Handcycling

how to optimize performance

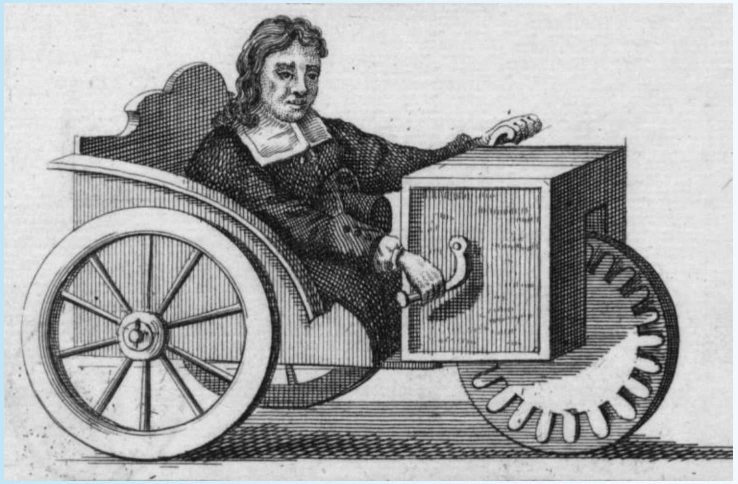
Sonja de Groot

Handcycling - research

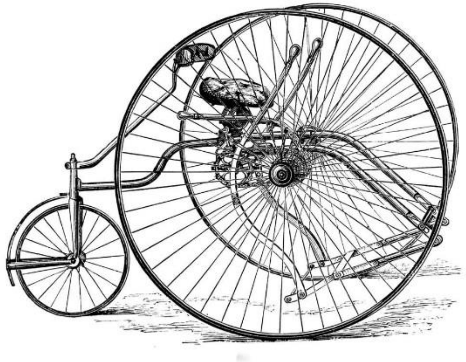
university of groningen

Handcycling - history

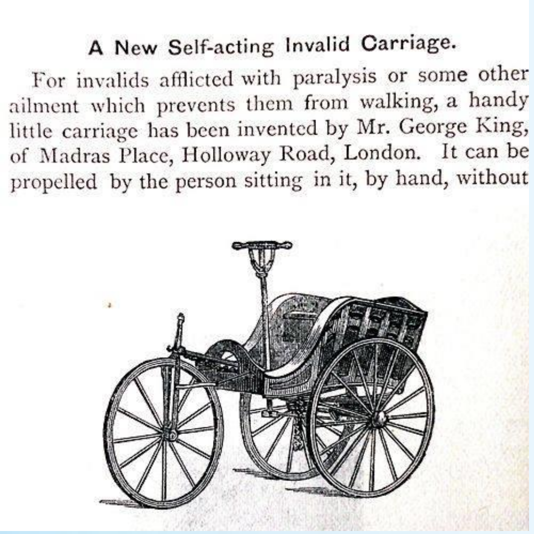
Reade revalidatie / reumatologie



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



1875 - Velociman

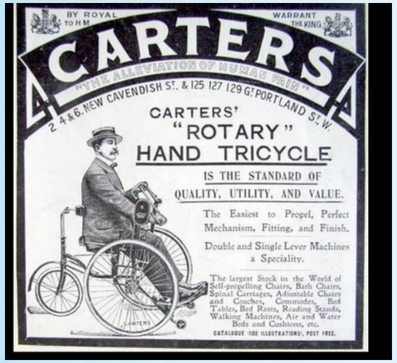

A New Self-acting Invalid Carriage.

For invalids afflicted with paralysis or some other ailment which prevents them from walking, a handy little carriage has been invented by Mr. George King, of Madras Place, Holloway Road, London. It can be propelled by the person sitting in it, by hand, without

1880

1898, first chain-driven wheelchair

Handcycling - history



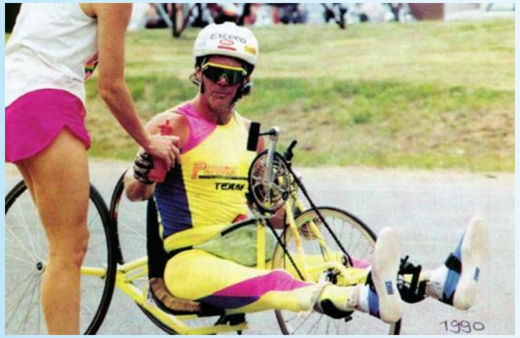
1907

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

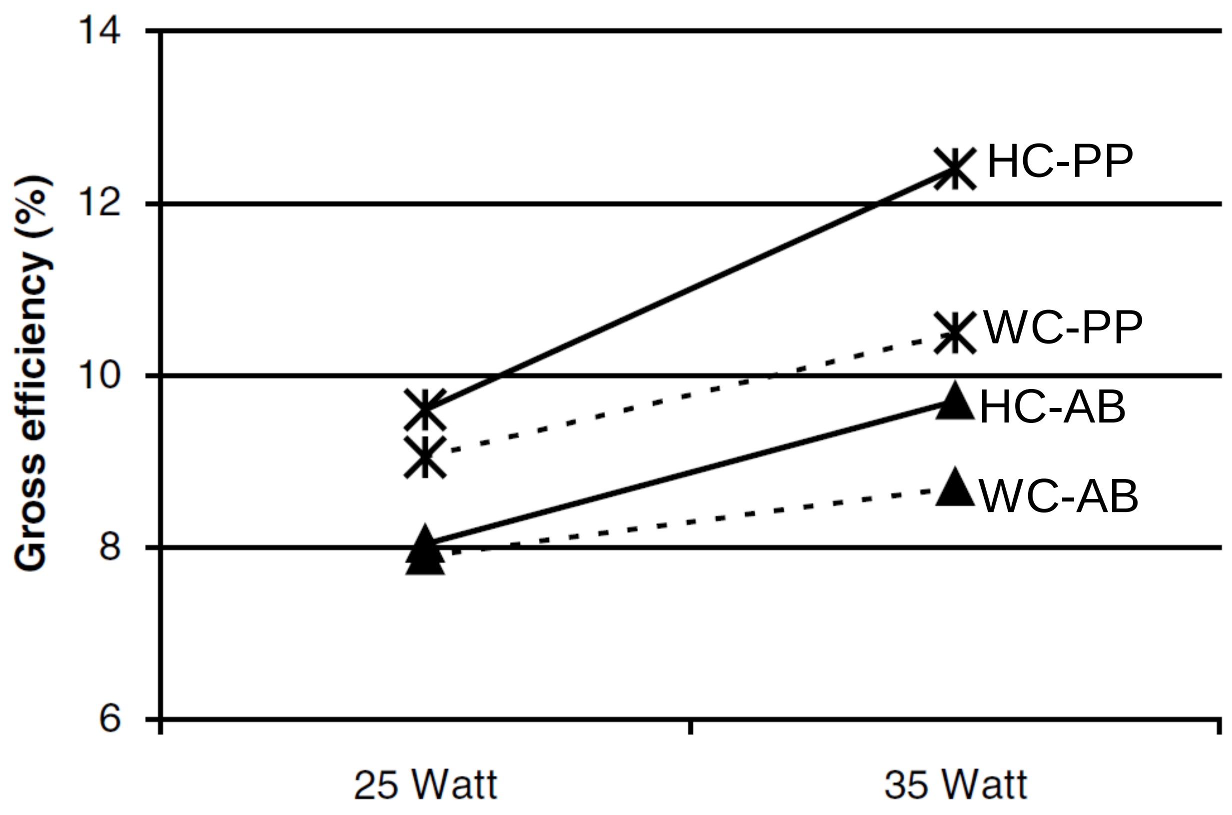
Handcycling – why?

Compared to wheelchair propulsion:

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

@ 35 W:

- Lower VO2, HR and RPE,
- Higher gross ME

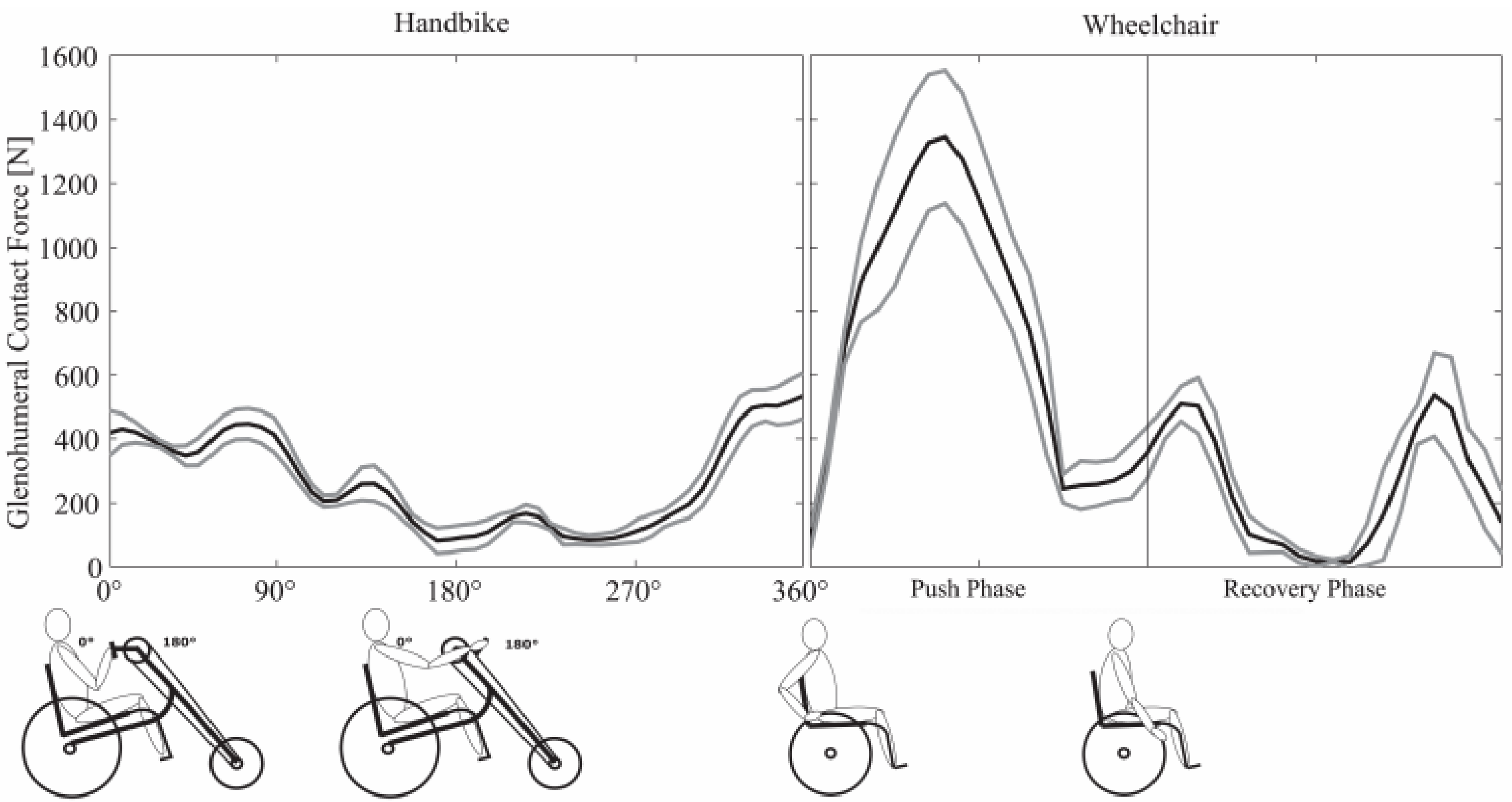


Handcycling – why?

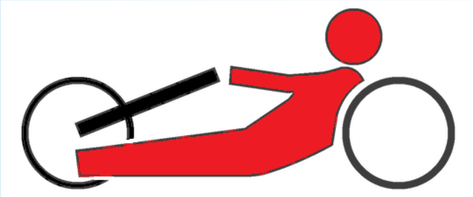
Compared to wheelchair propulsion:

- **Lower shoulder loads**

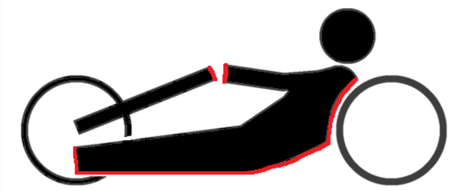
(Arnet et al., 2012)



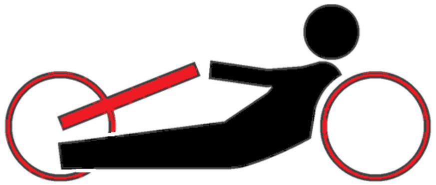
Handcycling - optimization



User



Interface



Handbike

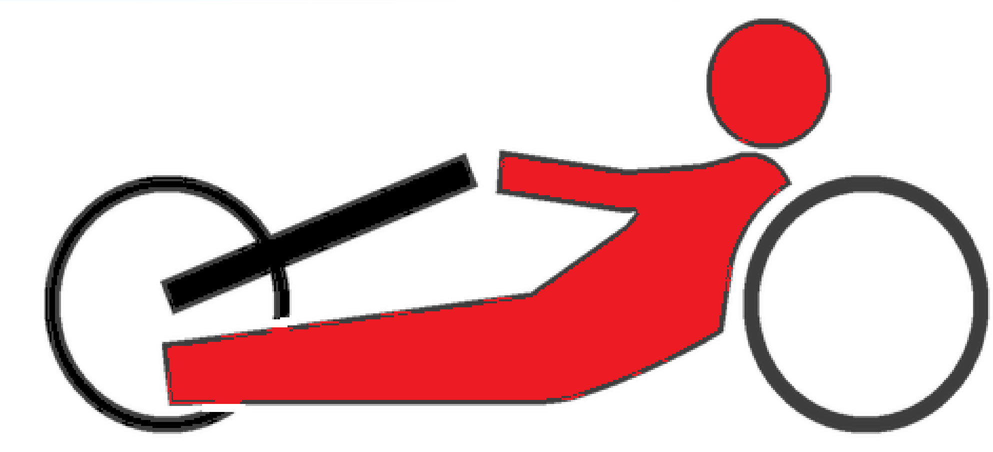
Fitness level
Skill

Gears
(A)Synchronuous
Crank & hand grip
Seat position

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

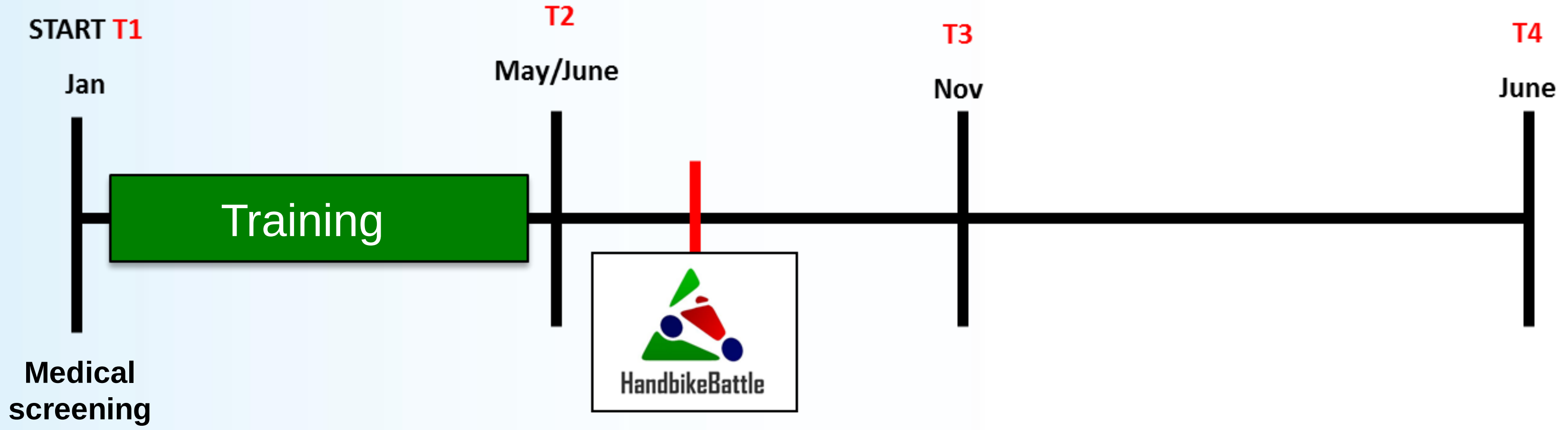
Impression:

Handcycling – HandbikeBattle

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)

Theoretical model POpeak/kg
(+) POmean Wingate (W)
(-) Age (years)
(-) Sex (M/F)
(-) Body mass index (kg/m²)
(-) Time since injury (years)
(+) Lesion level (TP vs PP)
R^2 76%
ICC 0.89 (excellent)

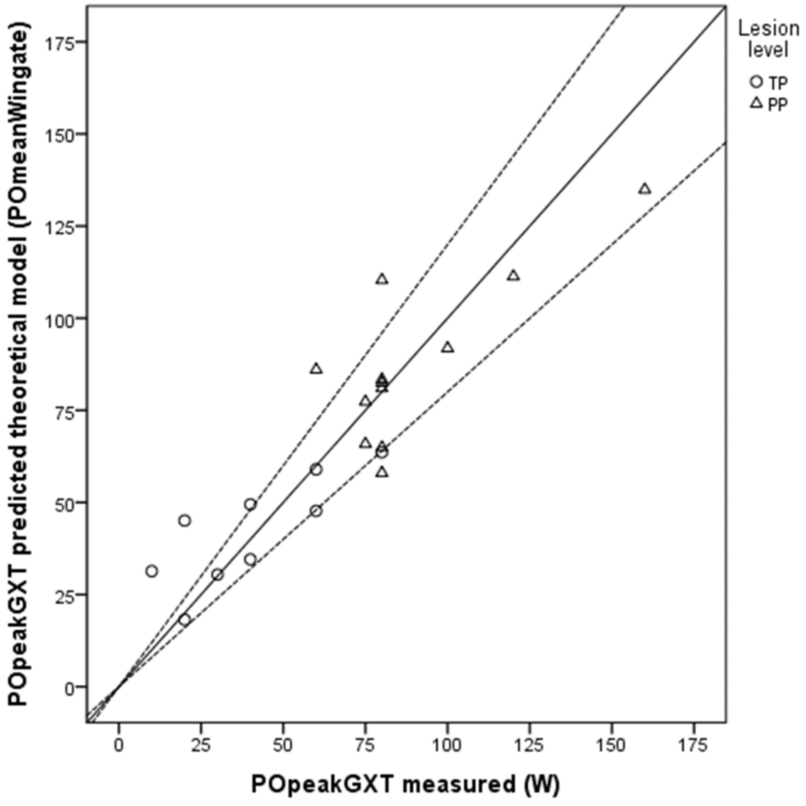


Figure 1. Scatter plots of the measured vs. predicted POpeakGXT and line of identity (solid line) and 20% deviation boundaries (dashed lines).

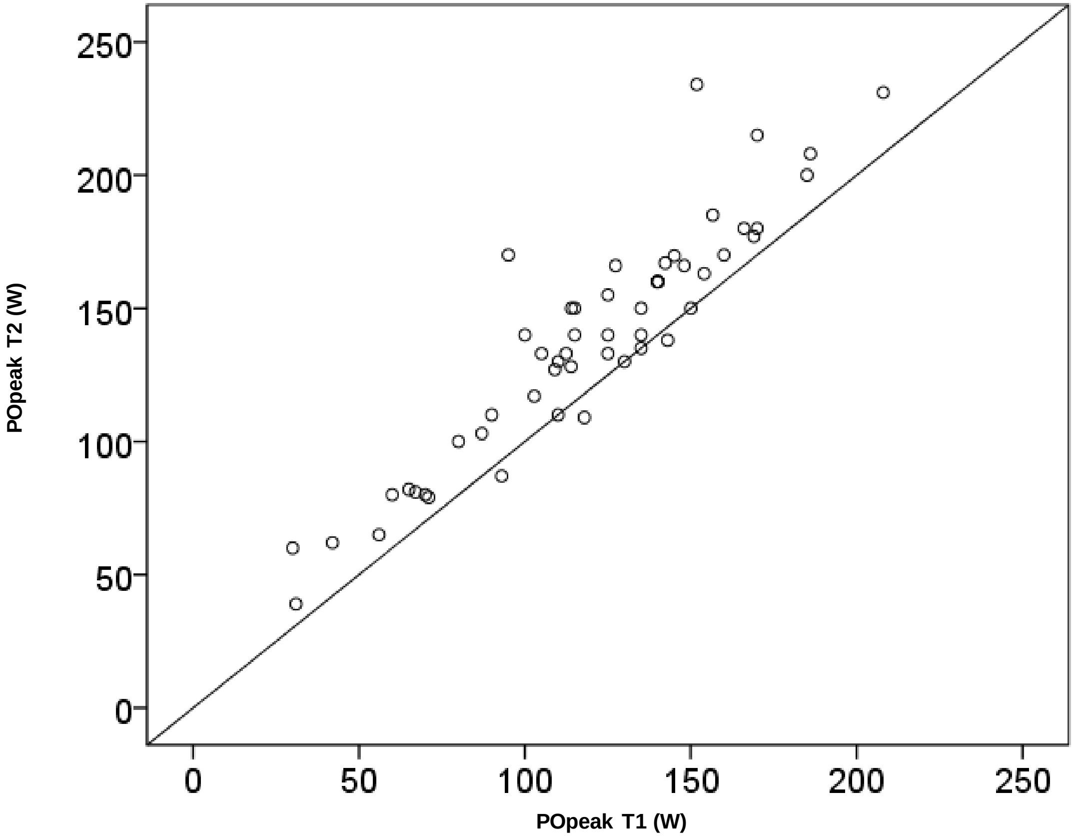
Handcycling – HandbikeBattle

- Training for the HandbikeBattle: (Hoekstra et al., 2017)

  16% ↑ POpeak

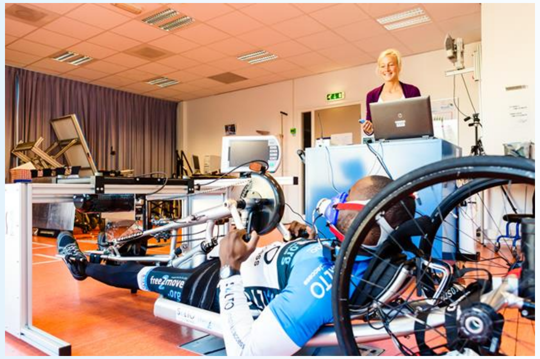
  7% ↑ VO2peak

- 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	$TRIMP_{sRPE}$ vs. TSS *r*	N
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

Handcycling – HandbikeBattle

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

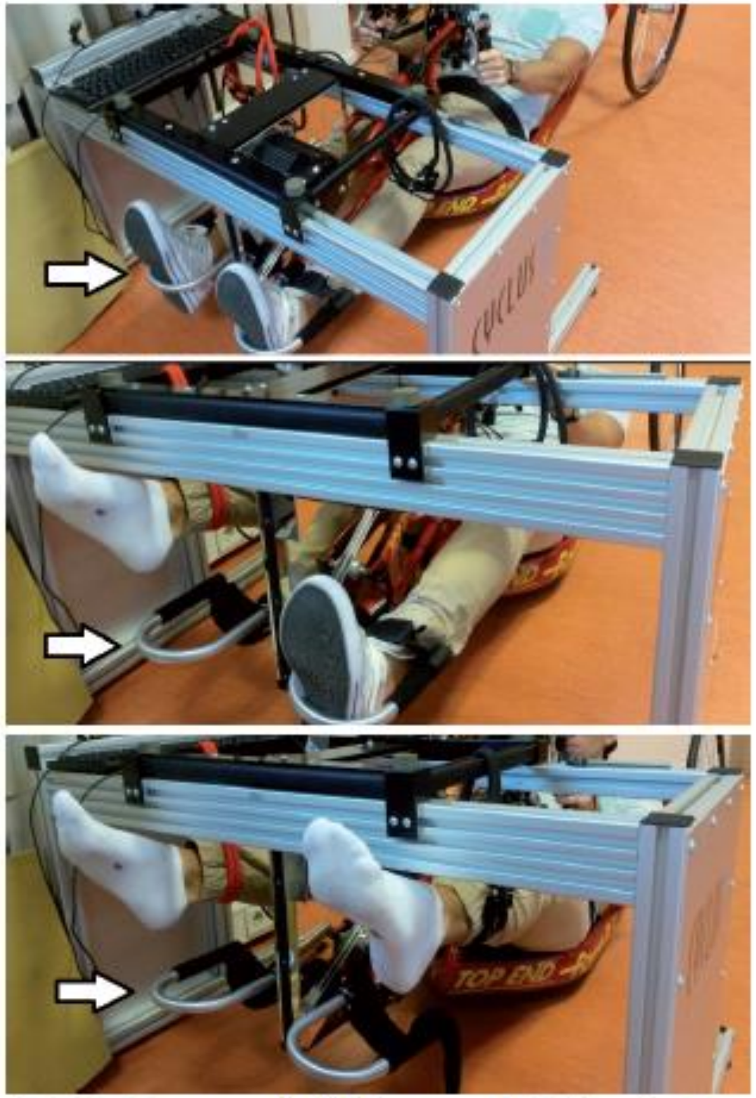
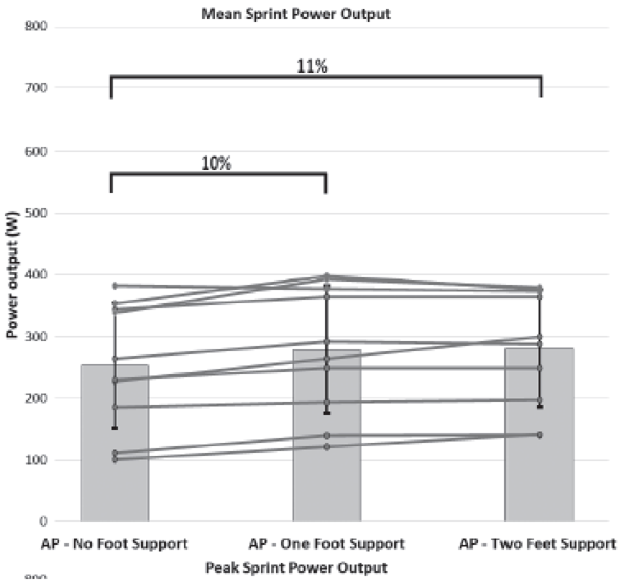


Fig. 2. Two-feet support (*top*), 1-foot support (*middle*), no foot support (*bottom*). *White arrow* indicates the metal frame of the footrests.



university of groningen

Handcycling – Classification

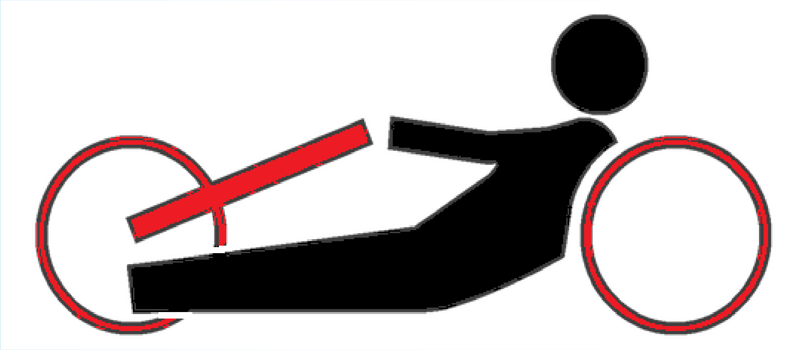
Reade
revalidatie / reumatologie

Evidence-based classification of handcycling athletes

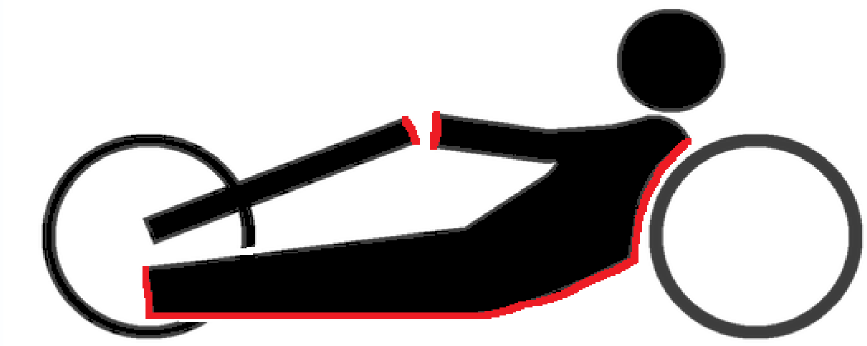
Rafael Muchaxo

- 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



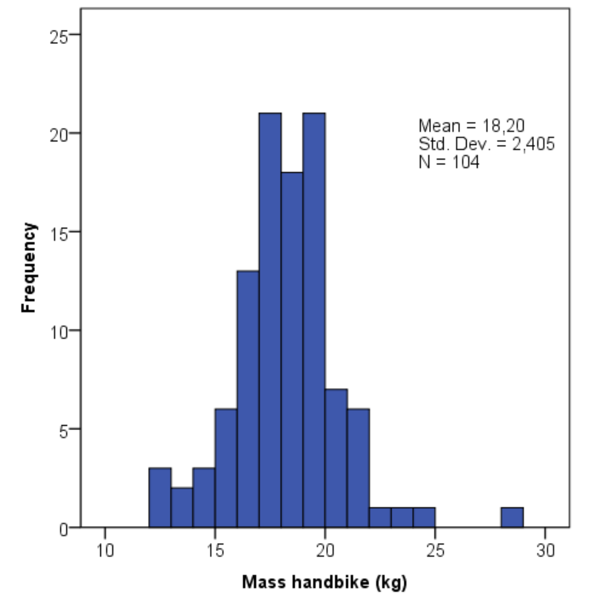
Handbike

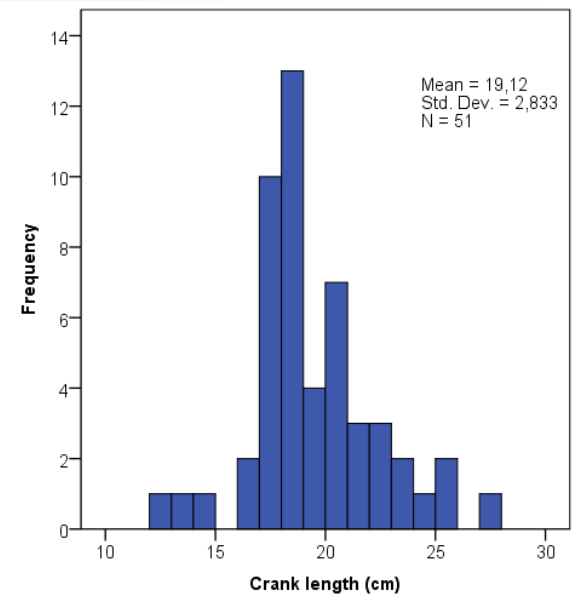


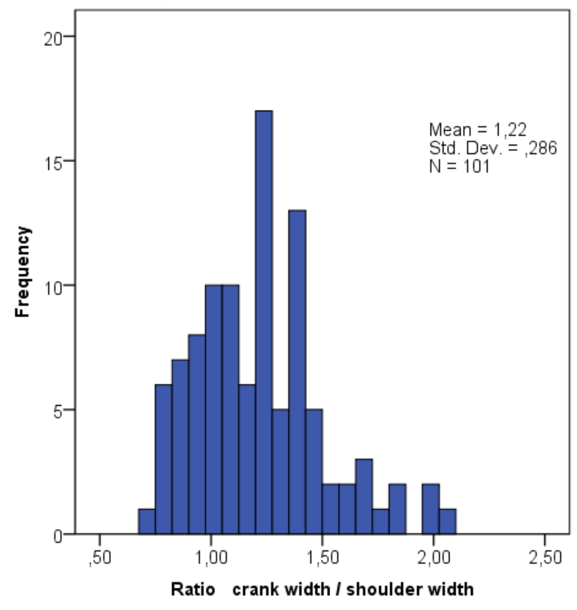
Interface

Handcycling – handbike/interface

Measuring the handcycles of the HandbikeBattle participants

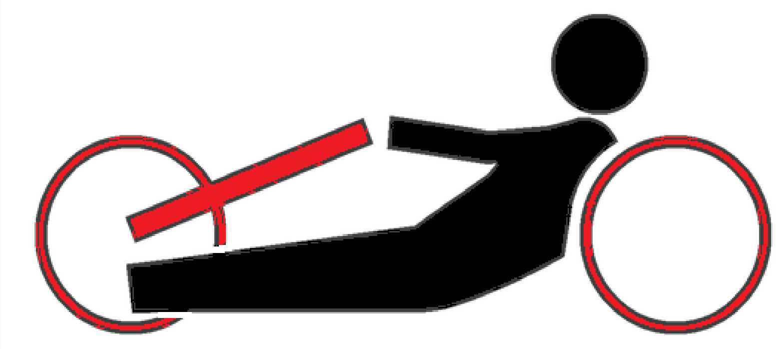






But what is good?? => Evidence?

Handcycling - handbike



Handbike

university of groningen

Handcycling – Handbike

Reade
revalidatie / reumatologie

Factor	(Rolling) Resistance
Mass handcycle ↑ De Groot et al., 2014	↑
Tyre pressure ↓	↑
Wheel size ↓	↑
Camber angle ↑	?
Toe in/toe out ↑	↑
Maintenance ↓	↑
Frontal surface ↑ Mannion et al., 2019; Perret Vista 2013	↑

Claudio Perret – Vista 2013

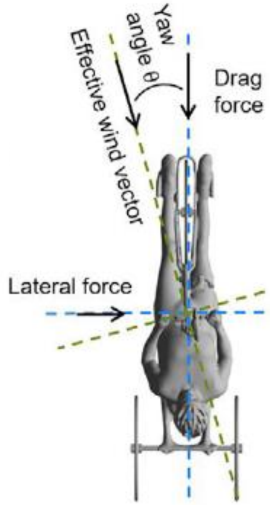
Handcycling - handbike

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



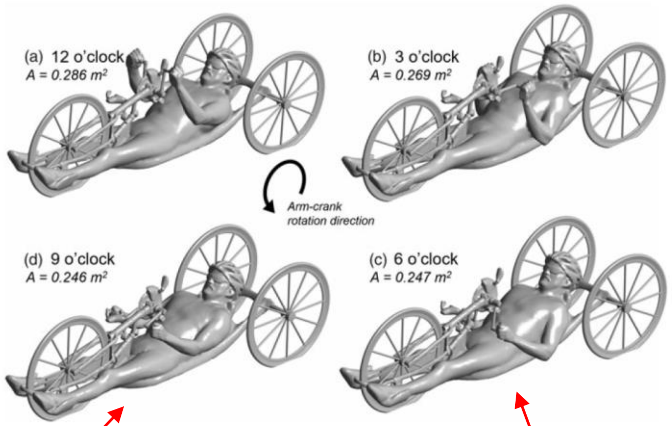


Figure 1. Four arm-crank positions of interest, denoted as (a) 12, (b) 9, (c) 6, and (d) 3 o'clock. The projected frontal areas corresponding to each arm-position are included for comparison.

Best

What they normally do

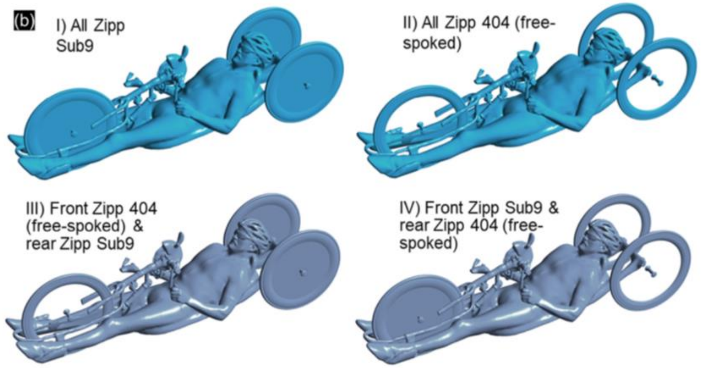
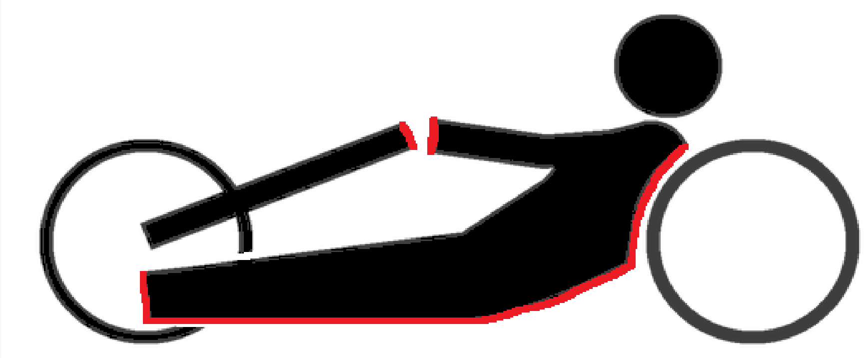


Fig. 1. (a) Three wheel geometries under study: Zipp Sub9 disk, free-spoked Zipp 404 and Zipp 404 with spokes included. (b) Depiction of hand-cycle geometry with four variants of wheel combination variations.

Handcycling - interface



Interface

Handcycling - interface

Factor	Physiology	Biomechanics
Synchronous vs Asynch Dallmeijer et al., 2004; Woude et al., 2008; Bafghi et al., 2008	*Sync*: ME ↑ HR ↓ POpeak ↑ VO2peak ↑	*Sync*: 2D total force ↑ FEF ↑
Gears Woude et al., 2001; Faupin et al., 2008	*Higher gear ratio (heavier):* VO2 ↑ HR ↑ ME ↓	*Higher gear ratio :* trunk flexion/ext ↑
Crank position Faupin et al. 2008; Arnet et al., 2014; Vegter et al., 2019	*Fore-aft*: ME =	Not above shoulder Elbow angle 15°: contact force ↓ Fore-aft closest to trunk
Crank length Krämer et al., 2009; Goosey-Tolfrey et al., 2008	*Longer*: PO ↑ ME ↓ *Width*: PO =	
Hand grip angles Krämer et al., 2009; Abel et al., 2015	+30° optimal PO generation HRpeak, VO2peak = Vertical grip: lactate ↑	
Seating position Faupin et al, 2008; Arnet et al., 2012 & 2014; Verellen et al., 2012; Kouwijzer et al., 2018	*Kneeling*: POpeak ↑ VO2peak ↑ ME ↓	*Back seat more upright*: Shoulder load ↓

NB Different test protocols, handbike set-ups, participants, etc.

Ben Stone
PhD thesis:
Handbike configuration

Handcycling - conclusion

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)

university of groningen

Reade
revalidatie / reumatologie

Thank you for your attention!

Email: s.d.groot@reade.nl