Wheeled mobility: an ergonomics perspective

Sonja de Groot, Riemer Vegter, Marieke Kloosterman, Floor Hettinga, Linda Valent, Lucas HV van der Woude
Restoration of mobility in SCI rehabilitation, *outcome measures at all levels of ICF*

- Lesion characteristics
- Secondary impairments, Co-morbidity

**Wheeled mobility**

- Cardiovascular & respiratory functions
- Motor, autonomic & sensory functions
- Hand & arm function, basic & complex skills
- Functional independence

- Work, school, sports, family, friends

- Rehabilitation, AT, strategy, treatment, exercise, training
- Age, cultural background, coping, fitness, gender,
Objectives

The attendees will appreciate, learn and understand:

- the importance of an ergonomics perspective on wheeled mobility (and assistive technology in general) in rehabilitation practice and in daily life.
- the mechanisms and outcomes as well as measurement of physiological strain and work capacity in wheelchair arm work.
- The mechanisms and measurement of upper body overuse, strain and its long term consequences.
- The mechanisms of physical inactivity in wheelchair use and its health consequences.
- The preventive role of an active lifestyle with optimal conditions of wheelchair mechanics, wheelchair-user interface and wheelchair work capacity in the context of these long term health problems and quality of life.
- The role of wheeled mobility technology in maintaining a healthy and a productive life.
Wheeled mobility: an ergonomics perspective

.WHEEL-I: the development of a wheelchair propulsion lab for rehabilitation and sports
Sonja de Groot, Rehabilitation Center Reade, Amsterdam, Center for Human Movement Sciences, UMCG/RUG, Groningen

.Motor learning in handrim wheelchair propulsion
Riemer Vegter, Center for Human Movement Sciences, UMCG/RUG, Groningen

.Power assist wheelchairs: the good alternative?
Marieke Kloosterman, Roessingh Research & Development, Enschede

.Handcycling sports & performance
Floor Hettinga, Center for Human Movement Sciences, UMCG, Groningen

.Staying fit in a wheelchair
Linda Valent, Rehabilitation Center Heliomare, Wijk aan Zee

.Ergonomics of sports wheelchairs
Lucas van der Woude, Center for Human Movement Sciences, UMCG/RUG, Groningen

.General discussion
Annual Congress 2012 of the Netherlands Society of Physical and Rehabilitation Medicine

‘Innovation: from creation to implementation’

Ergonomics of sports wheelchairs

Lucas HV van der Woude e.a.
Adapted Sports Performance ↑↑

Oita wheelchair semi-marathon

yr
2005
1999
1993
1987
1981

time (min)
40 50 60 70
Figure 1. Historical overview sport wheelchair innovation in different wheelchair sports (Van Breukelen 2009):

Rigid chair, box frame + axle plates (W1), camber bar (W2), foot placement: vertical (W3), backwards (W4), bucket seat (R1), 3-wheel racing chair (R2), wheelbase↑ (R3), Oversized tubing (R4), kneeling position (R5), front fork + frame alignment (R6), etc, etc, etc
Typical basketball wheelchair: task-specific, individualized

>> Agility, manouvrability, de-/acceleration, position in the field............speed, endurance

Mason 2011
Model Power Balance applied to wheeled mobility
Mechanical factors and their influence on rolling resistance:

Coping with taskload >> ...speed, endurance

<table>
<thead>
<tr>
<th>Factors</th>
<th>Rolling resistance</th>
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<tbody>
<tr>
<td>Body Mass ↑</td>
<td>↑</td>
</tr>
<tr>
<td>Wheelchair Mass ↑</td>
<td>↑</td>
</tr>
<tr>
<td>Tire pressure ↓</td>
<td>↑</td>
</tr>
<tr>
<td>Wheel size ↑</td>
<td>↓</td>
</tr>
<tr>
<td>Hardness floor ↓</td>
<td>↑</td>
</tr>
<tr>
<td>Camber angle ↑</td>
<td>?</td>
</tr>
<tr>
<td>Toe-in/out ↑</td>
<td>↑↑</td>
</tr>
<tr>
<td>Castor shimmy ↑</td>
<td>↑</td>
</tr>
<tr>
<td>Center of mass closer to large rear wheels</td>
<td>↓</td>
</tr>
<tr>
<td>Folding frame (vs. box frame)</td>
<td>↑</td>
</tr>
<tr>
<td>Maintenance ↓</td>
<td>↑</td>
</tr>
</tbody>
</table>
Fair

Need to reduce rolling & air resistance = POWER (W)

Speed, endurance!

40km/hr?

>> 11m/s!!

>>> 500W?

Figure 9.- Variation of power required to overcome retarding force with head-wind velocity.
Manipulating the wheelchair-athlete interface

Hand rim diameter variation

GROSS MECHANICAL EFFICIENCY (%)

<table>
<thead>
<tr>
<th>HAND RIM DIAMETER (m)</th>
<th>V=0.83 m/s</th>
<th>V=1.67</th>
<th>V=2.50</th>
<th>V=3.33 m/s</th>
</tr>
</thead>
<tbody>
<tr>
<td>D1 (0.30)</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>D2 (0.35)</td>
<td></td>
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<tr>
<td>D3 (0.38)</td>
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<tr>
<td>D4 (0.47)</td>
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<tr>
<td>D5 (0.56)</td>
<td></td>
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</tbody>
</table>

(Woude et al. '88)
Individual ‘fine-tuning’ seat height?

Sports?

N=12 subjects with SCI during Rehabilitation; 180 degrees is full extension
Figure 5.1 – Mean (± SD) power output and mechanical efficiency values across camber settings. \(^a\) denotes a significant difference to 15°; \(^b\) denotes a significant difference to 18°, \(P < 0.05\).

Table 5.1 – Relative increases (%) in mechanical efficiency, power output and oxygen uptake in relation to the 15° camber setting.

<table>
<thead>
<tr>
<th></th>
<th>15° to 20°</th>
<th>15° to 24°</th>
</tr>
</thead>
<tbody>
<tr>
<td>ME (%)</td>
<td>11.4</td>
<td>10.4</td>
</tr>
<tr>
<td>(P_0) (W)</td>
<td>11.7</td>
<td>14.1</td>
</tr>
<tr>
<td>(\dot{V}O_2) (L·min(^{-1}))</td>
<td>2.7</td>
<td>5.4</td>
</tr>
</tbody>
</table>
Handcycling vs hand rims

Dallmeijer et al 2001

Endurance, speed, ...... Shoulder preservation & health

Arnet et al 2011
=> Sport & Task-specific!!

Basketball

Dance

Racing

Tennis

Hockey

Rugby

=> Tuned to the Individual!
All in All: Take home messages

- Individual & task/sports specific fine tuning WC-Athlete combination
- Optimization WC-Athlete interface, WC, Athlete skill, technique, capacity
- What holds for Wheelchair ..... (= exemplary for any assistive technology)
- Propulsion Technique = complex, Athlete = highly adaptive learner
- Handrim wheelchair = inefficient & straining, risk for over-/underuse
- Handcycle (>> handrim wheelchair) training device
- Coach’s obligation: monitor, measure, learn, read.....lifetime investment!
Some additional information for further orientation
Human Biological (Movement) System

- An inherently *adaptive* system
- Seeking for *optimum* functioning within its *biological* and *environmental* (physical & social) boundary conditions & *developmental* stage
A sample of today’s top-class manual (sports) wheelchairs
Wheelchair configuration: Considerations for the court sports
ROLSTOELEN EN ORTHESEN
Locatie: Triavium Nijmegen
donderdag 29 november en vrijdag 30 november 2012

Programma donderdag 29 november 2012:
Rolstoelen

09:30 Ontvangst en registratie

Optimalisatie zitten
Voorzitter: L. van der Woude

10:00 Orthopedische en neurologische aspecten van zitcorrectie
J. Becher

10:30 De aetiologie van drukwonden
C. Oomens

11:00 De ergonomische rolstoelzitting
K. van Breukelen

11:30 Pauze

12:00 Belasting en belastbaarheid & ergonomische optimalisatie
L. van der Woude

12:30 Lunch

Optimalisatie verplaatsen
Voorzitter: J. Becher

13:30 Schouder-armbelasting bij rolstoel
ADL
D.J. Veeger

14:00 Elektrische rolstoelen en power-assist systemen
J. Schipper

14:30 Sport, lichamelijke activiteit en gezondheid
T. Janssen

15:00 ADL rolstoelen: vaardigheid en fitheid in de revalidatie
S. de Groot

15:30 Pauze

16:00 Eerste workshopronde:
• Observeren en meten van rolstoelaandrijvingstechniek (2x)
  R. Vegter, S. de Groot
• Zitdrukmeting & zithouding
  J. Hermkens
• Rolstoelpassage & zithouding (2x)
  C. Vuijk, K. van Breukelen
• Rolstoelvaardigheden: kan ik een wheely maken?
  L. van der Woude
• Handbiken voor fitheid en plezier
  T. Janssen

16:45 Tweede workshopronde
17:30 Toets
17:45 Schriftelijke evaluatie en sluiting
Groningen, April 23-25, 2014

UMCG, University of Groningen
5th International State-of-the-Art Congress
Rehabilitation: Mobility, Exercise & Sports