Cross-Country Sit Skiing: prominence of pushing poles gesture

Stefano PASTORELLI    Giulia LISCO    Laura GASTALDI

Politecnico di Torino
Department of Mechanical and Aerospace Engineering

1-4 May 2013
Summary

- cross-country sit-sky
- tests
- subjects & materials
- biomechanical model
- results
- discussion
- conclusions
Double Poling in cross-country sit ski

Progression achieved by pushing symmetrically on two hand-held poles.

Pushing poles gesture (PPG) is similar to double poling (DP) technique adopted by standing cross-country skiers.
FIELD TESTS DURING COMPETITION

- outdoor video capture
  - environment conditions
  - unstructured field
  - weather conditions
- competition contest
  - marker-less analysis
  - not repeatable
- elite athletes
Tests

✓ video-recording of the push gesture during Paralympics competition
✓ marker-less motion analysis

1-km sprint race
(qualification semifinal and final)
rectilinear segment with 2% slope
2-D kinematic analysis

Research financially supported by
Research approved and supported by International Paralympic Committee

1-4 May 2013
Subjects & Materials

VIDEO CAPTURE SYSTEM:

✓ **Cameras**: Basler Scout scA640-120fc
  - 120 fps at full resolution (659x490 pixel)
  - 1/4" CCD sensor color
  - FireWire interface
  - Synchronization via external trigger signal
  - Power supply over FireWire cable

✓ **Lents**: Pentax H6Z810
  - Manual Zoom
  - Focal length 8-48 mm
  - Iris range F1.0-22

✓ **PC Laptop** Celsius Mobile H270

✓ **SW** Simi Motion3D - 3D Motion Analysis System
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PARTICIPANTS

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<tr>
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<th>n. athletes</th>
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1-4 May 2013
seven anatomical points, (head temple, shoulder, elbow, wrist, hip, knee and ankle left joints)
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dfour technical additional points: (three to identify pole and one on sled)
seven anatomical points, (head temple, shoulder, elbow, wrist, hip, knee and ankle left joints)

four technical additional points: (three to identify pole and one on sledge)

angle convention
Results

PPG cycle  CC sit-skiers

PP Poling Phase
maximum body and arm extension
(maximum wrist ground elevation) -
maximum sledge velocity

TP Transition Phase
maximum sledge velocity - maximum elbow
extension

RP Recovery Phase
maximum elbow extension - maximum
body and arm extension

a) stick diagram with respect world
reference frame; b) sledge velocity; c)
elbow angle; d) wrist vertical ground
elevation; e) pole angle; f) shoulder angle;
g) trunk angle.
Results

LW10 athlete  
LW11 athlete  
LW12 athlete (bilateral amputee)  
LW12 athlete (monolateral amputee)

a) stick diagram;  b) wrist, elbow and shoulder trajectories
SLEDGE VELOCITY

Discussion

**SLEDGE VELOCITY**

deceleration during the PP plateau at the end of the PP

snow-pole contact

non effective pole pushing angle

85% women have this trend

87.5% men have this trend
**Discussion**

**Inertial effect**
acceleration early stage of PP
with no pole-snow contact
### Discussion

**Forearm kinematics**

\[
\begin{align*}
\vec{p}_{CMf} &= \vec{p}_E + f \cdot \left[ \vec{p}_W - \vec{p}_E \right] \\
\vec{v}_{CMf} &= \vec{v}_E + f \cdot \left[ \vec{w}_f \times \left( \vec{p}_W - \vec{p}_E \right) \right] \\
\vec{a}_{CMf} &= \vec{a}_E + f \cdot \left[ \vec{w}_f \times \left( \vec{p}_W - \vec{p}_E \right) \right] + f \cdot \left[ \vec{w}_f \times \left( \vec{w}_f \times \left( \vec{p}_W - \vec{p}_E \right) \right) \right]
\end{align*}
\]

**Upperarm kinematics**

\[
\begin{align*}
\vec{p}_{CMu} &= \vec{p}_S + u \cdot \left( \vec{p}_E - \vec{p}_S \right) \\
\vec{v}_{CMu} &= \vec{v}_S + u \cdot \left[ \vec{w}_u \times \left( \vec{p}_E - \vec{p}_S \right) \right] \\
\vec{a}_{CMu} &= \vec{a}_S + u \cdot \left[ \vec{w}_u \times \left( \vec{p}_E - \vec{p}_S \right) \right] + u \cdot \left[ \vec{w}_u \times \left( \vec{w}_u \times \left( \vec{p}_E - \vec{p}_S \right) \right) \right]
\end{align*}
\]

**Masses**

\[
\begin{align*}
m_u &= 0.022 \cdot m_t + \left( \frac{4.76}{g} \right) \\
m_f &= 0.013 \cdot m_t + \left( \frac{2.41}{g} \right) \\
m_a &= m_f + m_u \\
r_u &= \frac{m_u}{m_a} \quad r_f = \frac{m_f}{m_a}
\end{align*}
\]

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<td>(p_E)</td>
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<td>(p_W)</td>
<td>Position vector of Wr joint</td>
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<td>(p_{CMu})</td>
<td>Position vector of CM(_u) joint</td>
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<td>(w_f)</td>
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<td>(\dot{\omega})</td>
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<tr>
<td>(\ddot{\omega})</td>
<td>Angular acceleration of upper-arm link</td>
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Discussion

\[ \vec{f}_i = \frac{\vec{F}_i}{m_a} = \left[ (r_u \cdot \vec{a}_{CMu}) + (r_f \cdot \vec{a}_{CMf}) \right] \cdot \hat{i} \]

\[ f_{i_x} = - \left[ (r_u \cdot \vec{a}_{CMu}) + (r_f \cdot \vec{a}_{CMf}) \right] \cdot \hat{i} \]
POLE ANGLE
POLE ANGLE
POLE LENGTH

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<th>BASTONCINO</th>
<th>H SPALLA</th>
<th>H ATLETA</th>
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Conclusions

• check the feasibility of the motion capture during a contest

• velocity:
  most of the athletes present some similar features; residual motor potential influences shape and duration of the deceleration
  more performing athletes reach maximum sledge velocity when the arm is in a posterior position respect the trunk, increasing PP
  a “kneeling” position allows a positive gradient of velocity during PP
  arm inertia play an important role in propulsion

• pole
  ratio pole/height on sledge increases as increases the seat angle respect the vertical plane. In general with curled legs ratio < 1.
  LW 10 class pole angles in PP are heterogeneous, while for LW 11 and LW12 angles are more homogeneous, even if there are some difference between man and women
Thank you!