Stand Long Jump

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Introduction

- The standing long jump
  - An athletic event in the Olympic Games of Ancient Greece
  - Discontinued from the Modern Olympic Games after 1912

- Common use as a test of Explosive Leg Power
  - Fire Fighting
  - Law Enforcement
  - the Military
  - many sports coaches use it to monitor an athlete's response to a training program

(Wakai & Linthorne, 2005)
Introduction

- High correlations with isokinetic measures of leg strength
- Good predictor of sprint and long jump performance

(Wiklander & Lysholm, 1987)
Introduction

- A moderately complex movement
- A fundamental human movement that requires complex motor coordination of both upper and lower body segments
  
  *(Ashby & Heegaard, 2002)*

- A coordinated pattern of countermovement, Forward rotation of the whole body & A double-arm swing

  *(Wakai & Linthorne, 2005)*
Components of stand long jump

(Wakai & Linthorne, 2005)
Components of stand long jump

- Take-off distance
  - The jumper starts from a static standing position and then generates a large take-off speed by using a countermovement coupled with a double-arm swing and a double-leg takeoff.
Components of stand long jump

- **Flight distance**
  - The take-off is characterised by a large forward lean of the body, and during the flight phase the jumper swings the legs forward underneath the body in preparation for landing.
Components of stand long jump

- Landing distance
  - The jumper usually lands with a prominent forward lean of the trunk and with the feet extended well ahead of the hips.
Components of stand long jump

- \( d_{\text{jump}} = d_{\text{take-off}} + d_{\text{flight}} + d_{\text{landing}} \)
- \( h = h_{\text{take-off}} - h_{\text{landing}} \)
Optimum take-off angle in the standing long jump

- Wakai & Linthorne, 2005

**Purpose**

To identify and explain the *optimum projection angle*

**Method**

- Five physically active males performed maximum-effort jumps over a wide range of take-off angles
- The jumps were recorded and analysed using a 2-D video analysis procedure
Optimum take-off angle in the standing long jump

\[ d_{\text{flight}} = \frac{v^2 \sin 2\theta}{2g} \left[ 1 + \left( 1 + \frac{2gh}{v^2 \sin^2 \theta} \right)^{1/2} \right], \]  
(2)

\[ h_{\text{take-off}} = L \sin \alpha, \]  
(4)

\[ d_{\text{take-off}} = L \cos \alpha, \]  
(5)
Optimum take-off angle in the standing long jump

Fig. 2. Take-off height and landing height for Participant 1. The fitted curves are from Eqs. (6) and (8). The relative take-off height is the difference between the take-off height and the landing height.

\[ h_{\text{take-off}}(\theta) = L \sin[\alpha_p + A(\theta - \theta_p)], \]  
\[ h_{\text{landing}}(\theta) = h_p + B(\theta - \theta_p), \]
Optimum take-off angle in the standing long jump

Fig. 3. Take-off distance and landing distance for Participant 1. The fitted curves are from Eqs. (7) and (9).

\[
d_{\text{take-off}}(\theta) = L \cos[\phi + A(\theta - \theta_p)],
\]

\[
d_{\text{landing}}(\theta) = d_p - C(\theta - \theta_p),
\]
Optimum take-off angle in the standing long jump

Fig. 4. At higher take-off angles the jumper spent a greater fraction of his muscular force overcoming body weight and so the take-off speed decreased with increasing take-off angle. Data for Participant 1 and fitted curve from Eq. (10).

\[ v(\theta) = \left\{ \frac{2Fl}{m} \left[ 1 - \left( \frac{mg}{F} \right)^2 \sin^2(90^\circ + \theta) \right]^{1/2} - 2gl \sin \theta \right\}^{1/2} \]  

(10)
Optimum take-off angle in the standing long jump

- The calculated optimum take-off angle is about 19 degree, but the jumpers preferred take-off angle was about 33 degree.
Optimum take-off angle in the standing long jump

Table 3
Comparison of the calculated optimum take-off angle with the participant’s preferred take-off angle (value ± standard error)

<table>
<thead>
<tr>
<th>Participant</th>
<th>Calculated optimum take-off angle (°)</th>
<th>Preferred take-off angle (°)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>19.1 ± 5.8</td>
<td>33.3 ± 0.5</td>
</tr>
<tr>
<td>2</td>
<td>25.8 ± 5.8</td>
<td>39.1 ± 1.1</td>
</tr>
<tr>
<td>3</td>
<td>22.2 ± 4.5</td>
<td>34.3 ± 1.0</td>
</tr>
<tr>
<td>4</td>
<td>24.3 ± 3.5</td>
<td>31.4 ± 1.3</td>
</tr>
<tr>
<td>5</td>
<td>26.7 ± 5.4</td>
<td>35.1 ± 1.0</td>
</tr>
</tbody>
</table>
Optimum take-off angle in the standing long jump
Conclusion

- The three main influences that reduce the optimum take-off angle to below 45 are:
  - the relation between the take-off speed and take-off angle
  - the 10±30 cm height difference between take-off and landing
  - the relation between take-off distance and take-off angle

- Take-off angle $\uparrow$ Take-off speed $\downarrow$ because the jumper must expend a greater fraction of the take-off force in overcoming their body weight.

- The participants preferred take-off angle $>$ The calculated optimum take-off angle.
Halteres

Halteres (α λ τ η ρ ε ζ)

(Minetti & Ardigo, 2002)
Halteres used in ancient Olympic long jump

- These halteres were made of stone or lead and weighed 2½ 9 kg, which we calculate would increase a 3-metre jump by at least 17 cm, indicating that their purpose was to boost the performance of pentathletes.

- Halteres were swung back and forth by the jumper before take-off, thrust forwards during the first part of the flight, and finally swung backwards just before landing, as depicted in a variety of vase paintings.

(Minetti & Ardigo, 2002)
the ancient Greek long jump with weights

- Lenoir, Clercq & Laporte, 2005
- Four male physical education students
- 10 maximal single standing broad jumps with and without weights VS 10 maximal five-fold broad jumps with and without weights (with halteres of 2.3 kg each)
the ancient Greek long jump with weights

■ P<0.001
Conclusion

- Muscles are nonlinear actuators, capable of producing greater force and power at lower contraction speeds, and the slower forward swing of loaded upper limbs could increase the ground reaction force and affect the takeoff speed and flight distance, which reflect the mechanical power produced.

  (Minetti & Ardigo, 2002)

- This gain may be explained (a) by changes in the position of the centre of mass at takeoff and at landing, and (b) by an increase in the centre-of-mass velocity at take-off

  (Ashby & Heegaard, 2002)
Arm motion in the standing long jump

- Ashby & Heegaard, 2002
- Three unskilled adult males
- Six jumps with free arm movement (JFA) VS Six jumps with restricted arm movement (JRA)
- A three-dimensional (3-D) passive motion-capture system
Arm motion in the standing long jump

- A two-dimensional (2-D), six-segment (foot, calf, thigh, head/neck/trunk, upper arm, and forearm/hand) link model as shown in Fig. 2.

- The segmental mass fractions and CG locations were estimated from typical human body characteristics (Gowitzke and Milner, 1988; Hinrichs, 1990).
## Arm motion in the standing long jump

**Table 1**
Comparison of key parameters for JFA and JRA (LSM±95% CI)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>JFA</th>
<th>JRA</th>
<th>% Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jump distance (m)</td>
<td>2.09±0.03</td>
<td>1.72±0.03</td>
<td>21.2</td>
</tr>
<tr>
<td>$r_x$ at TO (m)</td>
<td>0.57±0.01</td>
<td>0.49±0.01</td>
<td>16.6</td>
</tr>
<tr>
<td>$r$ orientation at TO (°)</td>
<td>59.7±0.7</td>
<td>63.0±0.7</td>
<td>-5.2</td>
</tr>
<tr>
<td>$v$ at TO (m/s)</td>
<td>3.32±0.03</td>
<td>2.95±0.03</td>
<td>12.7</td>
</tr>
<tr>
<td>$r$ orientation at TO (°)</td>
<td>38.6±1.1</td>
<td>40.2±1.1</td>
<td>-4.2</td>
</tr>
<tr>
<td>x-position of toe w/r CG at TD (m)</td>
<td>0.31±0.01</td>
<td>0.29±0.01</td>
<td>8.8</td>
</tr>
<tr>
<td>Peak VGRF (BW)</td>
<td>2.31±0.08</td>
<td>2.25±0.08</td>
<td>2.6</td>
</tr>
<tr>
<td>Peak HGRF (BW)</td>
<td>0.85±0.04</td>
<td>0.74±0.04</td>
<td>15.4</td>
</tr>
<tr>
<td>Peak VGRF time (s before TO)</td>
<td>-0.168±0.034</td>
<td>-0.217±0.031</td>
<td>-22.6</td>
</tr>
<tr>
<td>Peak HGRF time (s before TO)</td>
<td>-0.085±0.004</td>
<td>-0.076±0.004</td>
<td>12.2</td>
</tr>
<tr>
<td>Peak $+M$ (Nm)</td>
<td>173±19</td>
<td>134±17</td>
<td>29.4</td>
</tr>
<tr>
<td>Peak $-M$ (Nm)</td>
<td>-115±14</td>
<td>-87±13</td>
<td>32.8</td>
</tr>
</tbody>
</table>

Subjects jumped 21% further in JFA than in JRA. This improvement was due to the 16.6% increase in the horizontal displacement of the CG ($r_x$) at TO, the 12.7% increase in the velocity at TO, and in the 8.8% increase in the position of the toe marker with respect to the CG at TD.
Arm movement improves standing long jump performance

- Ashby & Delp, 2005
- The standing long jump was simulated with a twodimensional, five-segment (foot, shank, thigh, head-neck-trunk, arm), seven degree-of-freedom link model.
Arm movement improves standing long jump performance

Equations

\[ T(a, q, \dot{q}) = a T_{\text{max}}(q) T_{\text{vel}}(\dot{q}), \quad (1) \]

\[ T_{\text{vel}} = \begin{cases} 
0 & \dot{q} > \dot{q}_{\text{max}} \\
1 - \frac{1}{\arctan(1.5)} \arctan\left(\frac{1.5\dot{q}}{\dot{q}_{\text{max}}}\right) & -\frac{1}{1.5} \dot{q}_{\text{max}} \tan(0.5 \arctan(1.5)) \leq \dot{q} \leq \dot{q}_{\text{max}} \\
1.5 & \dot{q} > -\frac{1}{1.5} \dot{q}_{\text{max}} \tan(0.5 \arctan(1.5)). \end{cases} \quad (2) \]

\[ T_{\text{lig}} = -100e^{-50(q-q_{\text{max}}-0.05)} + 100e^{-50(q-q_{\text{min}}+0.05)}, \quad (3) \]
Arm movement improves standing long jump performance

- The optimal control problem was to find the values for the joint torque activations (a) that minimized a scalar cost function (J) subject to equality constraints that satisfied the equations of motion and inequality constraints that bounded the activations (-1.0 \leq a \leq 1.0)
Arm movement improves standing long jump performance

- The simulated jump distance was 40 cm greater when arm movement was free (2.00 m) than when it was restricted (1.60 m).
- The majority of the performance improvement in the free arm jump was due to the 15% increase (3.30 vs. 2.86 m/s) in the take-off velocity of the center of gravity.
Arm movement improves standing long jump performance

- Some of the performance improvement in the free arm jump was attributable to the ability of the jumper to swing the arms backwards during the flight phase to alleviate excessive forward rotation and position the body segments properly for landing.

- In restricted arm jumps, the excessive forward rotation was avoided by holding back during the propulsive phase and reducing the activation levels of the ankle, knee, and hip joint torque actuators.
Arm movement improves standing long jump performance

- In addition, swinging the arm segments allowed the lower body joint torque actuators to perform 26 J more work in the free arm jump.

- However, the most significant contribution to developing greater take-off velocity came from the additional 80 J work done by the shoulder actuator in the jump with free arm movement.
Thank You