Biomechanical Analysis of the Pole Vault: London 2017 & Birmingham 2018

Dr Brian Hanley, Helen Gravestock, Dr Athanassios Bissas, Stéphane Merlino
TODAY

• Background
• New and previous studies
• Data collection
• Brief findings
ORIGINS
The Role of the European U23 Championships in the Development of Elite Athletes

by Brian Hanley

The Role of European Age-Group Championships in Senior Participation Rates

by Brian Hanley
Our study built on the excellent IAAF Biomechanics Research Projects of the past 30 years. Being the first IAAF project since 2011 meant that we could take advantage of new technologies – such as high definition cameras operating at 200 frames per second (fps). The first study of the pole vault was in Rome 1987 – timing gates were used to measure velocity on the runway. Most projects since then used the LAVEG (laser) system to measure runway velocity. In Daegu 2011, runway velocity was measured using a 2D camera set-up (60 fps). Projects varied as to where they measured runway velocity – some used 16-11 m (or 15-10 m), others 11-6 m (and some used both).
Biomechanical Analysis of the Pole Vault Event

Rosa M. Angulo-Kinzler, Stephen B. Kinzler, Xavier Balius, Carles Turro, Josep M. Caubet, Josep Escoda, and J. Antoni Prat


Comparison of the men’s and the women’s pole vault at the 2000 Sydney Olympic Games

FALK SCHADE,1* ADAMANTIOS ARAMPATZIS,1 GERT-PETER BRÜGGEMANN1 and PAAVO V. KOMI2

1Institute of Biomechanics, German Sport University of Cologne, Carl Diem Weg 6, 50933 Cologne, Germany and 2Neuromuscular Research Centre, University of Jyväskylä, PO Box 35, 40352 Jyväskylä, Finland
CAMERA POSITIONS: LONDON
TECHNOLOGY

- **London**: 7 x Cameras (Sony PXW-FS5 / Canon EOS 700D)
- **Birmingham**: 5 x Cameras (Sony PXW-FS5) / Sony RX10
- **Frame Rate**: Sony – 200 fps / Canon – 60 fps / Sony – 50 fps
- Focus and field of view were set before competition began
- **Resolution**: High-definition; 1920 x 1080 px / 1280 x 720 px
- Stable broadcaster platforms
- **Shutter speed**: 1/1250
- **Lighting**: Shutter vs. f-stop vs. ISO
- **Analysis**: SIMI Motion 9.2.2
CALIBRATION

- Rigid with 48 known points
- Large volume, multiple positions
3-DIMENSIONAL ANALYSIS

- **Software**: SIMI Motion (version 9.2.2)
  - 3D Direct Linear Transformation (DLT)
  - *Body segment parameter models*: de Leva (1996)
  - *Filters*: recursive second-order, low-pass Butterworth filter (cut-off identified through residual analysis) with zero time-lag

- **Event synchronisation**: 4 key events
3-DIMENSIONAL ANALYSIS
PAST REPORTS – RUNWAY VELOCITY

Figure 5: Development of approach velocity of Isinbayeva (5.01m, 1st place) and Pyrek (4.60m, 2nd place)

Data from IAAF Biomechanics Research Project: Helsinki, 2005

Data from IAAF Biomechanics Research Project: Berlin, 2009

Table 4: Jumping height, run-up velocity $v_A$ in section 10-5m, number of run-up steps AS and take-off position AP

<table>
<thead>
<tr>
<th>Athlete</th>
<th>Height [m]</th>
<th>$v_A$ [m/s]</th>
<th>AS</th>
<th>AP [m]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spiegelburg, S.</td>
<td>4.70</td>
<td>8.05</td>
<td>16</td>
<td>3.85</td>
</tr>
<tr>
<td>(GER)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Feofanova, S.</td>
<td>4.70</td>
<td>8.28*</td>
<td>17</td>
<td>3.90</td>
</tr>
<tr>
<td>(RUS)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pyrek, M.</td>
<td>4.70</td>
<td>7.76</td>
<td>16</td>
<td>3.70</td>
</tr>
<tr>
<td>(POL)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Golubchikova, Y.</td>
<td>4.50</td>
<td>8.20*</td>
<td>18</td>
<td>3.60*</td>
</tr>
<tr>
<td>(RUS)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Polnova, T.</td>
<td>4.50</td>
<td>7.69</td>
<td>17</td>
<td>3.85</td>
</tr>
<tr>
<td>(RUS)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hingst, C.</td>
<td>4.50</td>
<td>7.87</td>
<td>18</td>
<td>3.55*</td>
</tr>
<tr>
<td>(GER)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Murer, F.</td>
<td>4.50</td>
<td>8.06</td>
<td>16</td>
<td>3.75</td>
</tr>
<tr>
<td>(BRA)</td>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

Aveage

4.59 7.99 16.9 3.74

* the velocity has been deduced from the velocity of the other jumps because a direct measurement was not possible due to disturbances

Data from IAAF Biomechanics Research Project: Berlin, 2009
### RUNWAY VELOCITIES: MEN

|-------|------|------|------|------|------|------|------|------|

### RUNWAY VELOCITIES: WOMEN

<table>
<thead>
<tr>
<th></th>
<th></th>
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<th></th>
<th></th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Gold</td>
<td>8.46</td>
<td>8.31</td>
<td>8.25</td>
<td>8.05</td>
<td>8.68</td>
<td>8.27</td>
<td>8.13</td>
<td>8.30</td>
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<tr>
<td>Silver</td>
<td>7.97</td>
<td>8.01</td>
<td>8.10</td>
<td>8.28</td>
<td>8.32</td>
<td>8.23</td>
<td>8.33</td>
<td>8.21</td>
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<tr>
<td>Bronze</td>
<td>8.10</td>
<td>7.72</td>
<td>8.42</td>
<td>7.76</td>
<td>7.92</td>
<td>8.30</td>
<td>7.63</td>
<td>8.10</td>
</tr>
<tr>
<td>Top 8</td>
<td>7.98</td>
<td>7.98</td>
<td>8.10</td>
<td>7.99</td>
<td>8.25</td>
<td>8.23</td>
<td>7.92</td>
<td>8.02</td>
</tr>
</tbody>
</table>
A fast run-up is necessary but not sufficient for a successful jump” (Angulo-Kinzler et al., 1994).
THE IMPORTANCE OF LAST STEP VELOCITY

MEN: $r = 0.50$

WOMEN: $r = 0.65$

* Data include values from London and Birmingham projects
2.22 m 1.99 m 1.82 m 2.14 m
4.54 m 2.22 m 1.99 m
London:
4.45 2.22 2.09

London:
4.02 1.85 2.15
London: 2017: 5.89 m  2018: 5.85 m
London: 2018: 5.70 m  2017: 5.50 m

Take-off  Last step  2nd last step
4.05 m  2.07 m  2.14 m

London: 4.29  2.10  2.18

London: 3.60  1.84  2.09

LEEDS BECKETT UNIVERSITY
CARNegie SCHOOL OF Sport
1.96 m 2.07 m 1.73 m 1.89 m 3.61 m 3.28 m 2.07 m
3.61 m 1.96 m
3.28 m 1.73 m 1.89 m
London: 3.29 1.95 1.93

London: 3.29 1.65 2.00
### MCCARTNEY

<table>
<thead>
<tr>
<th></th>
<th>2017</th>
<th>2018</th>
</tr>
</thead>
<tbody>
<tr>
<td>Run-up phase</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2nd-last</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Last</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **London:**
  - 2017: 4.55 m
  - 2018: 4.75 m

### SILVA

<table>
<thead>
<tr>
<th></th>
<th>2017</th>
<th>2018</th>
</tr>
</thead>
<tbody>
<tr>
<td>Run-up phase</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2nd-last</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Last</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **London:**
  - 2017: 4.65 m
  - 2018: 4.60 m

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**Take-off** | **Last step** | **2nd last step**
---|---|---
3.68 m | 1.95 m | 1.89 m

**London:**
- 3.41 m 1.82 m 1.86 m

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**Take-off** | **Last step** | **2nd last step**
---|---|---
3.46 m | 1.74 m | 1.62 m

**London:**
- 3.36 m 1.80 m 1.77 m
TAKE-OFF POSITION

- 0.15 m
- 0.25 m
- 0.02 m
+ 0.02 m

3rd last step  2nd last step  Last step  Take-off

Runway horizontal velocity (m/s)

0.00  0.05  0.10  0.15  0.20  0.25  0.30  0.35  0.40  0.45  0.50  0.55  0.60  0.65  0.70

Time (s)
SUMMARY

• Our studies on the pole vault in London and Birmingham were built on the reports on the event from over 30 years of analysis.
• The results consistently show the importance of runway velocity to ensure a high kinetic energy that is transferred to the pole, which absorbs and returns elastic energy.
• The velocity achieved by the athlete during the last step is probably a better indicator of runway velocity “quality” than using a measurement of the steps before this (although they can help to highlight where velocity is gained or lost before take-off).
• These gains / losses can occur because of adjustments to the final steps.
• In training, dual-beam timing gates or systems like OptoJump Next might be useful to measure these important variables.
• Most athletes have already stored some elastic energy in the pole before take-off, but a more ‘free take-off’ style is likely to maintain horizontal velocity better.
THANK YOU FOR YOUR ATTENTION!

Photo credit: C. Hanley