Force-Velocity-Power individual profile
for jump-sprint performance and injury management

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Teammates & Inputs

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J. Lahti, Nick FR
1888 Motion, SW
Interpreting Power-Force-Velocity Profiles for Individualized and Specific Training

Jean-Benoît Morin and Pierre Samozino

MACROSCOPIC APPROACH: BIG PICTURE FIRST

Pietro E. di Prampero
Università Degli Studi di Udine (Italy)

R. McNeill Alexander
(1934-2006)
University of Leeds (UK)

Underlying mechanisms not studied first... but NOT NEGLECTED

The simpler the model, the clearer it is which of its features is essential to the calculated effect (performance)
MULTIJOINT EXERCISES: LINEAR F-V RELATIONSHIP

Rambaud et al., 2008, J Strength Cond Res

Why is the force-velocity relationship in leg press tasks quasi-linear rather than hyperbolic?

Maurice E. Habert
Research Institute MIRP, Faculty of Health Sciences, UQ University Anatomie, Amsterdam, Be Neuchatel
Submitted 27 June 2013, accepted for review 17 March 2014

C. Giroux

Where does the One-Repetition Maximum Exist on the Force-Velocity Relationship in Squat?

S J

HOW FAST IS A HORIZONTAL SQUAT JUMP?

Conditions
**NOT the reality**

Red: $F_0-V_0$ correlation
Blue: Individual FV profiles

**The reality**

Jimenez-Reyes et al.
Peer J, 2016

Relationship between vertical and horizontal force-velocity-power profiles in various sports and levels of practice

« Strong » at Low Velocity $\neq$ « Strong » at High Velocity
More maximal force $\neq$ More maximal velocity

14 sports >500 athletes Leisure to elite level
No correlation overall, same sub-group outcome for each level and each sport, SAME RESULTS FOR SPRINTING

**Vertical**
FVP Profile

Sports Medicine
https://doi.org/10.1007/s00122-019-05107-1

CURRENT OPINION

When Jump Height is not a Good Indicator of Lower Limb Maximal Power Output: Theoretical Demonstration, Experimental Evidence and Practical Solutions

Jean-Benoit Morin$^{1,2}$; Pedro Jiménez-Reyes$^3$; Matt Brughelli$^3$; Pierre Samozino$^4$
OK, How can we do with field devices??

A simple method for measuring squat jump power output

Pierre Samozino

Validity and reliability
SJ and CMJ

Samozino et al., 2008, J Biomech
Palmieri et al., 2014, CMBRE
Girou et al., 2015, LISM
Jimenez et al., 2017, JSSPP

F = mg (h/hp + 1)

β = \sqrt{\frac{gh}{2}}

ρ = mg (h/hp + 1) \sqrt{\frac{gh}{2}}

Mass + Load
Jump height
Push-off distance

You need something to accurately measure Jump Height!!

The validity and reliability of an iPhone app for measuring vertical jump performance

CARLOS BALSALOBE-fernández, MARK CLAISTER & RICHARD ANTHONY LOCKEY

Confirmed in 5+ studies!
Athlete 1

For a same given \( P_{\text{max}} \)

Athlete 2

Many F-V profiles possible....

Which one(s) maximize Jumping Performance ??

? All athletes need WATTS
In terms of F and V...who needs WHAT?

A MACROSCOPIC BIOMECHANICAL MODEL

\[
V_{\text{DEC}} = \sqrt{2h_{\text{PO}} \left( \bar{F} - g \right)}
\]

\[
\bar{F} = \bar{F}_0 \left( 1 - \frac{\bar{V}}{V_0} \right)
\]

\( \bar{F}_{\text{kg}} \) (N.kg\(^{-1}\))
A MACROSCOPIC BIOMECHANICAL MODEL

Optimal Force-Velocity Profile in Ballistic Movements—Alius: Citius or Fortius?

PIERRE SAMOZINO*, ENRICO FIACCO1, PIETRO INNOCENTI DI FRAPPIERE1, ALAIN BELL1, and JEAN-BENOIT MORE1

1Laboratory of Exercise Physiology (LAE), University of Savoie, Le Bourget du Lac, FRANCE;
2Department of Biomechanical Sciences and Technologies, University of Ulm, Ulm, GERMANY;
3Laboratory of Exercise Physiology (LAE), University of Savoie, Annecy, FRANCE.

Validity ?? ✓ Prediction errors: 4-6%

Interest ??

Optimal Fv profile

For a given Pmax

J -30%

-90 -80 -70 -60 -50 -40 -30 -20 -10 0

Forcing profile FV Profile Velocity profile

« force » profile « velocity » profile

Best Performance

Pmax

F-v Profile

Lower limb extension range

Force-Velocity Profile: Imbalance Determination and Effect on Lower Limb Ballistic Performance

Improve performance with

✓ ➔ Pmax
✓ ➔ FV imbalance

Samozin et al., 2010, J Theor Biol
Samozin et al., 2014, IJSM

TYPICAL EXAMPLES

Athlete A

VTC-Pmax = 31.3 W/kg

FV_{imb} = 49%

SJ height = 37.2 cm

Athlete B

VTC-Pmax = 27.8 W/kg

FV_{imb} = 99%

SJ height = 39.0 cm

B is less powerful...but has better individual FV balance ➔ better SJ performance
Typical Examples

- Player A, optimal profile
- Player A, actual profile
- Player B, actual profile
- Player B, optimal profile

Player A

VTC-Pmax = 30.7 W/kg
FV_{imb} = 137%
SJ height = 34.8 cm

Player B

VTC-Pmax = 31.6 W/kg
FV_{imb} = 72%
SJ height = 37.2 cm

Training should be individualized according to FV imbalance → better performance for BOTH players
PILOT TRAINING STUDY

→ 9 weeks (mistake #1)
→ OPTIMIZED (46) vs NON-OPTIMIZED (18)

Experimental group:

22 force deficit
18 velocity deficit
6 well-balanced

Effectiveness of an Individualized Training Based on Force-Velocity Profiling during Jumping

Pedro Jiménez-Reyes, Pierre Samozino, Matt Brughelli and Jean-Benoît Morin
Optimized Training

- High velocity deficit
- Low velocity deficit
- Low-force deficit
- High force deficit

NON-Optimized

JUMP HEIGHT

Optimized Group
46/46 subjects increased above SWC
12.7 ± 7.4 %

Non-Optimized Group
7/18 subjects increased above SWC
2.3 ± 4.7 %

Replication - Improvement
REALLY individualized
Training and Detraining kinetics

A

B

PLOS ONE

Training to Optimal Profile and Detraining
Works to Optimal Profile
Deficit in force... ok... but how do you fix a velocity deficit?

SUMMARY...

« Toothpaste Tube Theory »

Don't do the same better
Do something ELSE
Methods of Power-Force-Velocity Profiling During Sprint Running: A Narrative Review

Matt Cross
(Univ Savoie & Nice AUT, Auckland)
@MattCrossNZ

1 second...10 to 12-m
Two (im)possibilities

FORCE PLATES
INSEP, Paris, France (7m)
Kanoya, Japan (50m+)

INSTRUMENTED SPRINT TREADMILL
St-Etienne, France
Doha, Qatar

OK, How can we do with field devices??

2016: P. Samozino

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

\[ v(t) = v_{max} \cdot (1 - e^{(-t/\tau)}) \]
2016 AND 2019: VALIDATION AGAINST FORCE PLATES

A simple method for computing sprint acceleration kinetics from running velocity data: Replication study with improved design
Jean-Benoit Morin, Pierre Samozino, Munehiro Murata, Matt R Cross, Ryu Nagahara

- Exponential model velocity
- Laser velocity
- Force platforms velocity
- Vertical component
- Antero-Posterior component

- $F_x$
- $F_y$
- $F_z$
- Simple method data

- Simple inputs (body mass, running velocity)
- High reliability
- In practice...1 acceleration up to Vmax
FORCE VELOCITY POWER outputs of Usain Bolt’s World Record

Field Measurements in competition conditions

Specific Field Sprint Force-Velocity-Power profile

Max Power Output of 30 W/kg reached after about 1 s...

Simpler than simple...

2016: P. Jiménez-Reyes

Iphone / iPad:

240 frames/s

EJ Marey, 1885, 24 fps
Applications: Training

TYPICAL EXAMPLE:
Player is « slow »......but has high velocity capabilities!

40-m test:
6.21 vs 6.37 s
FRENCH ELITE RUGBY UNION TEAM FOLLOW-UP
2017-2018

Same 30-m time, very different FVP profiles...

<table>
<thead>
<tr>
<th>Height (m)</th>
<th>Mass (kg)</th>
<th>Age</th>
<th>30-m Time (s)</th>
<th>5m split (s)</th>
<th>10m split (s)</th>
<th>15m split (s)</th>
<th>20m split (s)</th>
<th>25m split (s)</th>
<th>30m split (s)</th>
<th>V Max (m/s)</th>
<th>FO (N)</th>
<th>FO (N/Kg)</th>
<th>V0 (m/s)</th>
<th>Max (W)</th>
<th>P Max (W/Kg)</th>
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<tbody>
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<td>3.20</td>
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<td>8.94</td>
<td>1741.84</td>
<td>19.25</td>
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</tbody>
</table>

Towards Individualized Sprint Training...

Training studies needed...

What training input(s) for what part(s) of the FV spectrum?
Applications: Injury Management

Prepare & Repair

CONI

ITALIA

SCUOLA DELLO SPORT

PREPARE & REPAIR
Season follow-up...

Primary prevention & Training Content Management

Sports-related workload and injury risk: simply knowing the risks will not prevent injuries

Michael K Drew,1,2 Jill Cook,2,3 Caroline F Finch2

ABSTRACT
Training loads contribute to sports injury risk but their mitigation has only been examined in a sports injury prevention framework. A key aspect behind monitoring training loads for injury prevention is to screen for those at increased risk of injury. Thus, workloads can be adjusted to minimize these risks. This review describes how advances in management of workload can be applied as a preventive measure. Primary prevention involves screening for preparticipation load risk factors, such as low training loads, prior to a training period or competition. Secondary prevention involves screening for workloads that are known to precede an injury developing so that modification can be undertaken to mitigate this risk. Tertiary prevention involves rehabilitation practices that include a guided return to training programme to reduce the risk of sustaining a subsequent injury. The association of training loads with injury incidence is now established. Prevention measures such as risk changes that affect the workload of an athlete are universal whereas those that address risk factors of a symptom-specific subgroup are more selective. Prevention measures, when implemented for asymptomatic individuals withholding possible injury risk factors, are indicated for an athlete at risk of developing a sports injury. From key indicated risks and associated prevention measures are proposed.

Return to sport ...or return to (sprint) Performance

A Multifactorial, Criteria-based Progressive Algorithm for Hamstring Injury Treatment

Jordi Mendiguchia
Centrum Center
Baranain, Spain

REHABILITATION TARGET REFERENCE PROFILE (PRE-INJURY)

Sprint Mechanics and Performance included in final functional steps

PREPARE REPAIR

![Image](https://example.com/image.png)
Return to sport ...or return to (sprint) Performance

FV Sprint profile for an injured player: 3 tests

1 & 2 = PRE-INJURY

<table>
<thead>
<tr>
<th>Test</th>
<th>Date</th>
<th>Height (m)</th>
<th>Mass (kg)</th>
<th>30-m Time (s)</th>
<th>V Max (m/s)</th>
<th>F0 (N/Kg)</th>
<th>V0 (m/s)</th>
<th>P Max (W)</th>
<th>P Max (W/Kg)</th>
<th>DRF</th>
<th>FV slope</th>
<th>RF 10 m</th>
<th>RF Peak</th>
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<td>6.98</td>
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<td>50%</td>
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<tr>
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<td>-83.9</td>
<td>32%</td>
<td>52%</td>
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<tr>
<td>3</td>
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<td>95</td>
<td>4.48</td>
<td>8.55</td>
<td>8.40</td>
<td>8.80</td>
<td>1755</td>
<td>18.5</td>
<td>-9%</td>
<td>-90.7</td>
<td>32%</td>
<td>55%</td>
</tr>
</tbody>
</table>

TEST 3: AFTER return-to-sport, to validate the « return to performance »

Use in prevention ??
Sprint mechanics as a « risk » factor

Return to sport ...or return to (sprint) Performance

Progression of Mechanical Properties during On-Field Sprint Running after Returning to Sports from a Hamstring Muscle Injury in Soccer Players


At return to sport (post hamstring injury):

- **Power (Pmax)** and **Max Force (F0)**, lower in injured players
- **but** not velocity (V0)
- 2 months later, values overall returned to normal

1/ what objective & functional data led to « RTS » decision?

2/ what « risk » during this 2-month (or shorter) period ?!
Return to sport ... or return to (sprint) Performance

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

J. Mendiguchia, P. Edouard, P. Samozino, M. Brugelli, M. Cross, A. Rocca, N. Giraud and J. B. Moore

Pre-Injury data...

Use in Prevention?

Ongoing 3rd-season large observational follow-up in several groups

1/ Is F-V-P profile related to a higher risk?

2/ Could it be an objective parameter in the prevention process?

Sprint « pattern » and pelvic control as additional pieces of the puzzle
Merci !