Handcycling
how to optimize performance

Sonja de Groot
Handcycling - research
Handcycling - history

1655 - first handcycle was invented by watchmaker Stephan Farffler (1633-1689)

1875 - Velociman

1880

1898, first chain-driven wheelchair
Handcycling - history

1907

1917

1950

1983 - first attachable handcycle for a wheelchair.

1989

1986 sport version – feet forward

1991

1993

1999 - kneeling
Handcycling - history

Arm Power

Arm Trunk Power
Handcycling
From rehabilitation - Paralympics
Handcycling – why?

Compared to wheelchair propulsion:

- **Physiologically more efficient** (Dallmeijer et al., 2004)

@ 35 W:
- Lower VO2, HR and RPE,
- Higher gross ME
Compared to wheelchair propulsion:

- **Lower shoulder loads**

  (Arnet et al., 2012)
Handcycling - optimization

User
- Fitness level
- Skill

Interface
- Gears
  - (A)Synchronous
- Crank & hand grip
- Seat position

Handbike
- Mass
- Size
- Wheel characteristics

Task dependent => mobility, recreation, sport
Handcycling - optimization

User
Handcycling – during rehab

• **Structured handcycle training – last 8 weeks of inpatient rehab** (Nooijen et al., 2015)
  - 3x/week 45-60 min interval training, Borg score 4-7 (N=45)
  - 91% completed handcycle training; no adverse events
  - Training intensity: mean Borg score 6.2 ± 1.4
  - Training frequency: 1.8 ± 0.5x/week
  - POpeak (36%) and VO2peak (10%) improved significantly
Handcycling – HandbikeBattle

To promote handcycling after rehabilitation -> HandbikeBattle

- Kaunertalergletscherstrasse in Austria; 20 km, 900m↑
- Teams: 4-6 former patients from 12 Dutch rehabilitation centers
- Goal: Encourage wheelchair-users to initiate or keep training after the rehabilitation period
Handcycling – HandbikeBattle

Impression:
HandbikeBattle started in 2013:
   -> testing and training people in a handcycle for such a challenging event

- Best protocol for testing?
- Best training program?
- What is the effect of participating in the HandbikeBattle (training & event) on physical and mental fitness?
Handcycling – HandbikeBattle

- Graded exercise test: arm ergometry
- What protocol to select? (De Groot et al., 2019)
  - 30 s Wingate test & GXT

N=93 SCI (35 TP, 58 PP) – 80% (model) vs. 20% (validation)

<table>
<thead>
<tr>
<th>Theoretical model POpeak/kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>(+) POmean Wingate (W)</td>
</tr>
<tr>
<td>(-) Age (years)</td>
</tr>
<tr>
<td>(-) Sex (M/F)</td>
</tr>
<tr>
<td>(-) Body mass index (kg/m²)</td>
</tr>
<tr>
<td>(-) Time since injury (years)</td>
</tr>
<tr>
<td>(+) Lesion level (TP vs PP)</td>
</tr>
</tbody>
</table>

R² 76%
ICC 0.89 (excellent)

*Figure 1. Scatter plots of the measured vs. predicted POpeakGXT and line of identity (solid line) and 20% deviation boundaries (dashed lines).*
• Training for the HandbikeBattle: (Hoekstra et al., 2017)
  16% ↑ POpeak
  7% ↑ VO2peak

• What kind of training regime led to these improvements?
  • Dose-response?
  • Which methods can be used to assess training load in handcycling?
Association internal vs. external training load measures

- moderate ($r=0.3-0.5$)
- large ($r=0.5-0.7$)
- very large ($r=0.7-0.9$)
- nearly perfect ($r>0.9$)

Subject no. | Class | $\text{TRIMP}_{\text{RPE}}$ vs. TSS
--- | --- | ---
1 | H3 | 0.92 | 15
2 | H3 | 0.99 | 5
3 | H3 | 0.61 | 45
4 | H3 | 0.87 | 42
5 | H3 | 0.77 | 14
6 | H4 | 0.79 | 47
7 | H4 | 0.95 | 20
8 | H4 | 0.77 | 26
9 | H4 | 0.92 | 31
10 | H5 | 0.97 | 28

$r$ within subjects | 0.814 | 260

De Groot et al., 2018
Ingrid Kouwijzer – PhD student HandbikeBattle

- What kind of training regime led to these improvements?
  - Dose-response?

- Effects on QoL and its relationship with fitness Arch Phys Med Rehab submitted
  -> presentation on Friday 6 September – 9.30-9.45h.

- Predictive modeling Disabil Rehabil, 2019
- Test protocols – ramp vs. 1-min vs. 3-min Eur J Appl Physiol, Accepted 2019
- Interrater & intrarater reliability ventilatory thresholds in SCI Spinal Cord, 2019
Handcycling – Paralympics

From rehab to HandbikeBattle to Paralympics:
Handcycling – Classification

Fair competition with respect to level of impairment => Classification

Effects of push-off ability (closed-chain)
Kouwijzer et al., 2018

- Interaction user - equipment

Fig. 2. Two-feet support (top), 1-foot support (middle), no foot support (bottom). White arrow indicates the metal frame of the footrests.
Evidence-based classification of handcycling athletes

- Is the average race speed different between current classes? (Poster Friday 6 Sept 16.00-18.00h)
- Influence of trunk strength on handcycling performance (Oral Saturday 7 Sept 11.30-11.45h)
Handcycling - handbike

Handbike

Interface
Handcycling – handbike/interface

Measuring the handcycles of the HandbikeBattle participants

But what is good?? => Evidence?
Handcycling - handbike

Handbike
## Handcycling – Handbike

<table>
<thead>
<tr>
<th>Factor</th>
<th>(Rolling) Resistance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass handcycle ↑</td>
<td>↑</td>
</tr>
<tr>
<td>De Groot et al., 2014</td>
<td></td>
</tr>
<tr>
<td>Tyre pressure ↓</td>
<td>↑</td>
</tr>
<tr>
<td>Wheel size ↓</td>
<td>↑</td>
</tr>
<tr>
<td>Camber angle ↑</td>
<td>?</td>
</tr>
<tr>
<td>Toe in/toe out ↑</td>
<td>↑</td>
</tr>
<tr>
<td>Maintenance ↓</td>
<td>↑</td>
</tr>
<tr>
<td>Frontal surface ↑</td>
<td>↑</td>
</tr>
<tr>
<td>Mannion et al., 2019; Perret Vista 2013</td>
<td></td>
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</tbody>
</table>
Thesis Paul Mannion - 2019

Impact of following factors on the drag of Paralympic hand-cyclists:

Arm-crank position: 9 o'clock position yielded the lowest drag area for all yaw angles

Disk vs. spoked wheels & the relationship with cross winds

Figure 1. Four arm-crank positions of interest, denoted as (a) 12, (b) 9, (c) 6, and (d) 3 o’clock. The projected frontal areas corresponding to each arm-position are included for comparison.
## Handcycling - interface

<table>
<thead>
<tr>
<th>Factor</th>
<th>Physiology</th>
<th>Biomechanics</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Synchronous vs Asynch</strong></td>
<td><strong>Sync:</strong> ME ↑ HR ↓ POpeak ↑ VO2peak ↑</td>
<td><strong>Sync:</strong> 2D total force ↑ FEF ↑</td>
</tr>
<tr>
<td>Dallmeijer et al., 2004; Woude et al., 2008; Bafghi et al., 2008</td>
<td></td>
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<tr>
<td><strong>Gears</strong></td>
<td>Higher gear ratio (heavier): VO2 ↑ HR ↑ ME ↓</td>
<td>Higher gear ratio: trunk flexion/ext ↑</td>
</tr>
<tr>
<td>Woude et al., 2001; Faupin et al., 2008</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Crank position</strong></td>
<td>Fore-aft: ME =</td>
<td>Not above shoulder Elbow angle 15°: contact force ↓ Fore-aft closest to trunk</td>
</tr>
<tr>
<td>Faupin et al. 2008; Arnet et al., 2014; Vegter et al., 2019</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Crank length</strong></td>
<td>Longer: PO ↑ ME ↓ Width: PO =</td>
<td></td>
</tr>
<tr>
<td>Krämer et al., 2009; Goosey-Tolfrey et al., 2008</td>
<td></td>
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<tr>
<td><strong>Hand grip angles</strong></td>
<td>+30° optimal PO generation HRpeak, VO2peak = Vertical grip: lactate ↑</td>
<td></td>
</tr>
<tr>
<td>Krämer et al., 2009; Abel et al., 2015</td>
<td></td>
<td></td>
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<tr>
<td><strong>Seating position</strong></td>
<td>Kneeling: POpeak ↑ VO2peak ↑ ME ↓</td>
<td>Back seat more upright: Shoulder load ↓</td>
</tr>
<tr>
<td>Faupin et al., 2008; Arnet et al., 2012 &amp; 2014; Verellen et al., 2012; Kouwijzer et al., 2018</td>
<td></td>
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NB Different test protocols, handbike set-ups, participants, etc.
Optimization of handcycling performance (physiological & biomechanical) is important from Rehabilitation to Paralympics

Optimization of:

• The user
• The handbike
• The interface

All individually adjusted in the context of the task (mobility, recreation, sport)
Thank you for your attention!

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