# Cross-Country Sit Skiing: prominence of pushing poles gesture

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VISTA CONFERENCE

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# Summary

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- cross-country sit-sky
- tests
- subjects & materials
- biomechanical model
- results
- discusison
- conclusions

# Double Poling in cross-country sit ski

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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

# Tests

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## FIELD TESTS DURING COMPETITION

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

# Tests

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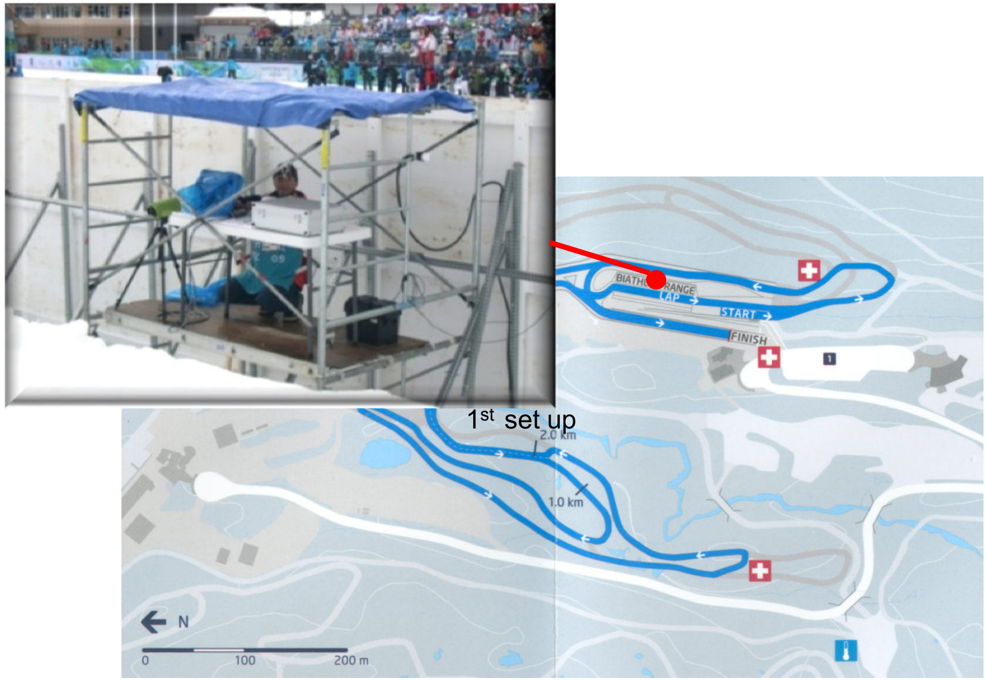
vancouver 2010
PARALYMPIC GAMES
JEUX PARALYMPIQUES

- ✓ 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** FONDAZIONE CRT
**Research approved and supported by** ***International Paralympic Committee***

# 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

# Subjects & Materials

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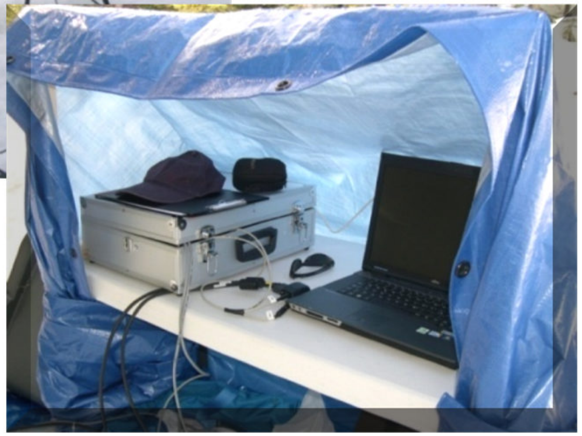


## PARTECIPANTS

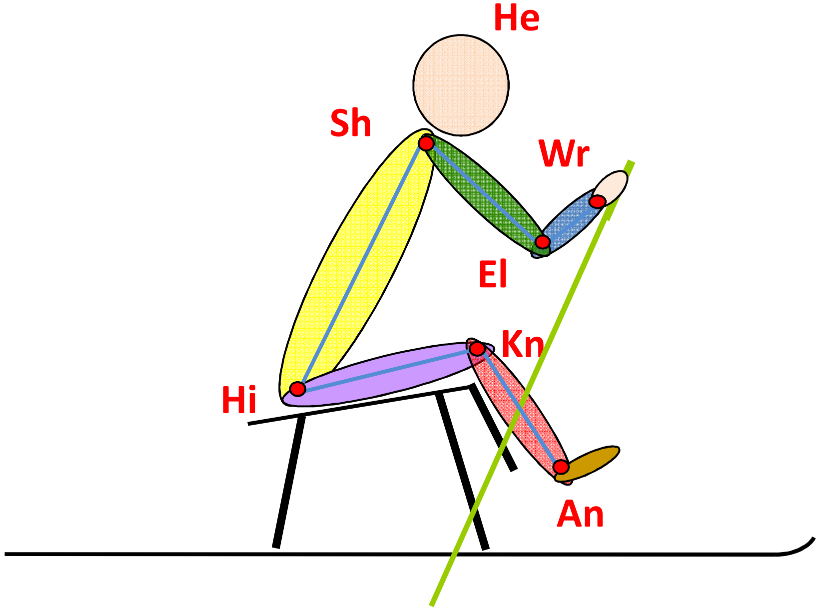
WOMEN

| women | n. athletes | % | age | s.d |
|---|---|---|---|---|
| **women** | **15** | | 34,3 | 8,6 |
| LW 10 | 4 | 27% | 39,0 | 6,8 |
| LW10.5 | 1 | 7% | 24,0 | |
| LW 11 | 3 | 20% | 36,3 | 6,4 |
| LW 11.5 | 2 | 13% | 31,0 | 2,8 |
| LW 12 | 5 | 33% | 32,6 | 12,0 |

MEN

| men | n. athletes | % | age | s.d |
|---|---|---|---|---|
| **men** | **35** | | 36,9 | 8,9 |
| LW 10 | 3 | 9% | 42,0 | 4,4 |
| LW10.5 | 2 | 6% | 28,0 | 5,7 |
| LW 11 | 10 | 29% | 40,8 | 8,3 |
| LW 11.5 | 5 | 14% | 38,2 | 9,1 |
| LW 12 | 15 | 43% | 34,1 | 9,2 |

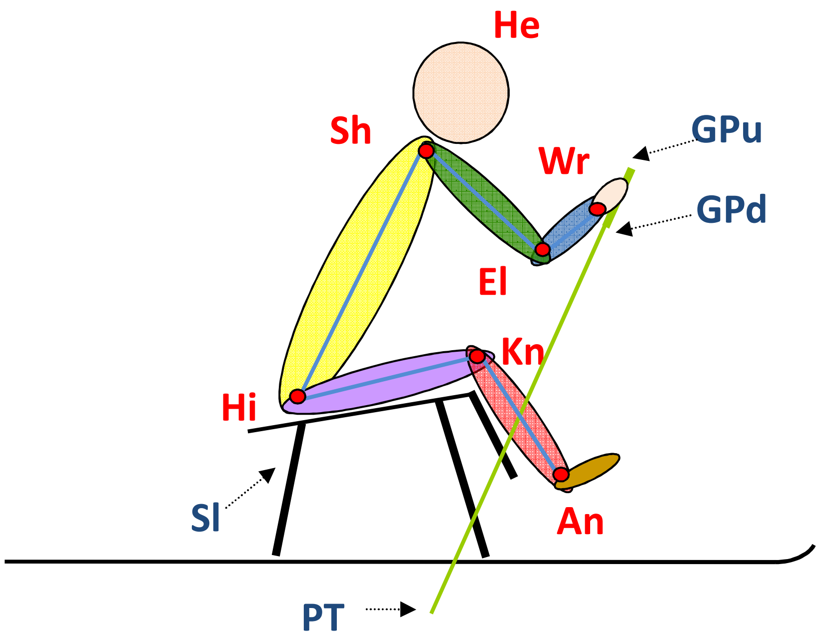
# Biomechanical Model




seven **anatomical points**, (head temple, shoulder, elbow, wrist, hip, knee and ankle left joints)

# Biomechanical Model






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)

# Biomechanical Model

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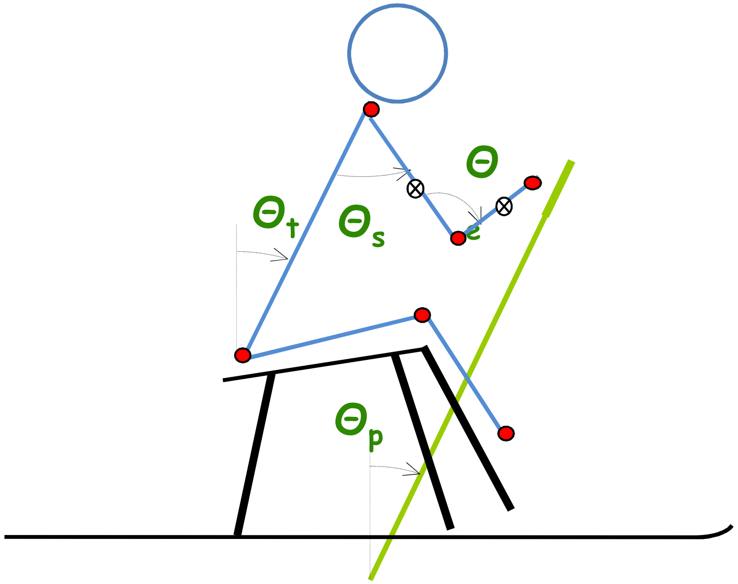



seven **anatomical points**, (head temple, shoulder, elbow, wrist, hip, knee and ankle left joints)

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

**angle convention**

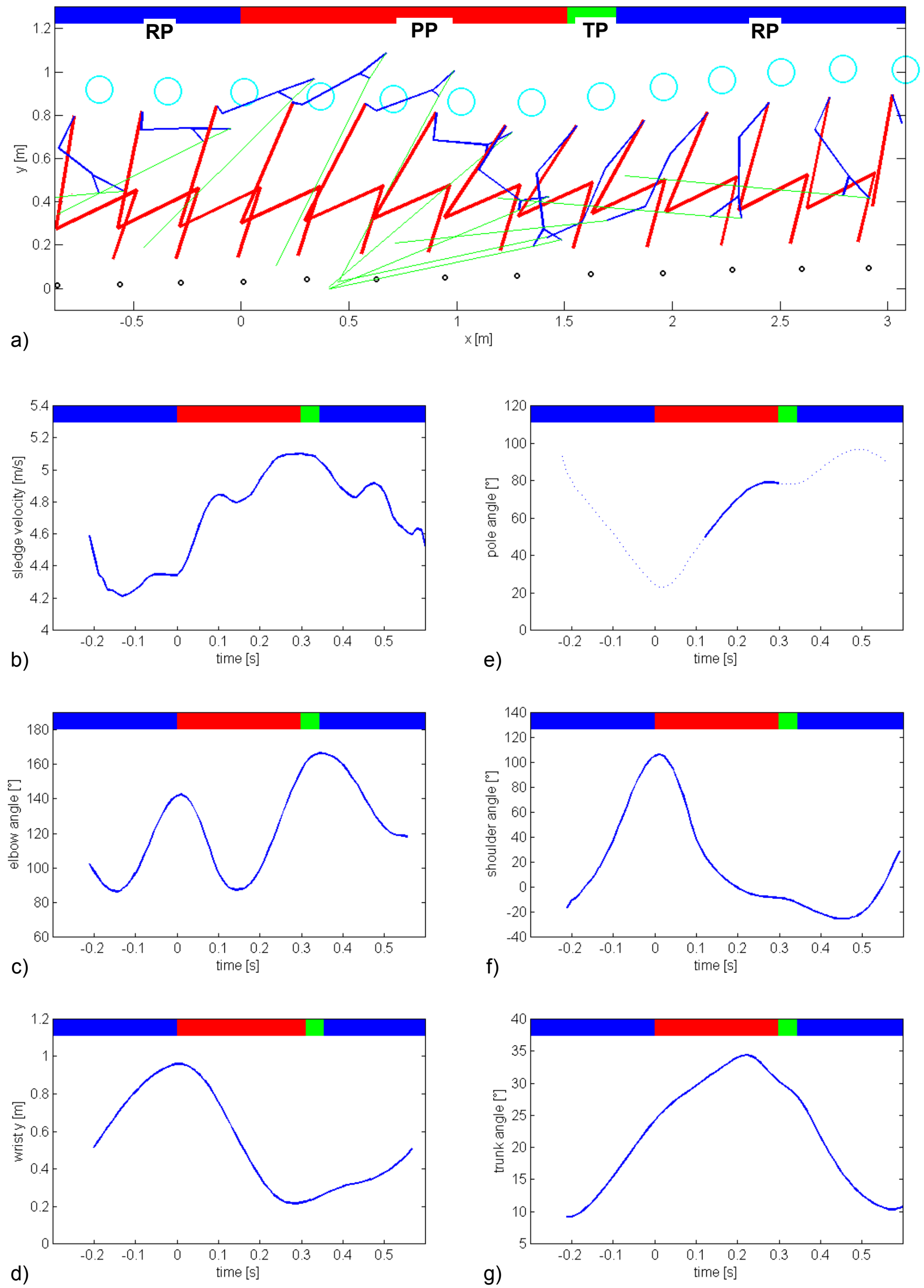
# Results

## 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.

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# Results

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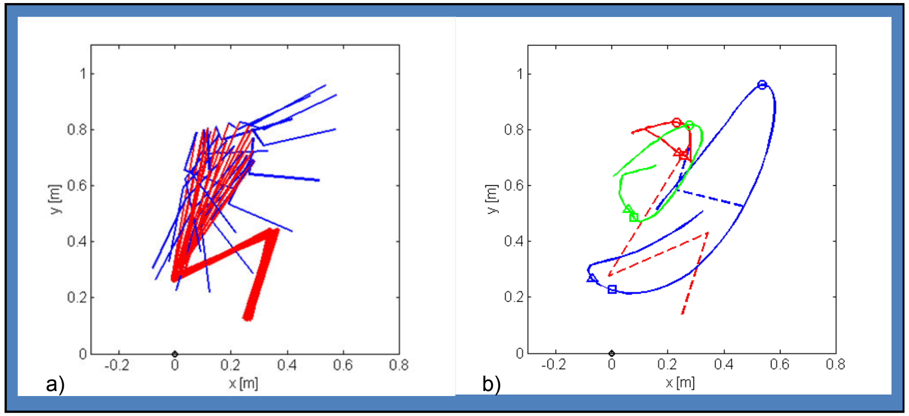
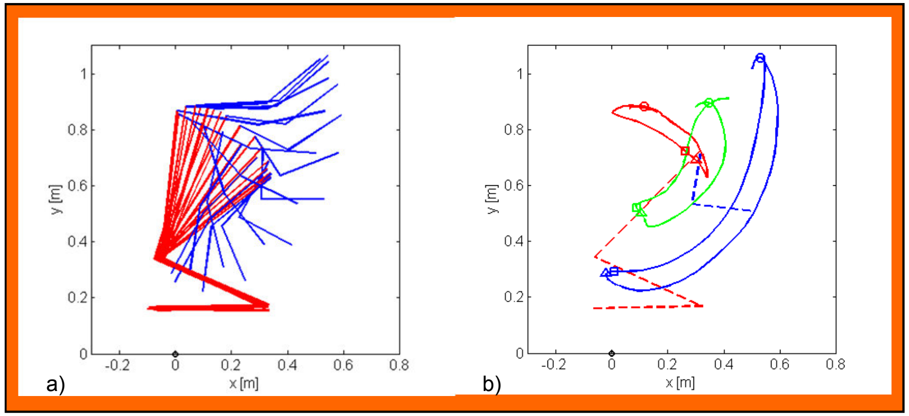
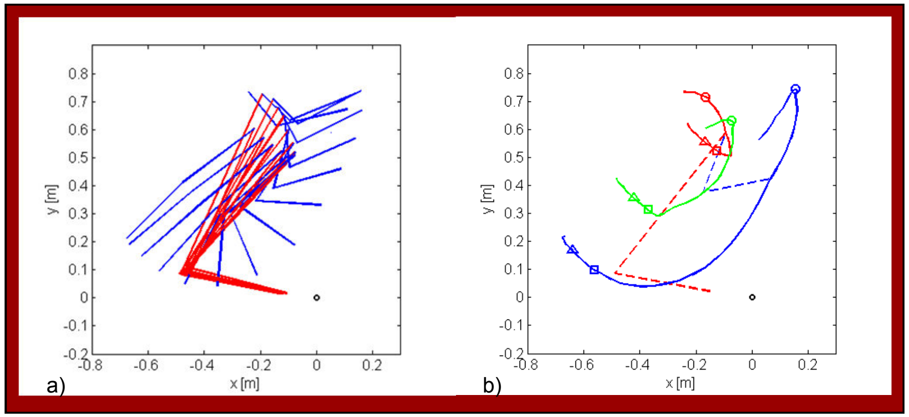
LW10 athlete



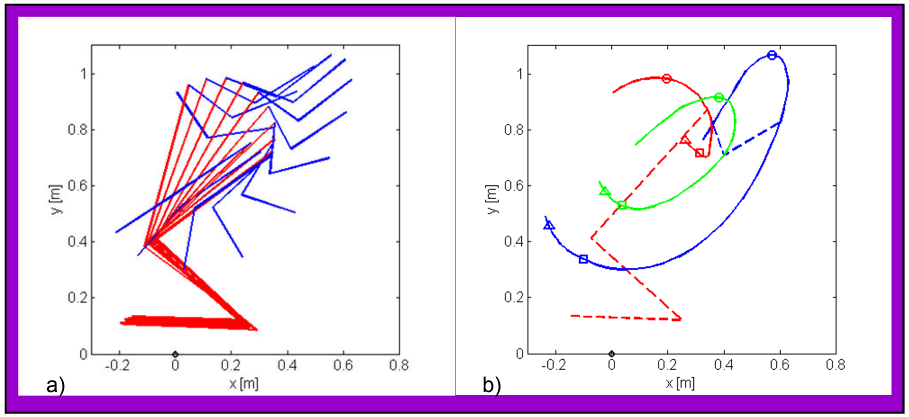

LW11 athlete




LW12 athlete (bilateral amputee)

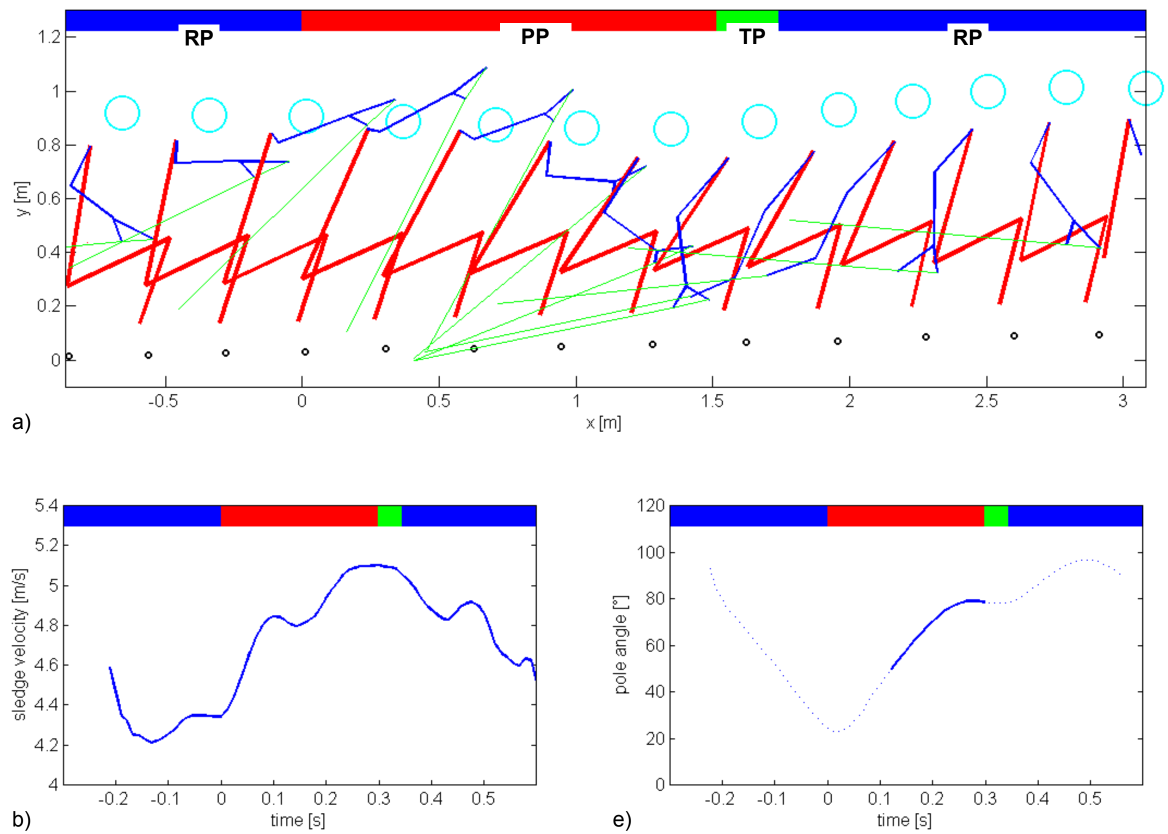



LW12 athlete (monolateral amputee)




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

## SLEDGE VELOCITY





Boninger, Met al. (2000). Manual wheelchair push rim biomechanics and axle position, *Archive of Physical Medicine Rehabilitation*; Vol. 81
Lentino, C., et al. (2008) Analisi cinematica della spinta in carrozzina: proposta di modello sperimentale. *Giornale It.. Med. Riab.*; 23(2)

## SLEDGE VELOCITY

deceleration during the PP

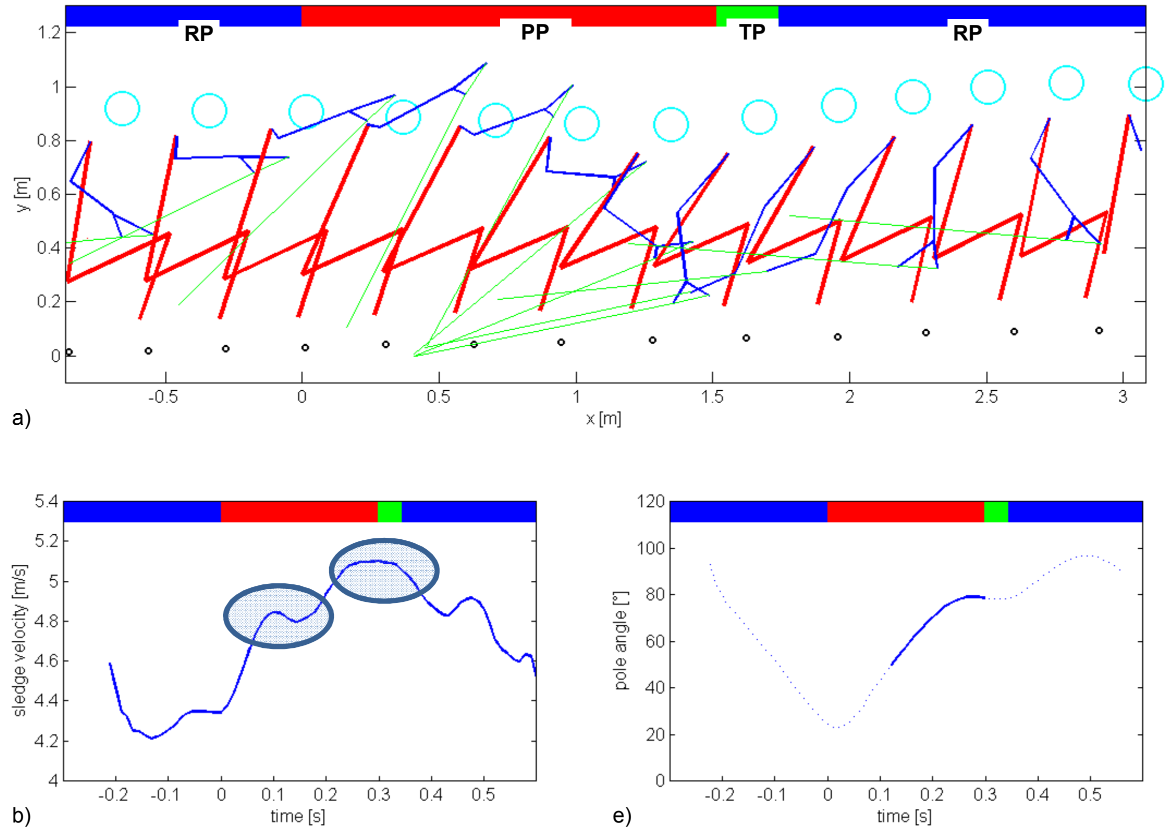
plateau at the end of the PP

snow-pole contact

non effective pole pushing angle

85% women have this trend

87.5% men have this trend



# Discussion

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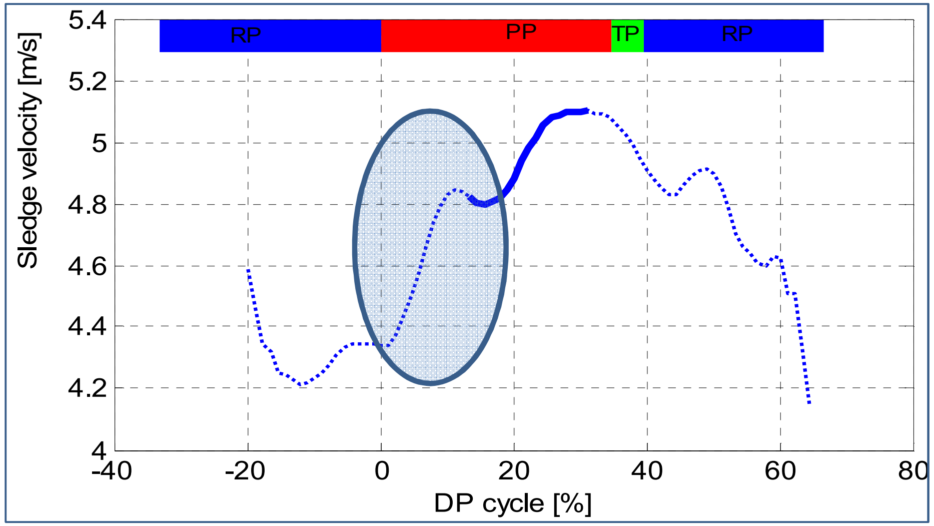
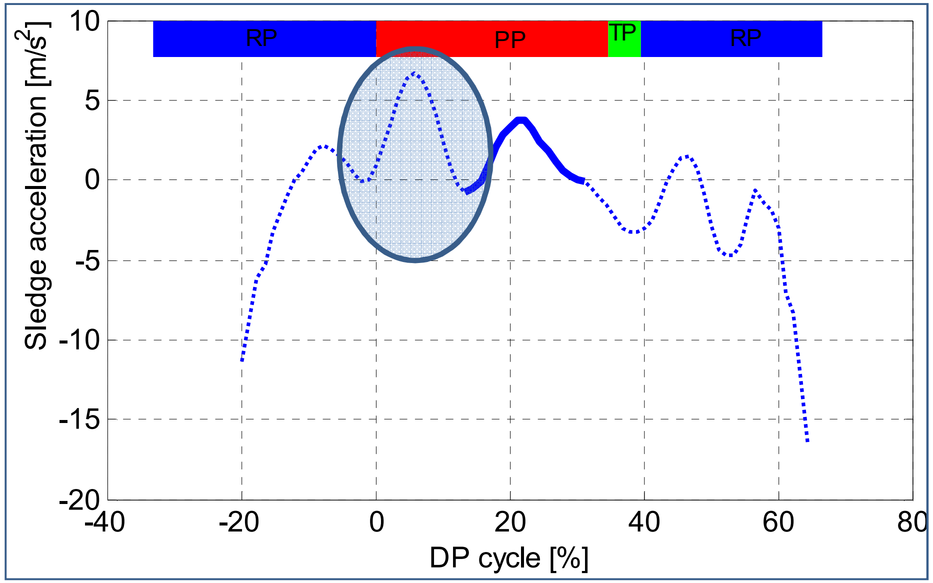
**Inertial effect**

acceleration early stage of PP

with no pole-snow contact



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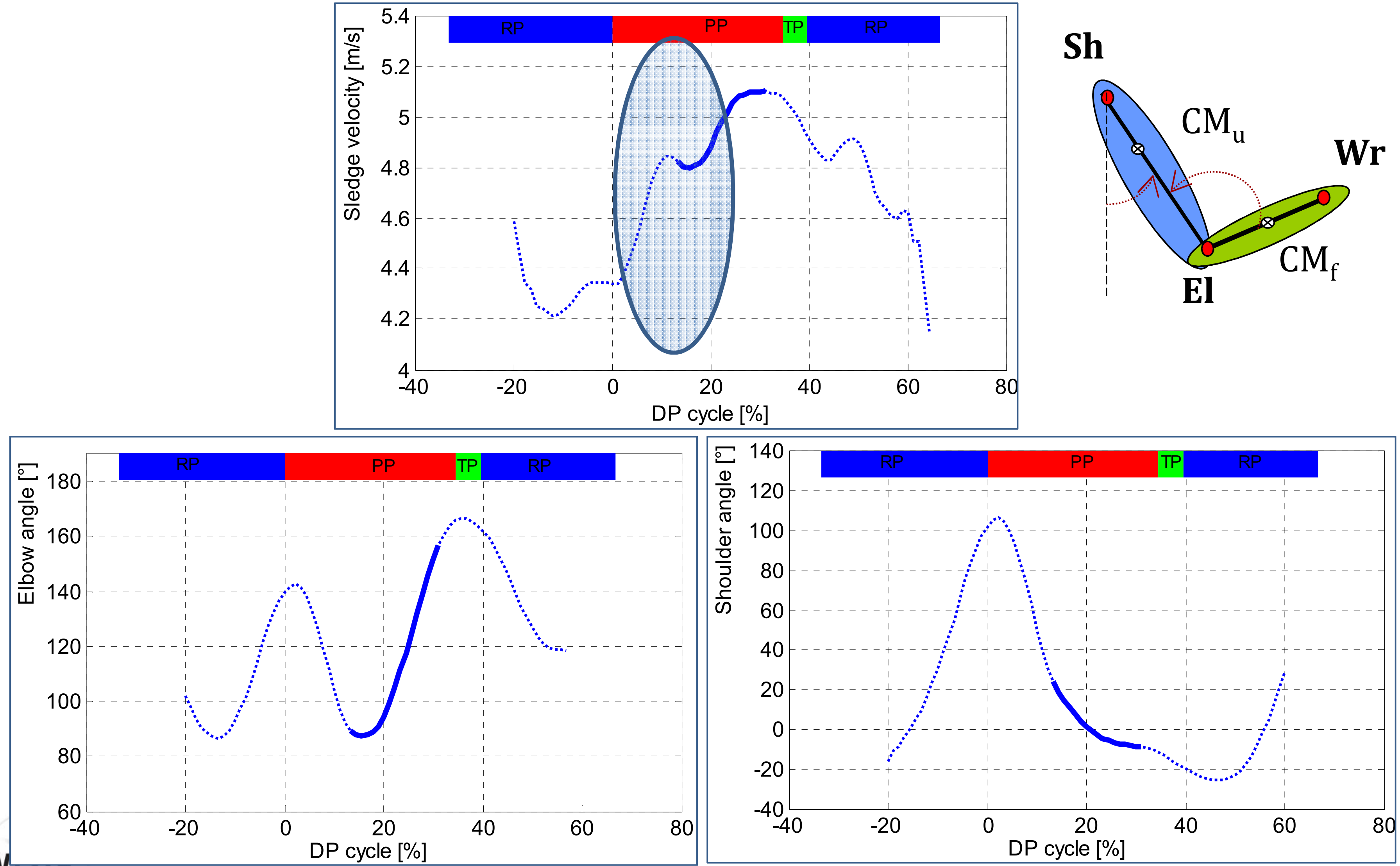

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## Forearm kinematics

$$\vec{p}_{CMf} = \vec{p}_E + f \cdot ((\vec{p})_W - \vec{p}_E)$$

$$\vec{v}_{CMf} = \vec{v}_E + f \cdot [\vec{w}_f \times ((\vec{p})_W - \vec{p}_E)]$$

$$\vec{a}_{CMf} = \vec{a}_E + f \cdot [\dot{\vec{w}}_f \times ((\vec{p})_W - \vec{p}_E)] + f \cdot [\vec{w}_f \times [\vec{w}_f \times ((\vec{p})_W - \vec{p}_E)]]$$

## Upperarm kinematics

$$\vec{p}_{CMu} = \vec{p}_S + u \cdot (\vec{p}_E - \vec{p}_S)$$

$$\vec{v}_{CMu} = \vec{v}_S + u \cdot [\vec{w}_u \times (\vec{p}_E - \vec{p}_s)]$$

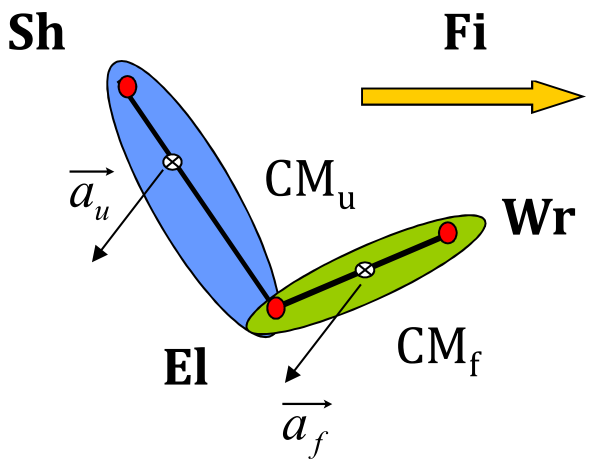
$$\vec{a}_{CMu} = \vec{a}_s + u \cdot [\dot{\vec{w}}_u \times (\vec{p}_E - \vec{p}_S)] + u \cdot [\vec{w}_u \times [\vec{w}_u \times (\vec{p}_E - \vec{p}_S)]]$$

## Masses

$$m_u = 0.022 \cdot m_t + \left(\frac{4.76}{g}\right) \qquad m_f = 0.013 \cdot m_t + \left(\frac{2.41}{g}\right);$$

$$m_a = m_f + m_u$$

$$\mathbf{r_u} = \frac{\mathbf{m_u}}{\mathbf{m_a}} \qquad r_f = \frac{m_f}{m_a}$$




| Terms | Description |
|---|---|
| $p_S$ | Position vector of **Sh** joint |
| $p_E$ | Position vector of **El** joint |
| $p_W$ | Position vector of **Wr** joint |
| $p_{CMu}$ | Position vector of **$CM_u$** joint |
| $p_{CMf}$ | Position vector of **$CM_f$** joint |
| $v_S$ | Velocity vector of **Sh** joint |
| $v_E$ | Velocity vector of **El** joint |
| $v_{CMu}$ | Velocity vector of **$CM_u$** joint |
| $v_{CMf}$ | Velocity vector of **$CM_f$** joint |
| $a_S$ | Acceleration vector of **Sh** joint |
| $a_E$ | Acceleration vector of **El** joint |
| $a_{CMu}$ | Acceleration vector of **$CM_u$** joint |
| $a_{CMf}$ | Acceleration vector of **$CM_f$** joint |
| $w_f$ | Angular velocity of **forearm link** |
| $w_u$ | Angular velocity of **upper-arm link** |
| $_f$ | Angular acceleration of **forearm link** |
| $_u$ | Angular acceleration of **upper-arm link** |

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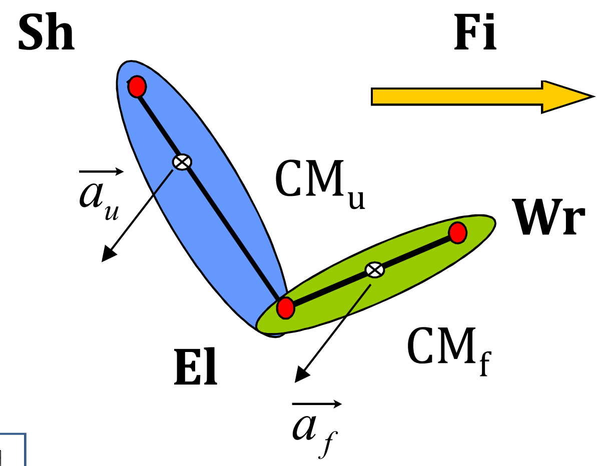
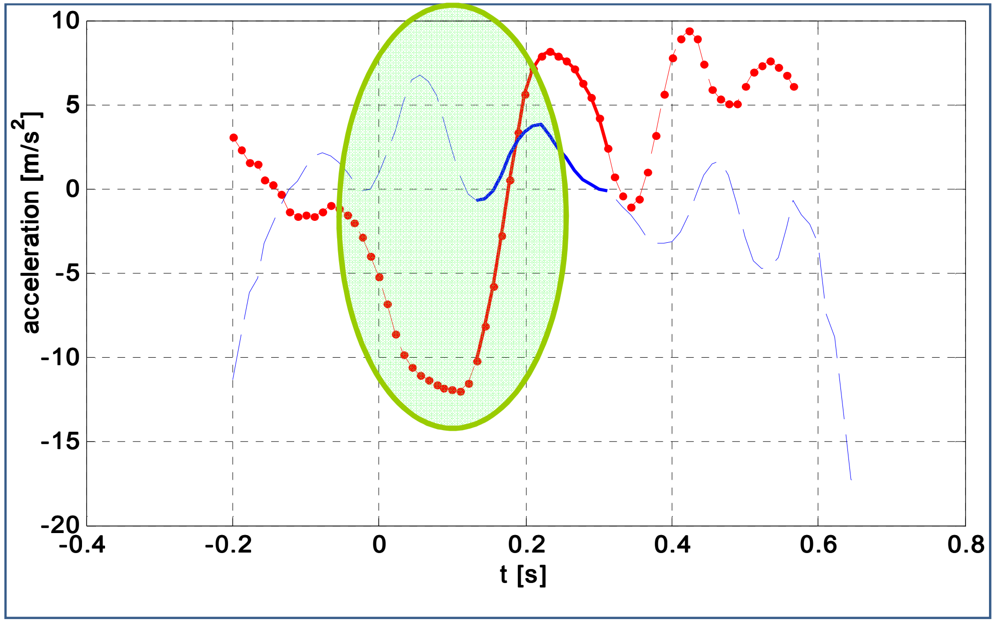
$$\vec{f}_i = \frac{\vec{F}_i}{m_a} = \left[\left(r_u \cdot \vec{a}_{CMu}\right) + \left(r_f \cdot \vec{a}_{CMf}\right)\right]$$

$$fi_x = -\left[\left(r_u \cdot \vec{a}_{CMu}\right) + \left(r_f \cdot \vec{a}_{CMf}\right)\right] \cdot \vec{i}$$



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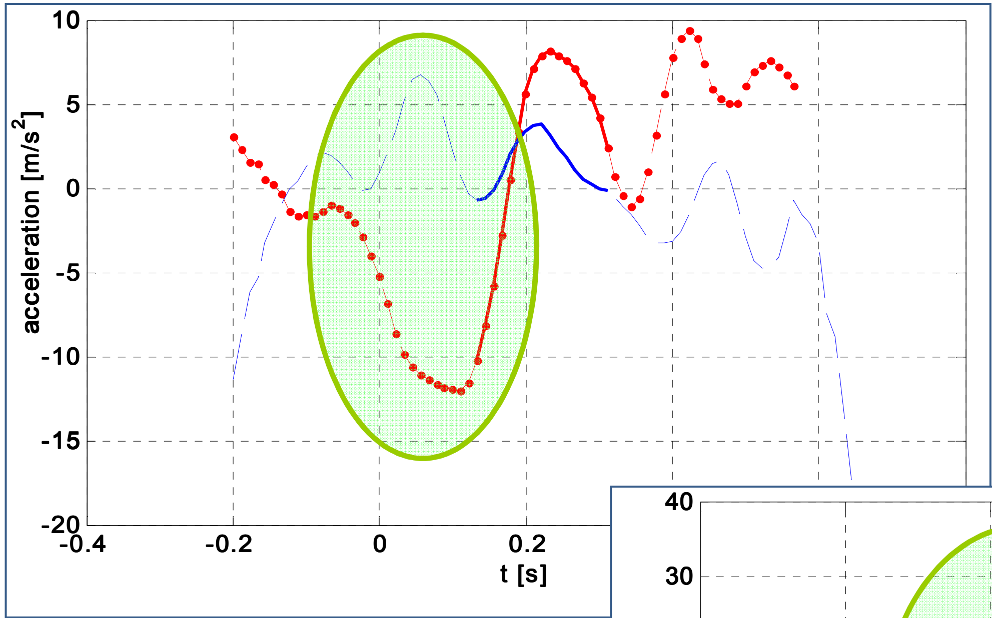


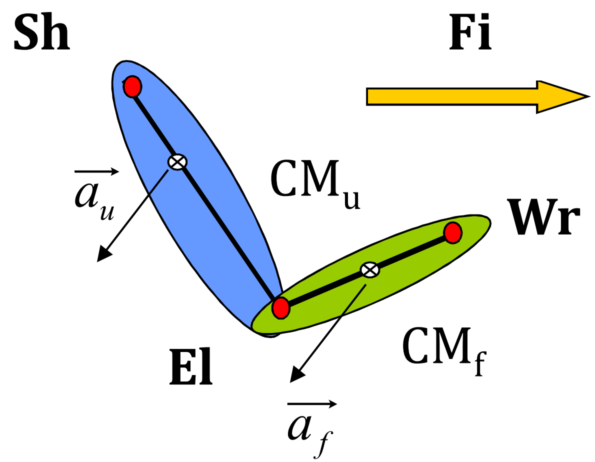


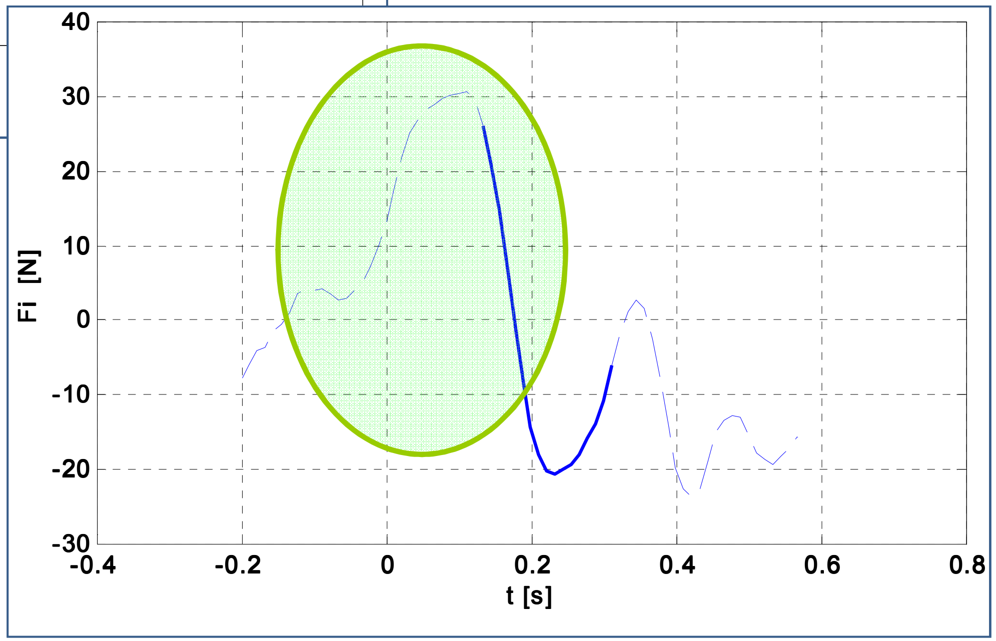

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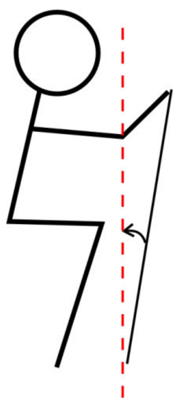
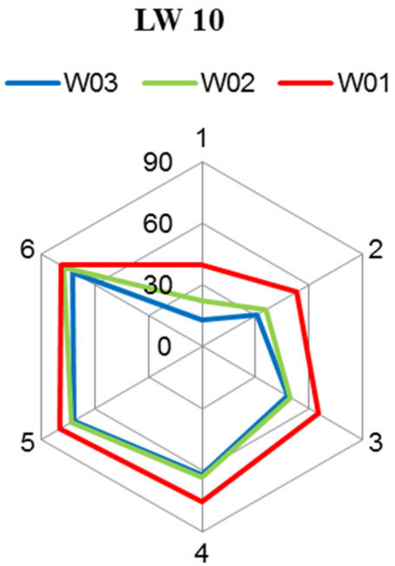
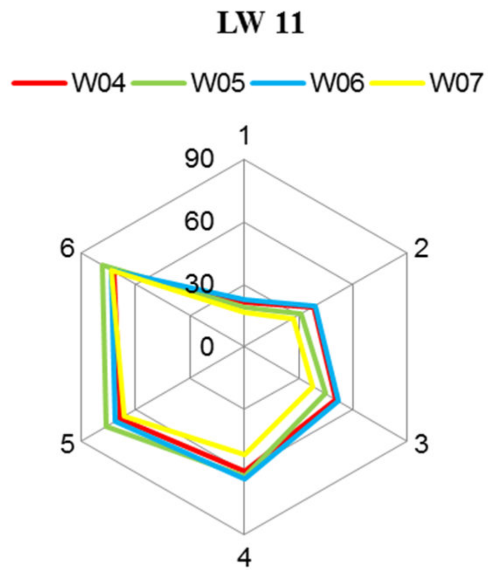
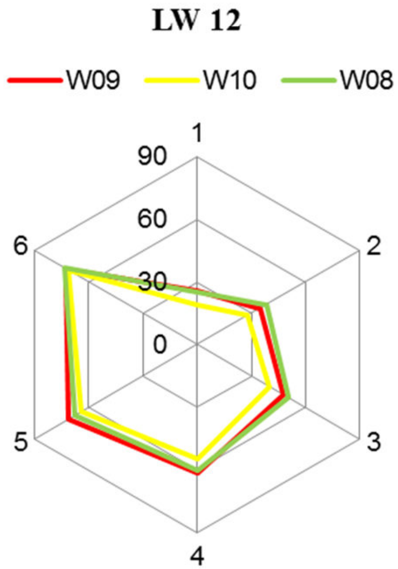
## POLE ANGLE





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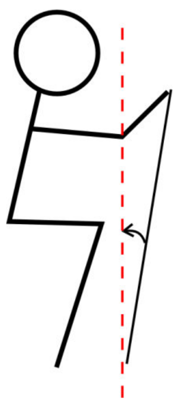
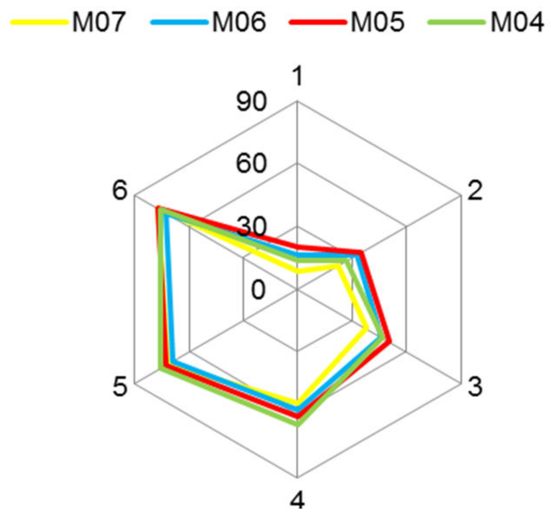
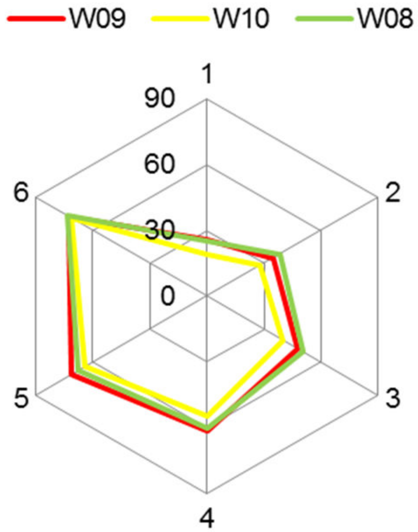
## POLE ANGLE



LW12 men




LW12 women



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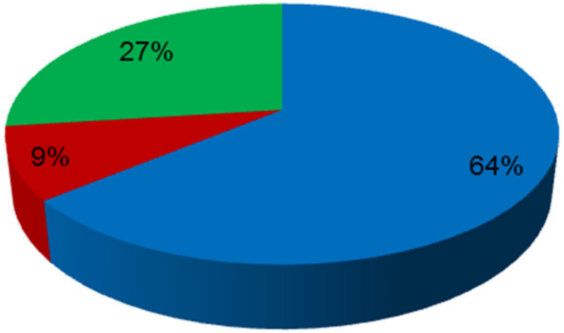
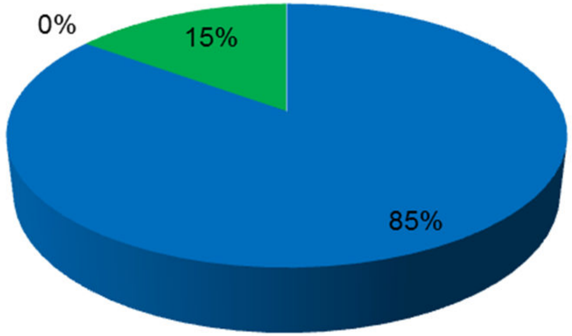
## POLE LENGTH




| CODICE ATLETA | BASTONCINO | H SPALLA | H ATLETA | H SLITTA | B/H | Δh |
|---|---|---|---|---|---|---|
| W01 | 105 | 76 | 94 | 15 | 1.38 | 11 |
| W02 | 99 | 77 | 92 | 18 | 1.07 | 7 |
| W03 | 103 | 86 | 108 | 22 | 0.95 | -5 |
| W04 | 122 | 94 | 116 | 31 | 1.05 | 6 |
| W05 | 94 | 74 | 88 | 10 | 1.06 | 6 |
| W06 | 95 | 77 | 93 | 23 | 1.02 | 2 |
| W07 | 129 | 103 | 123 | 50 | 1.04 | 6 |
| W08 | 160 | 127 | 149 | 47 | 1.07 | 11 |
| W09 | 104 | 88 | 110 | 35 | 0.94 | -6 |
| W10 | 119 | 99 | 119 | 38 | 1.00 | 0 |
| W11 | 93 | 77 | 95 | 21 | 0.97 | -2 |

| CODICE ATLETA | BASTONCINO | H SPALLA | H ATLETA | H SLITTA | B/H | Δh |
|---|---|---|---|---|---|---|
| M01 | 136 | 103 | 133 | 34 | 1.02 | 3 |
| M02 | 133 | 106 | 127 | 30 | 1.04 | 6 |
| M03 | 145 | 108 | 128 | 32 | 1.34 | 17 |
| M04 | 120 | 103 | 113 | 32 | 1.06 | 7 |
| M05 | 104 | 94 | 110 | 36 | 0.89 | -6 |
| M06 | 129 | 102 | 112 | 33 | 1.15 | 17 |
| M07 | 116 | 97 | 113 | 34 | 1.19 | 3 |
| M08 | 150 | 114 | 137 | 25 | 1.09 | 13 |
| M09 | 126 | 110 | 135 | 126 | 0.93 | -9 |
| M10 | 111 | 91 | 102 | 27 | 1.21 | 9 |
| M11 | 112 | 96 | 110 | 33 | 1.16 | 2 |
| M12 | 160 | 118 | 148 | 38 | 1.35 | 12 |
| M13 | 151 | 108 | 135 | 39 | 1.11 | 16 |



# Conclusions

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- 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!