MOVEMENT ANALYSIS IN WHEELCHAIR RACING

Technische Universität München
Fakultät für Sportwissenschaft
Christiane Peters

Deutsche Sporthochschule Köln
Institut für Individualsport
Axel Knicker

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PURPOSE

1. Identification of muscle strength during start

2. Identification of neuromuscular and segment coordination in wheelchair propulsion

3. Identification of differences between performance levels regarding propulsion techniques during steady state and full speed
SUBJECTS

18 Athletes

5 female
2 A-level 1 B-level 2 junior
both T4 T2 T4 / T3

13 male
7 A-level 1 B-level 5 junior
4 T4 3 T3 T4 3 T4 1 T3 1 T2

Height of lesions

T4
Th 10 / L 1
Th 10
Th 10 / 11
Th 9 / 10
Th 8
L 1
L 3 / 4
lower thoracic-upper lumbar spine
4 Athletes n.n.

T3
Th 4 / 5
Th 4 / 5
Th 3 / 4
Th 8
upper thoracic spine
1 Athlete n.n.

T2
C 6 / 7
C 5
cervical spine
**Start diagnostics**

*general characteristics of the start*

1. to achieve an individually optimal propulsion performance through maximum initial change of velocity of the wheelchair-athlete system
   
   *(acceleration function)*

2. to control the tactically favourable position within the field of drivers
   
   *(tactical function)*

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**Start diagnostics**

*mechanical demands*

1. overcome the moment of inertia of the wheelchair-athlete system as fast as possible
Start diagnostics

mechanical demands

1. overcome the moment of inertia of the wheelchair-athlete system as fast as possible
2. optimum friction between hand/glove and handrim
3. application of maximum propulsion forces over an optimal propulsion path in shortest time (maximise momentum)
Start diagnostics

mechanical demands

1. overcome the moment of inertia of the wheelchair-athlete system as fast as possible

2. optimum friction between hand/glove and handrim

3. application of maximum propulsion forces over an optimal propulsion path in shortest time (maximise momentum)

4. direct transfer of muscle forces onto the handrim (= minimise loss of energy)

5. Positioning of the athletes’ CM well in front of the point of force application for optimum energy transfer and to keep the front wheel on the ground
Start diagnostics

Methods

Parameters
Start diagnostics

Methods

Parameters of start diagnostics

- \( A_{\text{init}} \) start of propulsion – angle between the connecting line between hand and axle at the initial handrim contact and the vertical through the axle

- \( A_{\text{weg}} \) range of propulsion – distance [degrees] between initial and terminal contact on handrim

- \( A_{\text{fin}} \) end of propulsion = \((A_{\text{weg}} + A_{\text{init}})\)

- \( \Delta v_{\text{antrieb}} \) change of velocity during propulsion from initial to terminal handrim contact

Results

<table>
<thead>
<tr>
<th>start parameters</th>
<th>( \Theta )</th>
<th>best performers (n=5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>( A_{\text{init}} )</td>
<td>42.2°</td>
<td>65° - 65°</td>
</tr>
<tr>
<td>( A_{\text{fin}} )</td>
<td>125.6°</td>
<td>125 - 183°</td>
</tr>
<tr>
<td>( A_{\text{weg}} )</td>
<td>83.4°</td>
<td>37 - 117°</td>
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<td>+2.27 m/s</td>
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**Start diagnostics**

**Results**

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**significant differences in initial hand position between performance levels**

![Graph showing start parameters](graph.png)
Results

- The higher the range of propulsion, the higher the increase of velocity.

- The acceleration abilities appear to be related to hand position on the handrim.

Hand positions:
1. $< 22.5^\circ$
2. $< 45^\circ$
3. $> 45^\circ$
Start diagnostics

Results

amplitude of shoulderpoint

elbow shoulder head

wrist hand

Results

Schulter Amplitude

-0.12 -0.08 -0.04 0.00 0.04 0.08 0.12
### Results

The rise of the shoulder point corresponds to a drop of the velocity time course at the end of the drive phase, loss of energy in musculo-skeletal system?

### Problem

- relation between hand position at handrim and force transfer
- relation between preferred hand position at handrim and optimal force transfer
Position of hands at the handrim is usually given according to a dial with:

- 12:00h = 0°
- 15:00h = 90°
- 18:00h = 180°

Preferred hand position: between 13:00h and 15:00h

Methods / Procedures

- Force transducer registered horizontal forces
- Hand position at:
  1. 13:00h
  2. Between 13:00h and 15:00h (preferred hand position)
  3. 15:00h
  4. 17:00h
**Methods / Procedures**

- $F_{\text{max}}$: initial maximum force – the force which is achieved after the first push. The absolute maximum force during the drive phase is likely to be higher but does not represent the athletes’ initial strength potentials.

- $\Delta t_{\text{max}}$: time interval from start of force increase until $F_{\text{max}}$

- $S_{\text{ind}}$: power index – $S_{\text{ind}} = \frac{F_{\text{max}}}{\Delta t_{\text{max}}}$

**Results**

![Graph showing F(max) and Anstiegsdauer](image)
Results

- Correlation coefficient: \( r = -0.64 \), \( r^2 = 0.41 \)

- Force [N] vs. hand position [°]

**Power Index vs. \( F_{\text{max}} \)**

\[ \text{power index} = 500 + 0.5 \times F_{\text{max}} \]

**Correlation coefficient:**

- \( r = 0.95 \), \( r^2 = 0.90 \)

**Variations:**

- 13:00h
- 15:00h
- 17:00h
**Results**

1. smallest force application to handrim in 5:00h position
Propulsion

Results

1. smallest force application to handrim in 5:00h position
2. smallest power index in 5:00h position due to small muscle length of elbow extensors
3. maximum force correlates significantly with power index
Results

1. smallest force application to handrim in 5:00h position
2. smallest power index in 5:00h position due to small muscle length of elbow extensors
3. maximum force correlates significantly with power index
4. force angle relation resembles force length relation of elbow extensors?
Institut für Individualsport
Axel Knicker
Rollstuhlschnellfahren
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Fakultät für Sportwissenschaft
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propulsion phases after Morse(1999):

acceleration

catch and drive

lift and stretch

release
1. hand position at the handrim is velocity dependent
2. hands are in a fixed and stable position within the gloves
3. arms are strongly adducted during catch and drive
4. hands are in radial abduction from initial handrim contact until 3 o’clock position
5. active ulnar abduction of the hands in further drive phase
6. big variations within techniques
**Race Conditions**

**Technique**

1. higher velocities reached by A-level athletes
2. higher velocity gain during drive by A-level athletes
3. higher loss of velocity during free roll by A-level athletes due to ?:
   a. higher frictional forces with higher velocities
   b. higher air resistance due to higher velocities
1. higher initial angle at catch for A-level athletes
2. shorter range of propulsion for A-level athletes
3. shorter range of propulsion for junior athletes in full speed conditions compared to steady state
considerable hand movements take place prior to release

ulnar abduction and palmarflexion are supposed to reinforce the final push

final radial abduction and/or dorsiextension of the hands are most obviously detrimental for further acceleration
- during drive phase final hand movements in either direction should be avoided
- stiffening of the wrist joint complex seems to be advantageous for maximal acceleration
Race Conditions

- huge variations in activation duration
- no consistent intermuscular coordination patterns of the muscles relevant for propulsion
- trend to increase activation level (amplitude) at higher velocities.
1. focus on muscular features such as force length and force velocity relations and their contribution to performance

2. considerations about energy transfer from the musculoskeletal system to the wheelchair

3. development of a wheelchair bound force measuring device