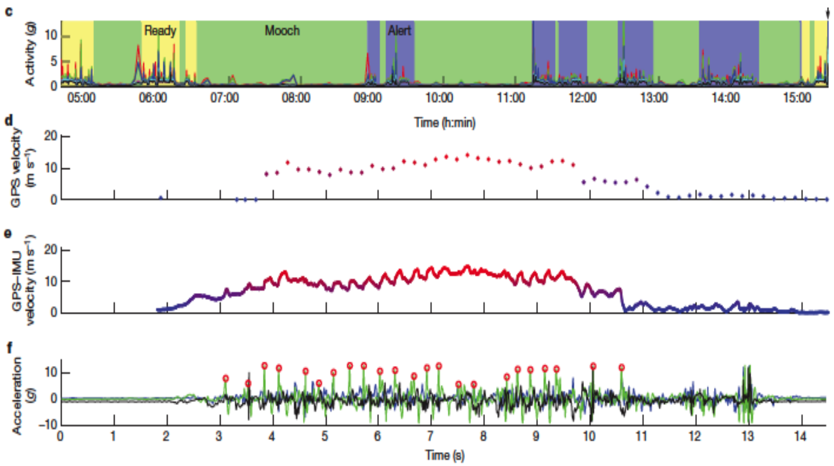
J. Delaney
SPSR
2018



KEY: 1. Early vs. 3. Undrafted; 1. Early vs. 2. Late; 2. Late vs. 3. Undrafted.

Fig. 2. Difference between draft statuses for each of the selected F-V profile variables. F = force; V = velocity; P = power, N= Newton; m = metre; s = second; W = Watt; * = likely; ** = very likely; *** = almost certainly.

Wilson et al. *Nature* June13, 2013



ARTICLE

doi:10.1038/nature12295

Locomotion dynamics of hunting in wild cheetahs

A. M. Wilson[1], J. C. Lowe[1], K. Roskilly[1], P. E. Hudson[1]†, K. A. Golabek[2]† & J. W. McNutt[2]

Although the cheetah is recognised as the fastest land animal, little is known about other aspects of its notable athleticism, particularly when hunting in the wild. Here we describe and use a new tracking collar of our own design, containing a combination of Global Positioning System (GPS) and inertial measurement units, to capture the locomotor dynamics and outcome of 367 predominantly hunting runs of five wild cheetahs in Botswana. A remarkable top speed of 25.9 m s^{-1} (58 m.p.h. or 93 km h^{-1}) was recorded, but most cheetah hunts involved only moderate speeds. We recorded some of the highest measured values for lateral and forward acceleration, deceleration and body-mass-specific power for any terrestrial mammal. To our knowledge, this is the first detailed locomotor information on the hunting dynamics of a large cursorial predator in its natural habitat.

Measurements of instantaneous speed, acceleration and manoeuvring during athletic competition or hunting are rare[1–4], even for humans, horses and dogs, the most studied species. The cheetah (*Acinonyx jubatus*) is acknowledged as the ultimate cursorial predator, and its published[5] top speed of 29 m s^{-1} is considerably faster than racing speeds for greyhounds[2] (18 m s^{-1}), horses[1] (19 m s^{-1}) or humans (12 m s^{-1}; see 'Analysis of Bolt's 100m' at http://berlin.iaaf.org/records/biomechanics/index.html). Quantitative measurements of cheetah locomotion mechanics have only been made on captive animals chasing a lure in a straight line, with few studies eliciting speeds faster than racing greyhounds[6,7]. For wild cheetahs, estimates of speed and track have been made from direct observation or film only, and are limited to open habitat[8,9] and daylight hours.

Tracking collar design

To collect free-ranging locomotion data on wild cheetahs during hunting in their normal environment, we designed and built a tracking collar similar in size and weight to a conventional wildlife collar[10,11] (Fig. 1a; mass of 340 g), equipped with a GPS module capable of delivering processed position and velocity data, and raw pseudo-range, phase and Doppler data for individual satellite signals at 5 Hz, and an inertial measurement unit (IMU) consisting of triaxial microelectromechanical systems (MEMS) accelerometers, gyroscopes and magnetometers (Methods). The collar was powered by a rechargeable battery charged from solar cells, plus a non-rechargeable auxiliary battery. Data download and configuration upload was via radio. Collar software monitored the accelerometers to create activity summaries and detect the brief hunting events, buffered accelerometer data to capture the start of hunts, and adapted collar operation to battery voltages, time of day and activity. We increased the effective sample rate of the positioning system to 300 Hz, and reduced noise in the kinematic parameters, by fusing data from GPS and the IMU with a loosely coupled extended Kalman smoother (Methods). This was especially important during hunting because GPS accuracy was degraded both during initialization, and under conditions of high acceleration and high jerk[12].

Collection of hunting data

We recorded GPS–IMU data from 367 runs by three female and two male adult cheetahs (100, 66, 61 and 84, 56 runs respectively) over 17 months. A further 530 runs were identified in the activity data because the collar did not trigger on every run owing to the time of day and conservative trigger thresholds. An episode of feeding after a run indicated hunting success, and was identified in the activity data

Figure 1 | Cheetah with collar and anatomical features contributing to performance. **a**, Cheetah with a mark 2 collar is shown. **b**, Gravitational and centripetal accelerations acting on a turning cheetah; *g* denotes acceleration due to gravity, v^2r^{-1} denotes centripetal acceleration, and *a* is the resultant acceleration (effective gravity). **c**, Non-retractable cheetah claws that enhance grip. **d**, Low posture used in deceleration, which prevents pitching and engages hind limb musculature to absorb kinetic energy.

PERFORMANCE

HEATLH

PRE-POST HAMSTRING INJURY DATA…

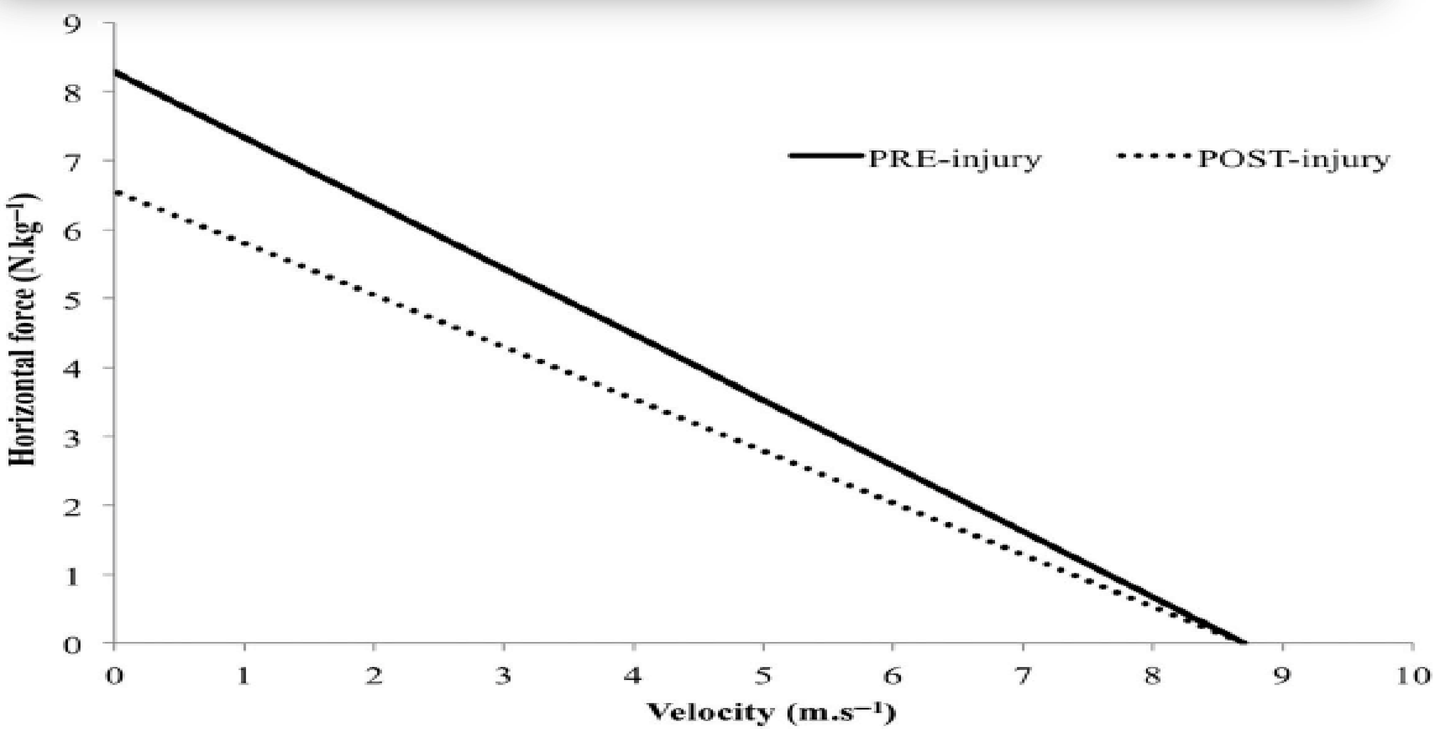
JOURNAL OF SPORTS SCIENCES, 2015
http://dx.doi.org/10.1080/02640414.2015.1122207

Routledge
Taylor & Francis Group

Field monitoring of sprinting power–force–velocity profile before, during and after hamstring injury: two case reports

J. Mendiguchia[a], P. Edouard[b,c], P. Samozino[d], M. Brughelli[e], M. Cross[e], A. Ross[e], N. Gill[e,f] and J. B. Morin[g]

Jurdan Mendiguchia
Zentrum Center, Baranain



PERFORMANCE  HEATLH

PROSPECTIVE PILOT STUDY

+ *ongoing 2-season large follow-up*

1/ Is Sprint Force profile related to hamstring-injury risk?

2/ Could it be an objective, specific parameter in the re/pre-hab process?

IOC WORLD CONFERENCE
ON PREVENTION OF INJURY AND ILLNESS IN SPORT

YouTube


Sprint & HSI Management: win-win strategy?!

Preventing hamstring muscle injuries
by sprint acceleration performance evaluation
What? When? How?

JB MORIN & Pascal EDOUARD

Workshop March 17, 2017

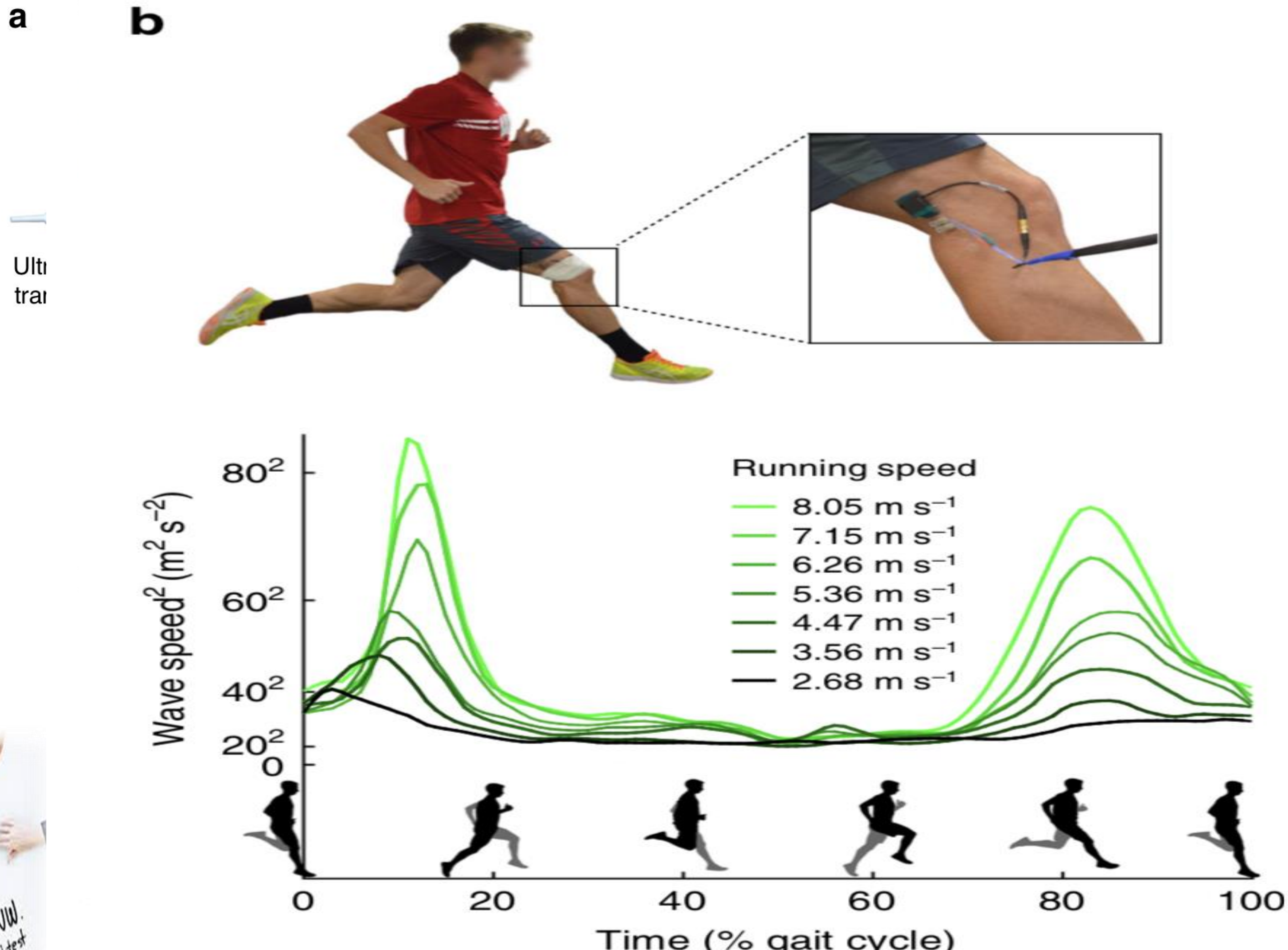
MONACO, 16-18 MARCH 2017
GRIMALDI FORUM

The future is now

Muscle Force

In-SITU Output

nature COMMUNICATIONS April 23, 2018



In-SITU Output

GPS – ACCELEROMETER SYSTEMS ??

©Journal of Sports Science and Medicine (2015) **14,** 698-701
http://www.jssm.org

Research article

Assessing Stride Variables and Vertical Stiffness with GPS-Embedded Accelerometers: Preliminary Insights for the Monitoring of Neuromuscular Fatigue on the Field

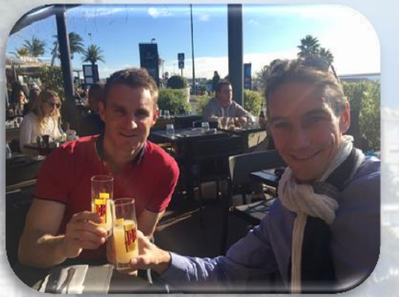
Martin Buchheit [1,2,3]✉, Andrew Gray [4,5] and Jean-Benoit Morin [6]
[1] Sport Science Department, Myorobie Association, Montvalezan, France; [2] Performance Department, Paris Saint-Germain Football Club, Saint-Germain-en-Laye, France; [3] Institute of Sport, Exercise and Active Living, College of Sport and Exercise Science, Victoria University, Melbourne, Australia; [4] Athletic Data Innovations, Sydney, Australia; [5] Cronulla Sharks Rugby League Football Club, Australia; [6] Laboratoire Motricité Humaine Education Sport Santé, Université de Nice Sophia Antipolis, Nice, France.

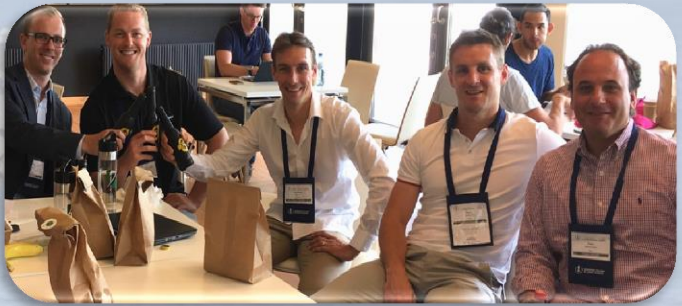
ONGOING RESEARCH....

Team Work

Teammates & Inputs

P. Samozino, Chambery FR
J. Mendiguchia, Baranain SP
P. Jimenez-Reyes, Murcia SP
M. Brughelli, Auckland NZ
M. Cross, Auckland NZ
B. Marrier, Marcoussis FR
Y. LeMeur, Monaco
M. Buchheit, Paris FR
G. Rabita, INSEP Paris FR
N. Gill, Auckland NZ
A. Ross, Auckland NZ
S. Brown, Auckland NZ
S. Dorel, Nantes FR
J. Slawinski, Paris FR
A. Couturier, Paris FR
E. Saez de Villarreal, Sevilla SP
C. Balsalobre-Fernandez, Mardid SP
P. diPrampero, Udine IT
R. Nagahara, JP
B. Contreras, Phoenix AZ
G. Petrakos, Dublin IRL
J. Lahti, Nice FR
A. Hegyi, Jyvaskyla FIN





Teammates & Inputs

P. Samozino, Chambery FR
J. Mendiguchia, Baranain SP
P. Jimenez-Reyes, Murcia SP
M. Brughelli, Auckland NZ
M. Cross, Auckland NZ
B. Marrier, Marcoussis FR
Y. LeMeur, Monaco
M. Buchheit, Paris FR
G. Rabita, INSEP Paris FR
N. Gill, Auckland NZ
A. Ross, Auckland NZ
S. Brown, Auckland NZ
S. Dorel, Nantes FR
J. Slawinski, Paris FR
A. Couturier, Paris FR
E. Saez de Villarreal, Sevilla SP
C. Balsalobre-Fernandez, Mardid SP
P. diPrampero, Udine IT
R. Nagahara, JP
B. Contreras, Phoenix AZ
G. Petrakos, Dublin IRL
J. Lahti, Nice FR
A. Hegyi, Jyvaskyla FIN

MERCI !

jean-benoit.morin@unice.fr