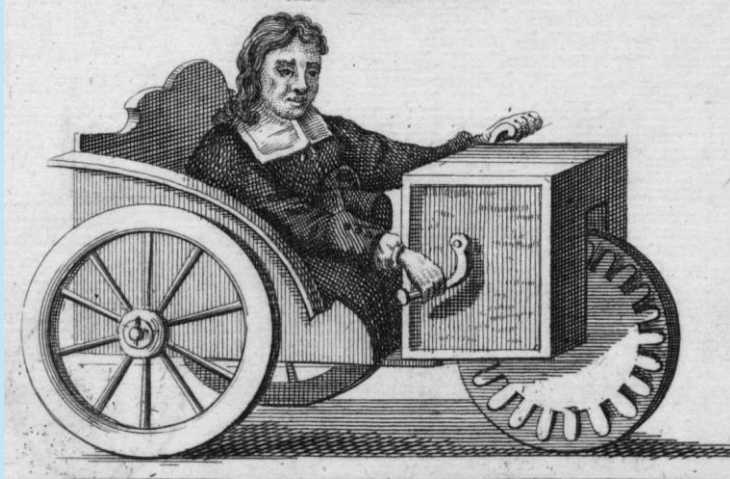


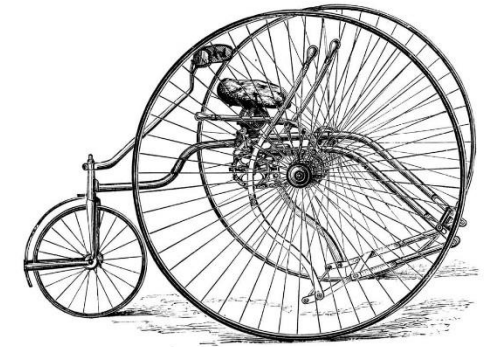
Handcycling

how to optimize performance

Sonja de Groot



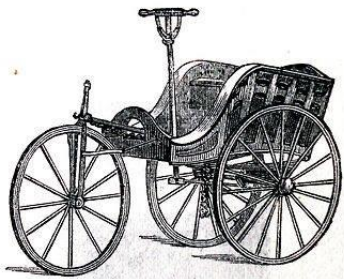
1655 - first handcycle was invented by watchmaker Stephan Farffler (1633-1689)



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



EAMES TRICYCLE CO.

Manufacturers and patentees of the very latest designs of Tricycles for the crippled. Also Tricycles for those who would



like the pleasures of cycling and do not ride the bicycle. Wheel chairs for invalids, and Hospital Appliances. Send for illustrated catalogue.

EAMES TRICYCLE CO. 2100 Market St. San Francisco.

12 STEVENS CHAIR CO., PITTSBURG, PA.

STEVENS' INVALIDS' TRICYCLES.

The illustrations below and on next page show our new styles of Self-Propelling Chairs. Strength, beauty and tractability is the triad of excellence embodied in them. In this special design of chairs we present some very useful ideas for suffering humanity. They are arranged to be propelled by sprocket, crank and chain movement. Simple in construction and not liable to get out of order. Any of our Tricycles will pass through doorway 29 in. wide.



No. 60 Tricycle.

Illustrates a well-made, comfortable and strong chair.
Height of back 25 1/2 in., width of seat 18 in., depth of seat 15 in., seat to step-board 17 in., height of arms 8 in., seat to floor 20 1/2 in.
Front wheel axle is 25 in. in diameter and rear wheel 10 in.

PRICE \$28.00.



No. 61 Tricycle.

The above illustration is a good representation of one of our new models.
Height of back 20 in., width of seat 18 in., depth of seat 15 in., seat to step-board 17 in., height of arms 8 in., seat to floor 20 1/2 in.
Front wheel axle is 25 in. in diameter and rear wheel 10 in.

PRICE \$30.00.



No. 74 Tricycle.

Represents another strong and slightly chair of this class.
Height of back 20 1/2 in., width of seat 17 1/2 in., depth of seat 15 1/2 in., seat to step-board 17 in., seat to floor 20 1/2 in., height of arms 8 in.
Front wheel axle is 25 in. in diameter with 10 in. rear wheel.

PRICE \$32.00.



1907



1917



1950



1983 - first attachable handcycle for a wheelchair.

HAND-PEDALED TRICYCLE
from Freedom Specialties, Inc.



Freedom Specialties' hand-pedaled cycles provide enjoyable aerobic exercise and access to the great outdoors, let physically challenged individuals join the rest of the bikers... all this, and a wheelchair can follow along for errands, daily work transportation, and greater freedom. For information, call or write:
Freedom Specialties Box 83 • Cleghorn, IA 51014 (712) 436-2666

- 3-speed
- cruise up to 20 mph
- coaster brake, toggle-type parking brakes
- rack under seat
- wheelchair hitch, if desired
- adult and children's models
- 4130 chrome-moly tube frame/ 12 colors
- 5-year warranty on frame, manufacturer's warranty on bike parts and seat
- delivery 2-4 weeks
- \$895 + shipping

1989



1986 sport version – feet forward

GET CRANKING



Top End "Predator" the first hand crank that really cranks. Speeds obtainable up to 30 mph. It's Safe, and corners like a dream. Great Exercise and Fun. Faster, more maneuverable than anything on the market. Get the "Predator" The Crank that Cranks.

TOP END

6551 44th Street North, #5002
Pinellas Park, FL 33565
(813) 522-8677
Fax (813) 522-1007
Visa and MasterCard accepted

"The Predator" 32 lbs.
In Europe, Contact Amigo Mobility
Dr. Kees Van Breukelen
Fax (0) 1726-17305
Phone (0) 1726-19355

1991



1993



1999 - kneeling



Arm Power



Arm Trunk Power

Handcycling

From rehabilitation - Paralympics

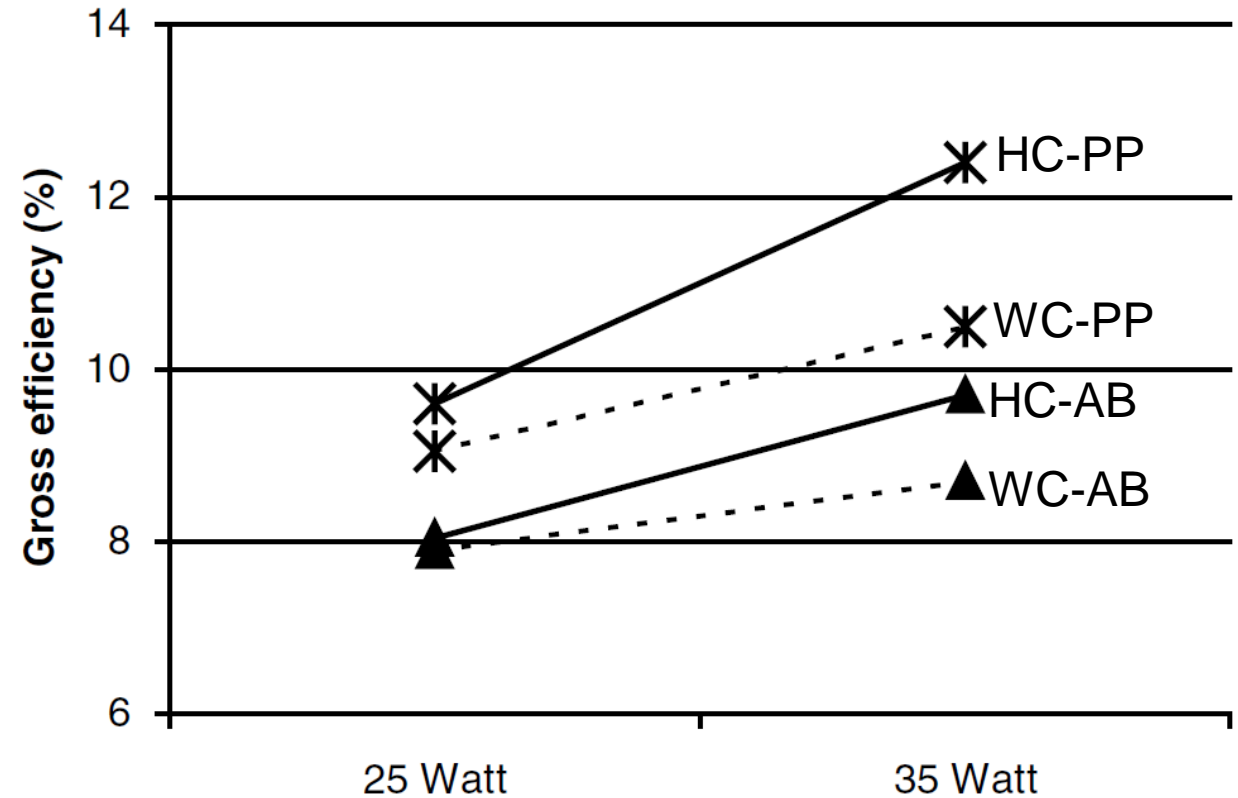


Compared to wheelchair propulsion:

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

@ 35 W:

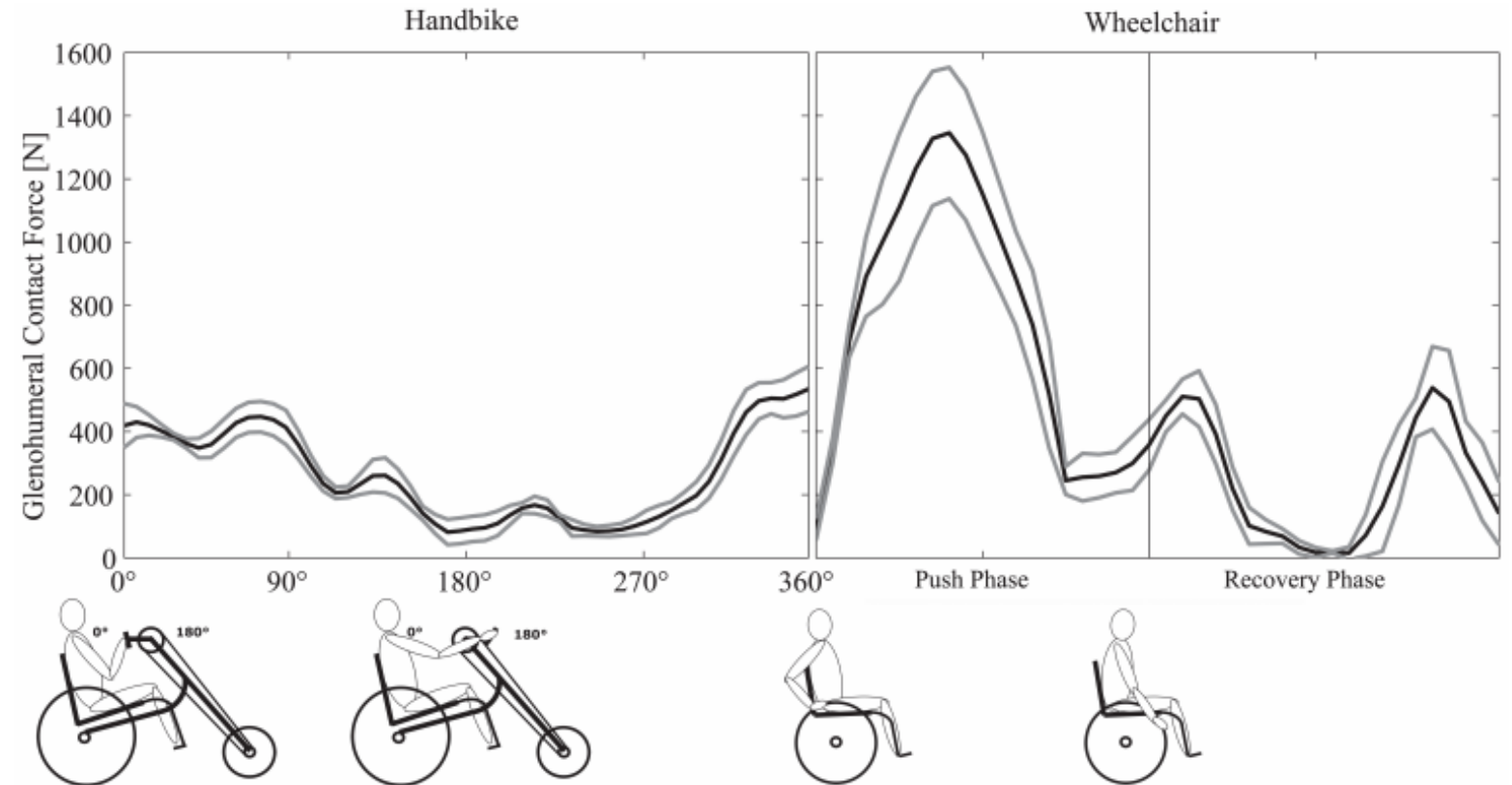
- Lower VO₂, HR and RPE,
- Higher gross ME

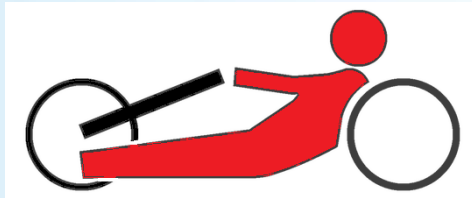


Compared to wheelchair propulsion:

- **Lower shoulder loads**

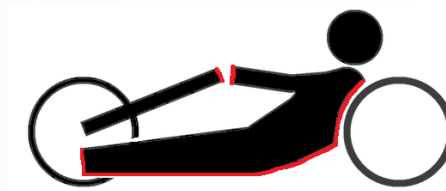
(Arnet et al., 2012)





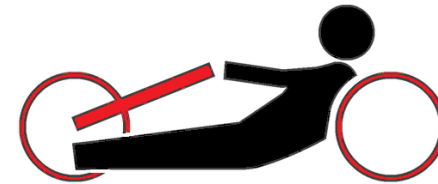
User

Fitness level
Skill



Interface

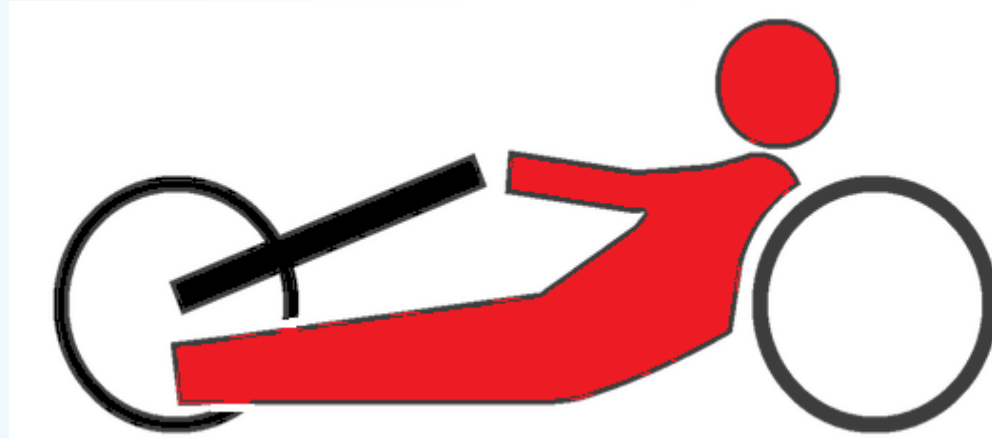
Gears
(A)Synchronuous
Crank & hand grip
Seat position



Handbike

Mass
Size
Wheel characteristics

Task dependent => mobility, recreation, sport



User

- **Structured handcycling 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 handcycling training; no adverse events
 - Training intensity: mean Borg score 6.2 ± 1.4
 - Training frequency: 1.8 ± 0.5 x/week
 - POpeak (36%) and VO2peak (10%) improved significantly



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



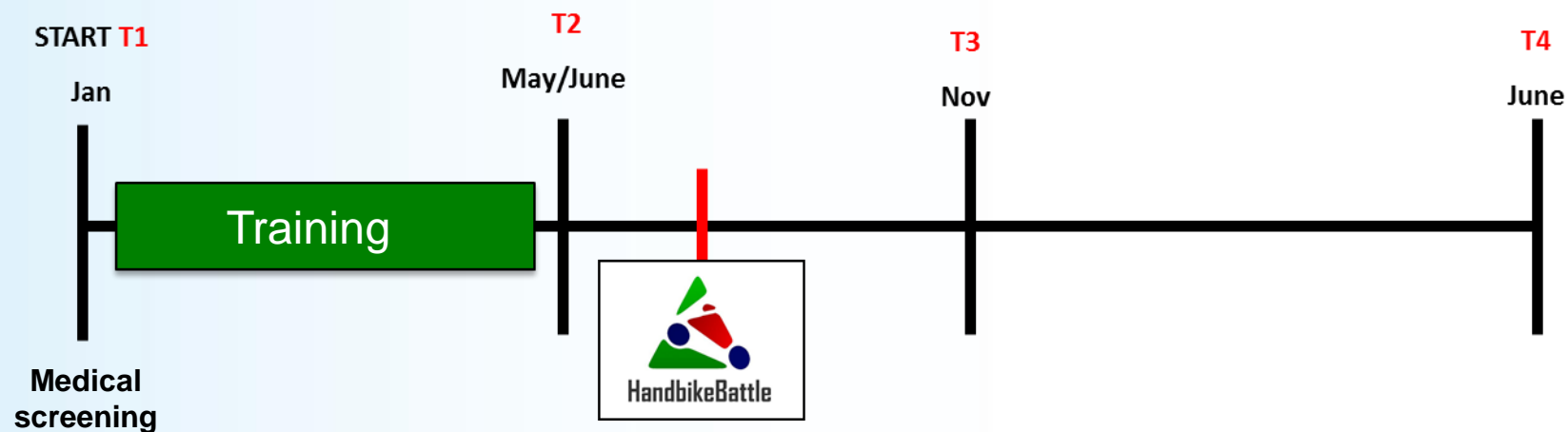
Impression:



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?



- 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/m ²)
(-) Time since injury (years)
(+) Lesion level (TP vs PP)
R² 76%
ICC 0.89 (excellent)

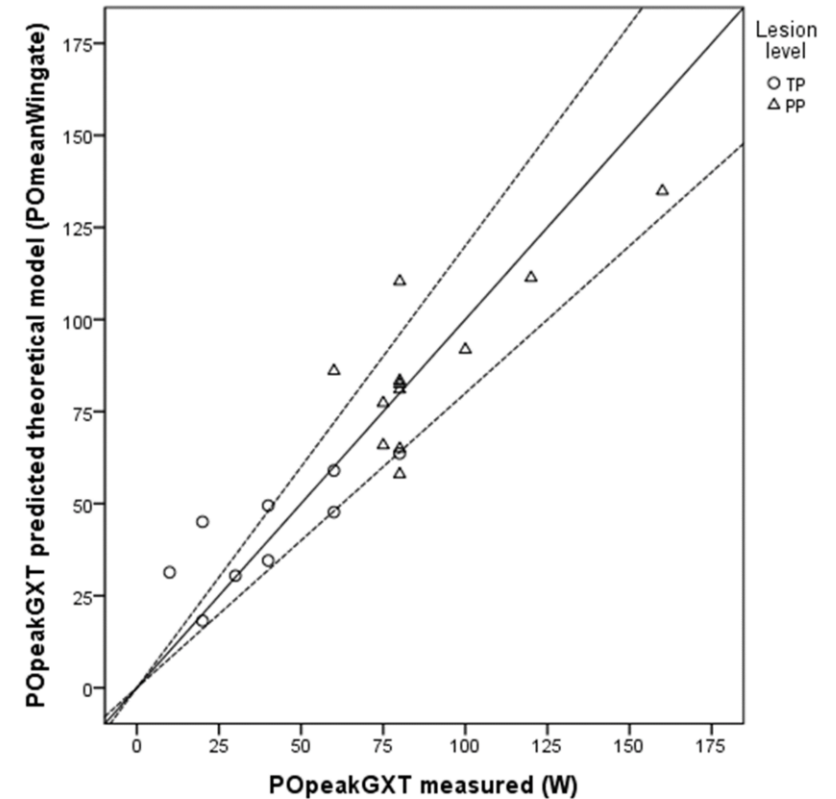
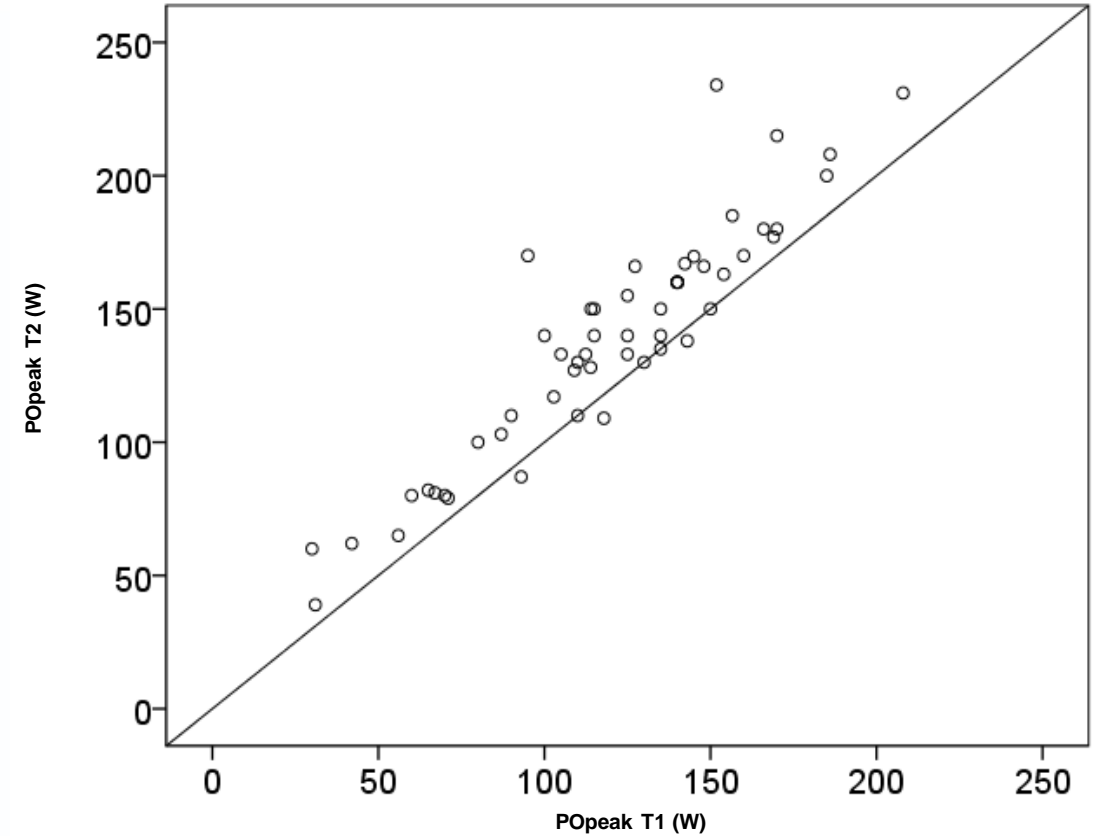


Figure 1. Scatter plots of the measured vs. predicted POpeakGXT and line of identity (solid line) and 20% deviation boundaries (dashed lines).

- Training for the HandbikeBattle: (Hoekstra et al., 2017)
 - 16% ↑ PO_{peak}
 - 7% ↑ VO_{2peak}
- 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 ($r>0.9$)



1 - 10 Borg Rating of Perceived Exertion Scale	
0	Rest
1	Really Easy
2	Easy
3	Moderate
4	Sort of Hard
5	Hard
6	
7	Really Hard
8	
9	Really, Really, Hard
10	Maximal: Just like my hardest race

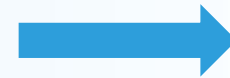
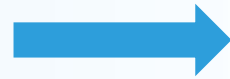
Subject no.	Class	TRIMP _{SRPE} vs. TSS	
		<i>r</i>	N
1	H3	0.92	15
2	H3	0.99	5
3	H3	0.61	45
4	H3	0.87	42
5	H3	0.77	14
6	H4	0.79	47
7	H4	0.95	20
8	H4	0.77	26
9	H4	0.92	31
10	H5	0.97	28
<i>r</i> within subjects		0.814	260

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

From rehab to HandbikeBattle to Paralympics:



Fair competition with respect to level of impairment => Classification

Effects of push-off ability (closed-chain)

Kouwijzer et al., 2018

- Interaction user - equipment

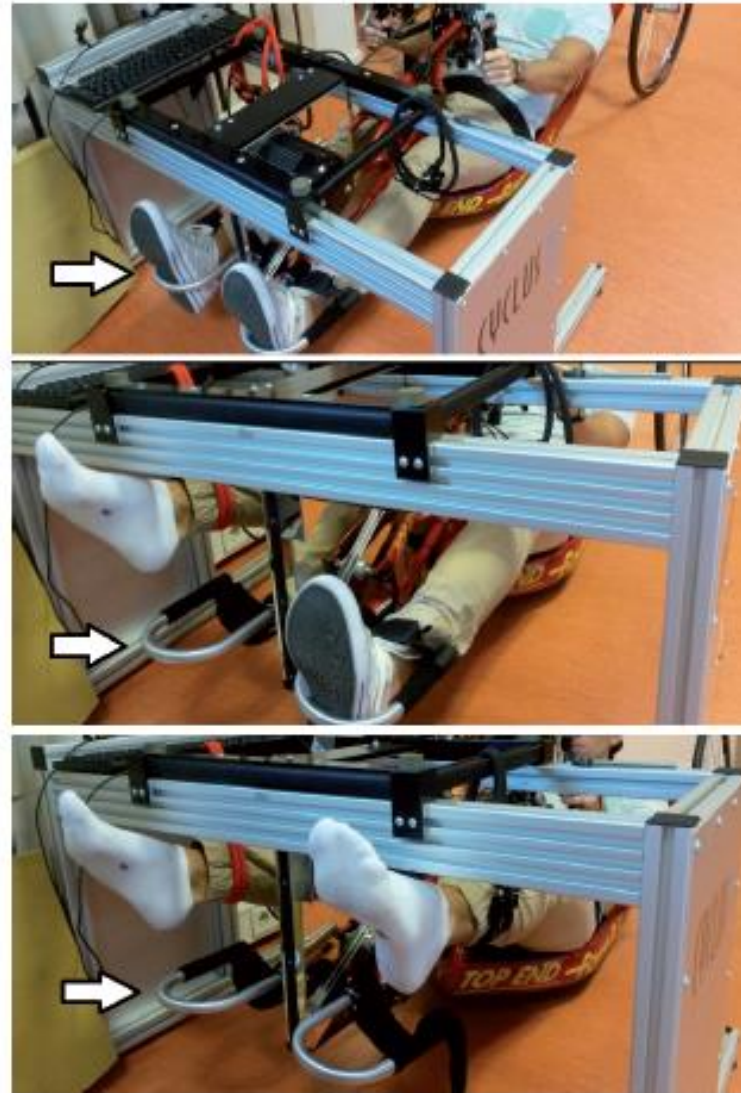
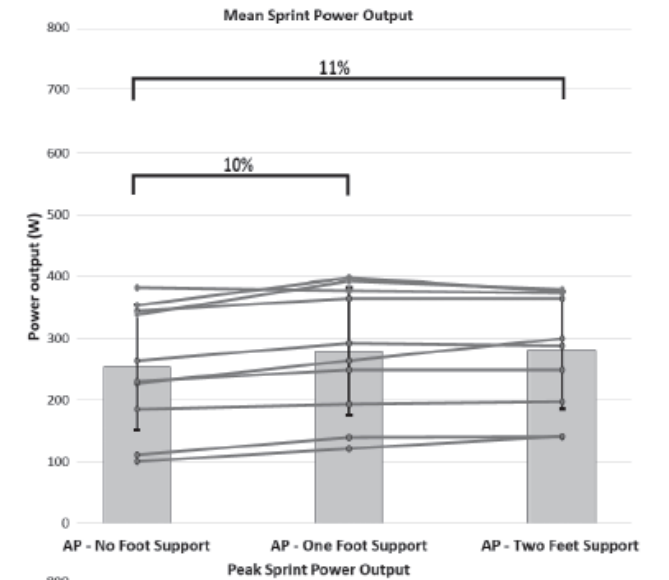


Fig. 2. Two-feet support (top), 1-foot support (middle), no foot support (bottom). White arrow indicates the metal frame of the footrests.

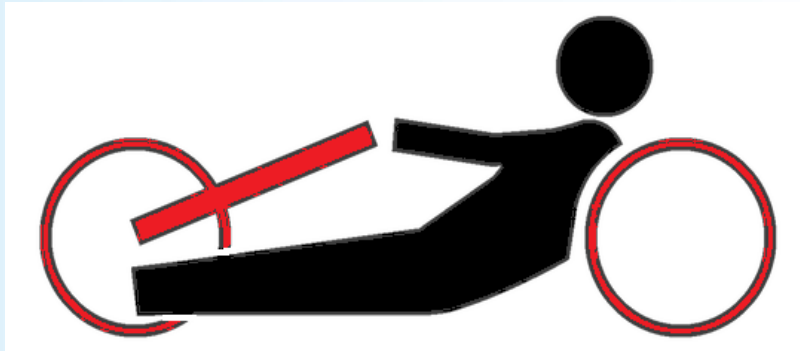


Evidence-based classification of handcycling athletes



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)

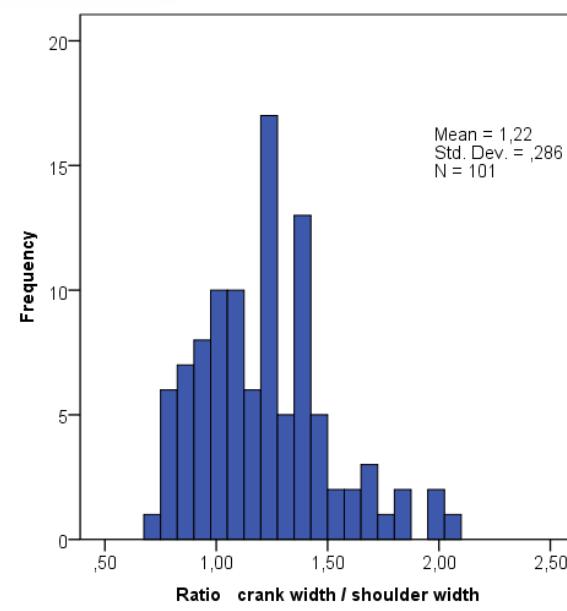
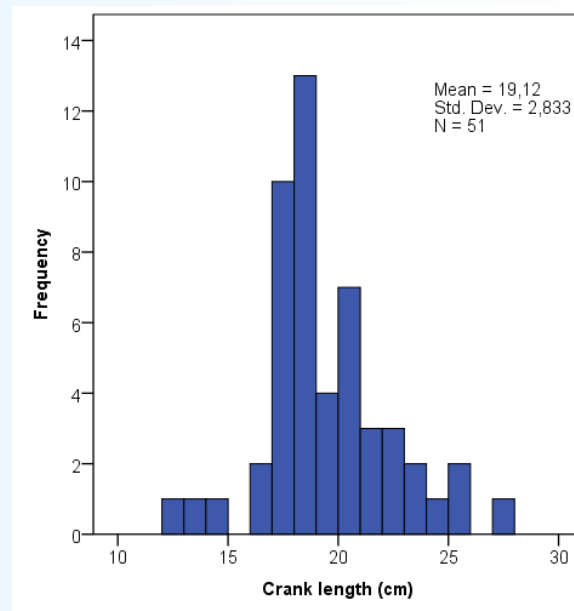
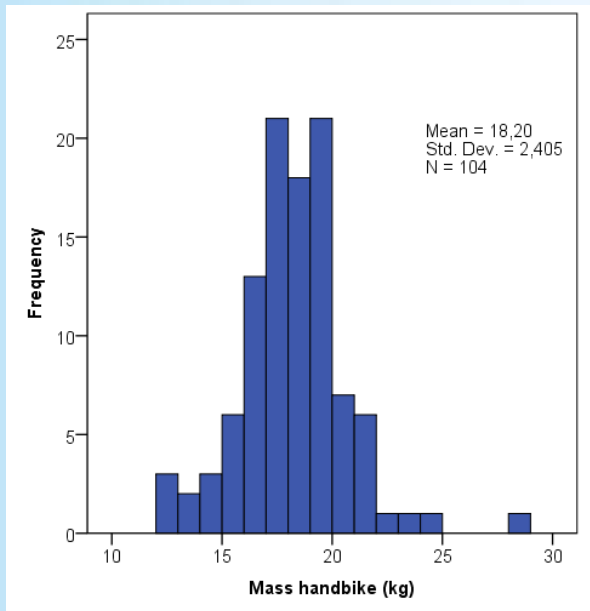
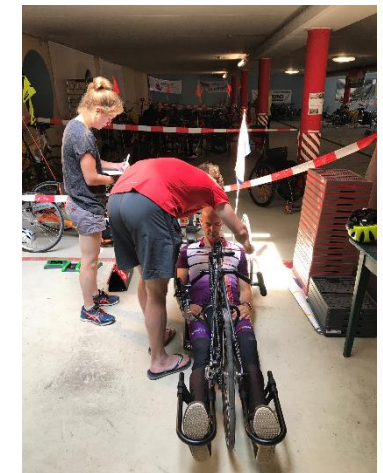


Handbike

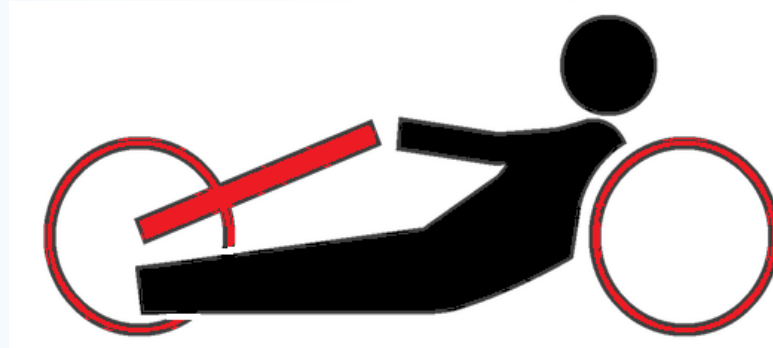


Interface

Measuring the handcycles of the HandbikeBattle participants

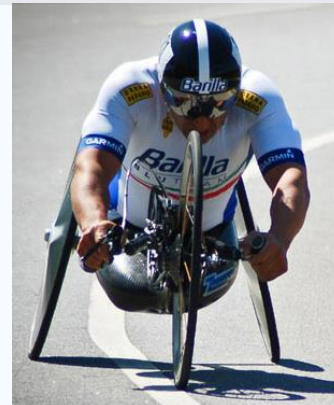


But what is good?? => Evidence?

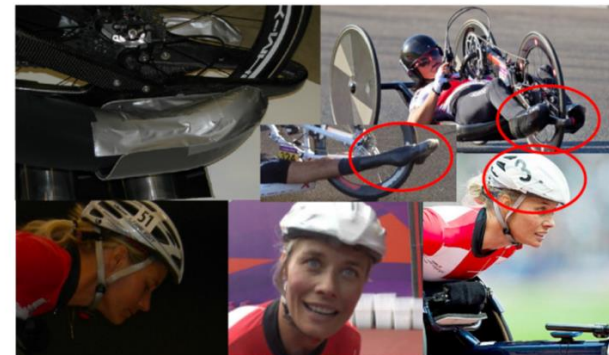


Handbike

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	↑



Practical applications at the Paralympics



Claudio Perret – Vista 2013

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

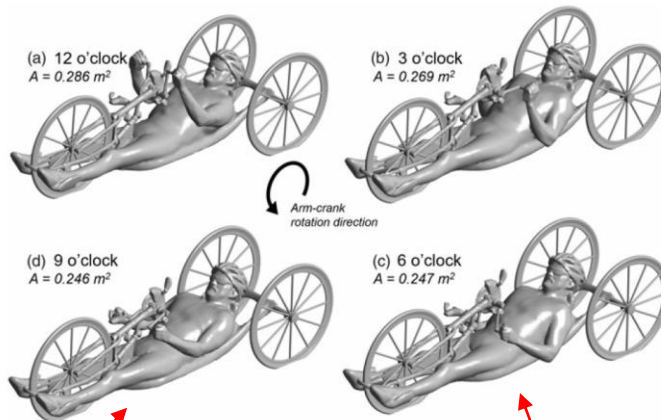
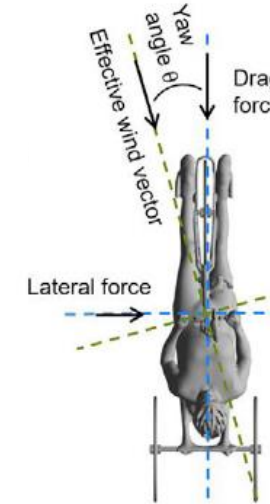


Figure 1. Four arm-crank positions of interest, denoted as (a) 12, (b) 9, (c) 6, and (d) 3 o'clock. The projected frontal areas corresponding to each arm-position are included for comparison.

Best

What they normally do

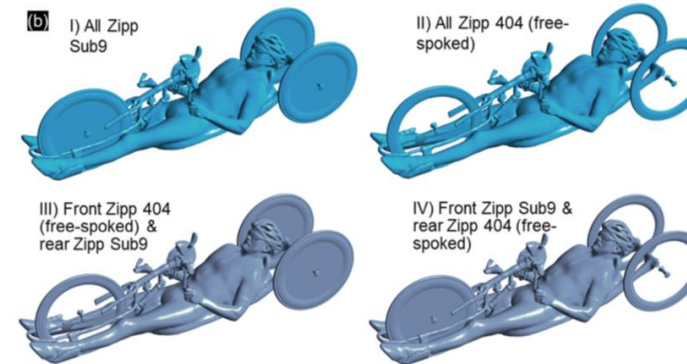
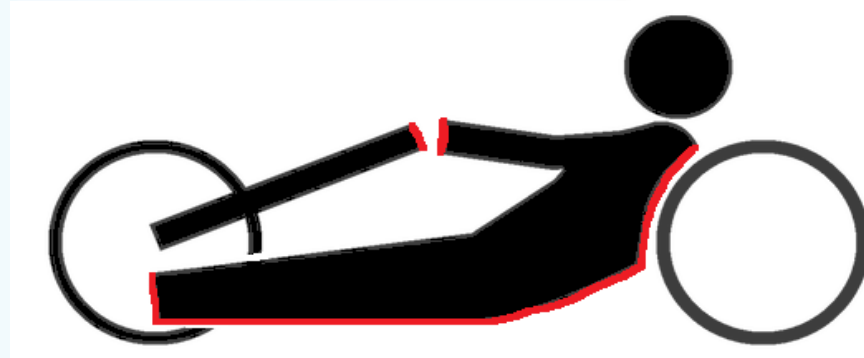


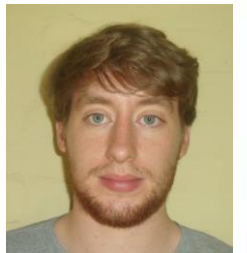
Fig. 1. (a) Three wheel geometries under study: Zipp Sub9 disk, free-spoked Zipp 404 and Zipp 404 with spokes included. (b) Depiction of hand-cycle geometry with four variants of wheel combination variations.



Interface

Factor	Physiology	Biomechanics
Synchronuous vs Asynch Dallmeijer et al., 2004; Woude et al., 2008; Bafghi et al., 2008	<i>Sync:</i> ME ↑ HR ↓ POpeak ↑ VO2peak ↑	<i>Sync:</i> 2D total force ↑ FEF ↑
Gears Woude et al., 2001; Faupin et al., 2008	<i>Higher gear ratio (heavier):</i> VO2 ↑ HR ↑ ME ↓	<i>Higher gear ratio :</i> trunk flexion/ext ↑
Crank position Faupin et al. 2008; Arnet et al., 2014; Vegter et al., 2019	<i>Fore-aft:</i> 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	<i>Longer:</i> PO ↑ ME ↓ <i>Width:</i> 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	<i>Kneeling:</i> POpeak ↑ VO2peak ↑ ME ↓	<i>Back seat more upright:</i> Shoulder load ↓

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



Ben Stone
 PhD thesis:
 Handbike
 configuration

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!



Email: s.d.groot@reade.nl