



## FITTING A WHEELCHAIR, BIOMECHANICS, AND DESIGN



February 21, 2008



## CORRECT FITTING OF A WHEELCHAIR

### Complications from improper fitting

#### Sitting habits

- Able bodied person – long period of sitting usually 1-2 hours, shifting weight all the time
- Disabled person may sit for 3 to 10 hours per day without repositioning

#### Complications due to poor posture

- Contractions and deformities
- Tissue breakdown
- Reduced performance and tolerance
- Urinary and respiratory infection
- Fatigue and discomfort

#### Correct posture?

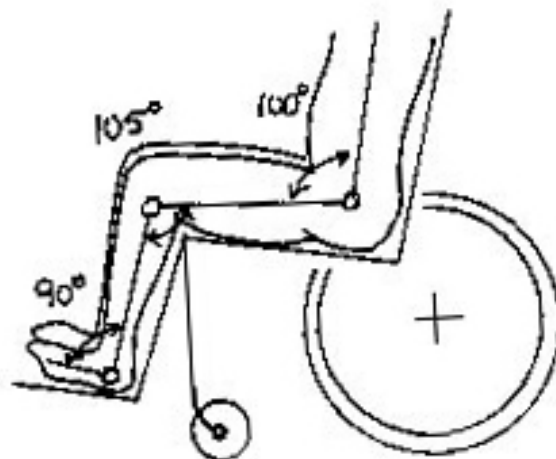


**Free Wheelchair Mission Chair**  
([www.doitfoundation.org](http://www.doitfoundation.org))



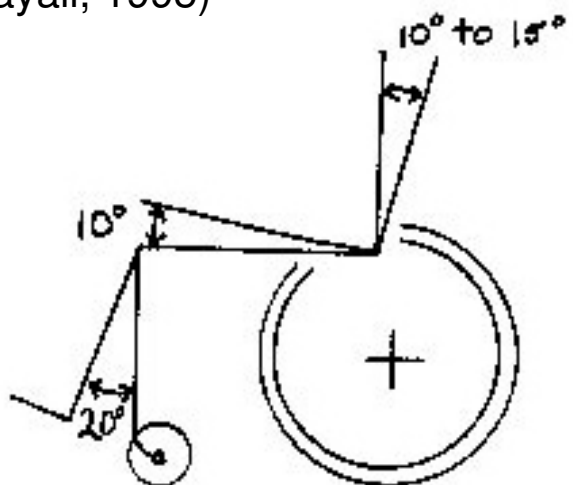
## CORRECT FITTING OF A WHEELCHAIR

### Correct anatomical and wheelchair positions



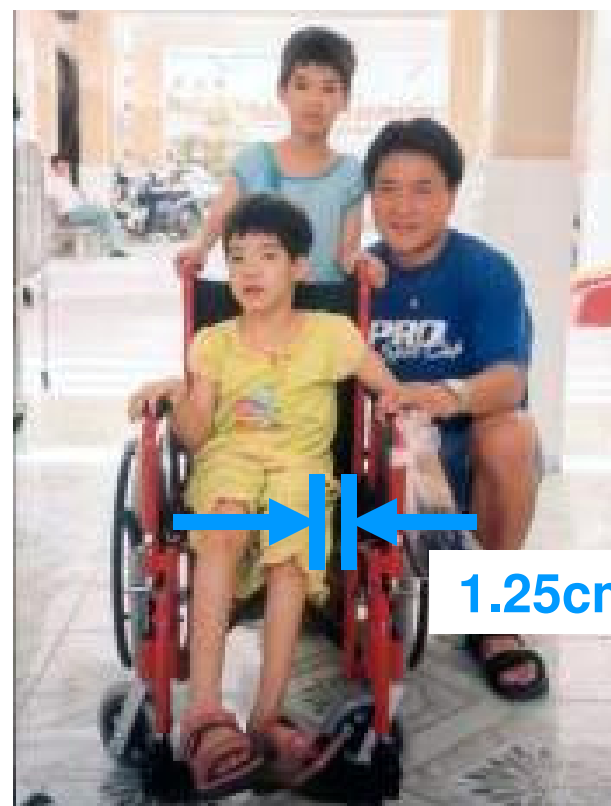
**Correct body position**

Figures from  
(Mayall, 1995)



**Correct wheelchair position**

- Want to distribute weight over butt and thighs
- Only want 1.25cm clearance between butt and frame



**Wheelchair Foundation Chair**  
([www.kidswithoutborders.com](http://www.kidswithoutborders.com))

**February 21, 2008**



## CORRECT FITTING OF A WHEELCHAIR

### Considerations during assessment

#### Considerations during prescription

- Diagnosis and prognosis
- Age
- Communication status
- Cognitive function
- Perceptual function
- Physical ability
- **Level of independence in activities during daily living**
- Transfer ability and modality
- Mobility (ambulation and wheelchair mobility)
- Body weight
- Sensory status
- Presence of edema
- Leisure interests
- **Transportation to and from home**
- **Roughness of usage**
- Time spent in wheelchair daily
- **Financial resources of patient**

List from (Mayall, 1995)

#### Wheelchair Foundation in Tanzania

##### Tanzania Big Game Safari:

- Largest donator in Tanzania, giving away nearly 7,000 chairs so far.
- Said Wheelchair Foundation will give a chair to anyone who seems to need one – a loose requirement that may include people who are crawling on the ground to people who may walk with a crutch.
- Admitted they get so many chairs every year that after the first few hundred have been distributed, it is very difficult to find genuinely disabled people to whom they can give them.

##### Monduli Rehab Center:

- Criticized the WC Foundation and said wheelchairs should not be given out like candy.
- Because the village terrain is so rough, people should be encouraged to walk with crutches or braces, and WCs should be a last resort.

**February 21, 2008**





## CORRECT FITTING OF A WHEELCHAIR

### Cushioning and positioning

#### Pressure Sores

(Close eyes if squeamish)

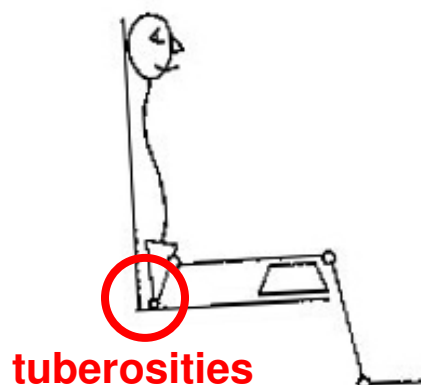


Figure 5-1. Pelvis positioning with a pre-tibial bar.

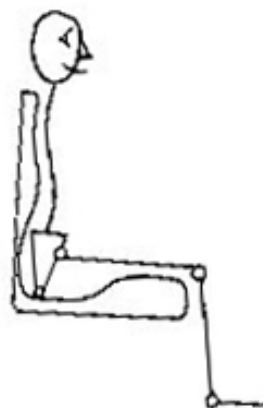


Figure 5-4. Pelvis positioning with contoured firm seat and back.

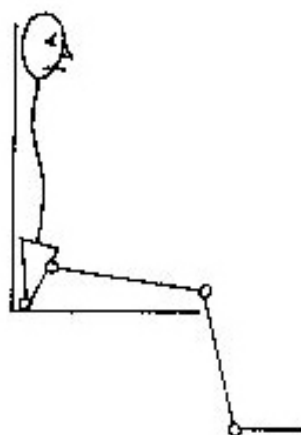


Figure 5-2. Pelvis positioning without a pre-tibial bar.

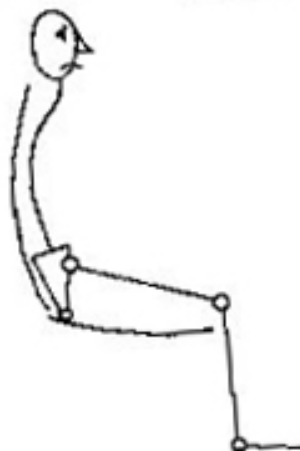


Figure 5-3. Pelvis positioning with sling seat and back.

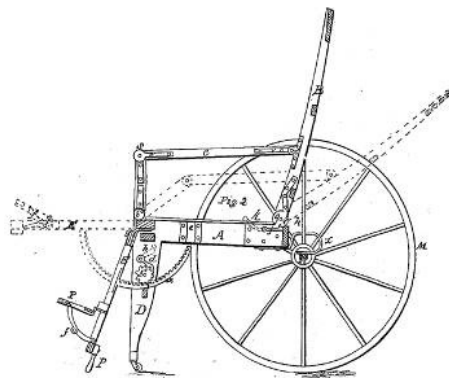


Figures from (Mayall, 1995)

February 21, 2008



# WHEELCHAIR PROPULSION



**First US wheelchair patent  
A.P. Blunt, et. al., 1869**



**Example state-of-the-art  
Quickie wheelchair, 2006**

- Wheelchair propulsion 2-10% efficient (Woude et al, 1986, 1998)
- Optimal human chemical-mechanical whole body efficiency ~ 25% (Mark's STD Handbook, 1978)
  - Occurs at  $\frac{1}{2}$  max muscle force and  $\frac{1}{4}$  max muscle speed
  - Optimal efficiency and max power output do not occur together → **Engage more muscles for more power**

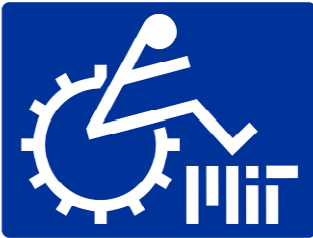


**UROP: Mario Bollini**

## **Determine best system → Wheelchair propulsion project**

- Determine the upper body motion that yields highest sustainable power at highest efficiency to deterministically design a wheelchair drive system

**February 21, 2008**



# WHEELCHAIR PROPULSION RESEARCH

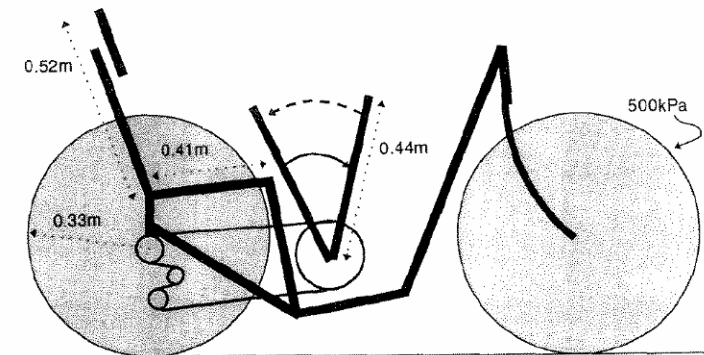
Previous work: **Power output measured from different drive systems**



**Conventional chair**

$$P_{out} = 26.5W$$

(van der Linden, et al, 1996)



**Lever-powered tricycle**

$$P_{out} = 39.3W$$

(van der Woude, et al, 1997)

Motivation: **To deterministically design a drive system for long and short distance travel, the maximum available efficient power should dictate the design**

$$\underbrace{\eta P_{human}}_{\text{TBD}} = \eta T_{human} \omega_{human} = P_{out} = F_{resist} V_{device} = \underbrace{F_{resist} R_{wheel}}_{\text{dictated by environment}} \underbrace{\omega_{wheel}}_{\text{calculated}}$$

$$\frac{\omega_{wheel}}{\omega_{human}} = \underbrace{\text{Gear Ratio}}_{\text{tune through design}}$$

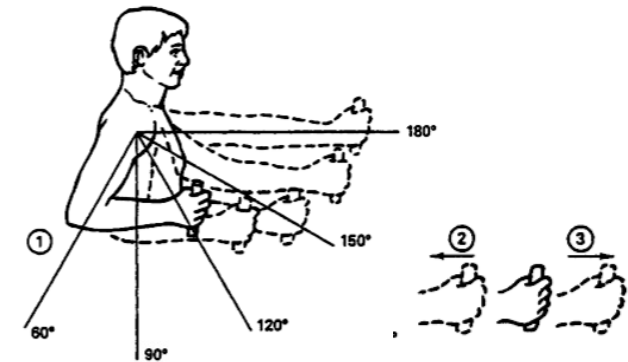


# WHEELCHAIR PROPULSION RESEARCH

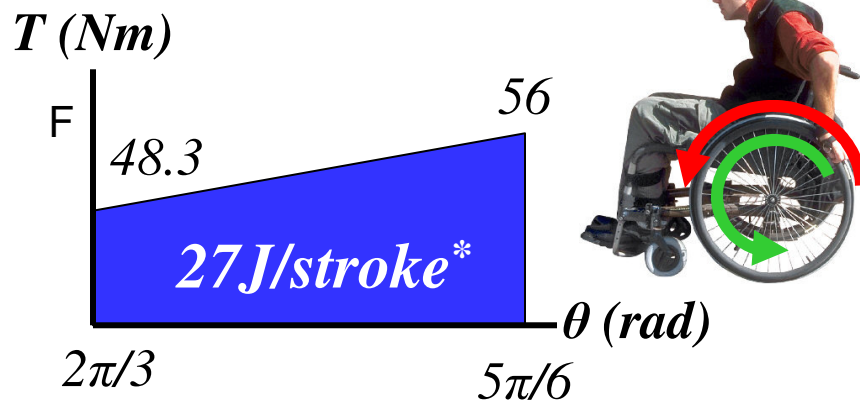
## Upper body biomechanics data

Fifth-percentile arm strength (N) exerted by sitting men											
(1)	(2)		(3)		(4)		(5)		(6)		(7)
elbow flexion (deg)	Pull		Push		Up		Down		In		Out
	Left	Right	L	R	L	R	L	R	L	R	L R
180	222	231	187	222	40	62	58	76	58	89	36 62
150	187	249	133	187	67	80	80	89	67	89	36 67
120	151	187	116	160	76	107	93	116	89	98	45 67
90	142	165	98	160	76	89	93	116	71	80	45 71
60	116	107	96	151	67	89	80	89	76	89	53 71

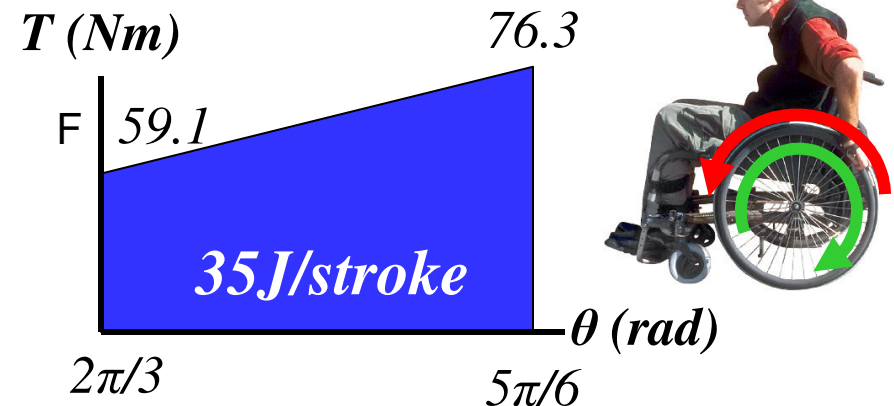
(Shigley, Mischke, 1996)



## Single arm energy output



Conventional wheelchair propulsion



Opposed handrim-wheel rotation

\*2% error from van der Linden, et al, 1996

February 21, 2008

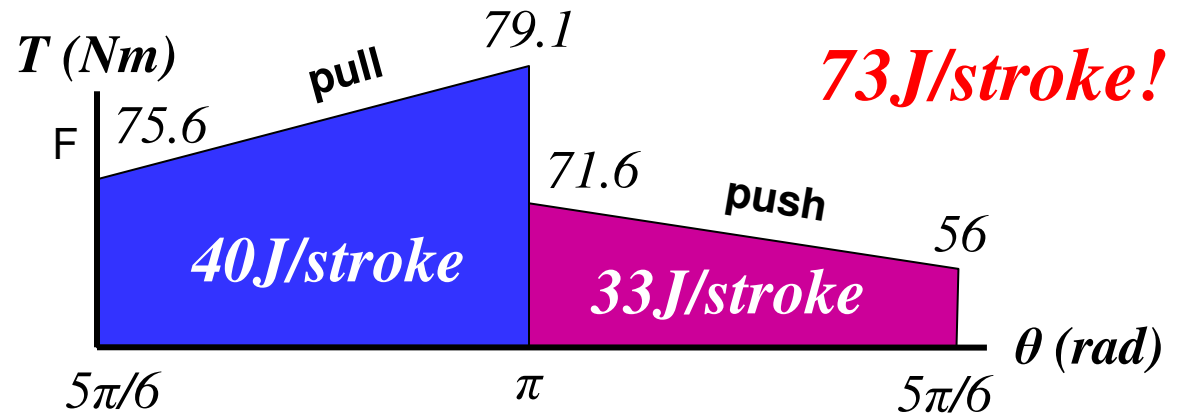




# WHEELCHAIR PROPULSION RESEARCH



Single arm energy output



Rowing-motion propulsion

## Additional questions

- What unidentified upper body motions can give high power output
- How different disabilities affect range of motion
- What type of resistance forces will be encountered depending on the environment



Unidentified high-power motions?



## DESIGN FOR HUMAN USE

### Safety factors

#### Uncertainties in strength

$$\sigma_p = \sigma_y / n_s$$

Where  $\sigma_p$  = permissible stress,  
 $\sigma_y$  = yield strength,  
 $n_s$  = strength factor of safety  
(typically 1.2 to 1.4)

#### Uncertainties in Loading

$$F_p = F_y / n_L$$

Where  $F_p$  = permissible load,  
 $F_y$  = max load,  
 $n_L$  = strength factor of safety

$$n_{\text{total}} = n_s n_L$$

For machines that can cause injury or death,  $n_{\text{total}}$  is typically 4 to 10+

#### When choosing a safety factor, consider:

- Does the load come from human activity
- Does loading come from natural sources (terrain, etc)
- What are the consequences of failure?
- Is the loading due to a prelaod?
- Does the load come from a power source (ex. starting vs. steady torque)?
- Does the load come from driven machinery that can change its output?





## EXAMPLE

### Estimating loading factor in bicycles (drop case)



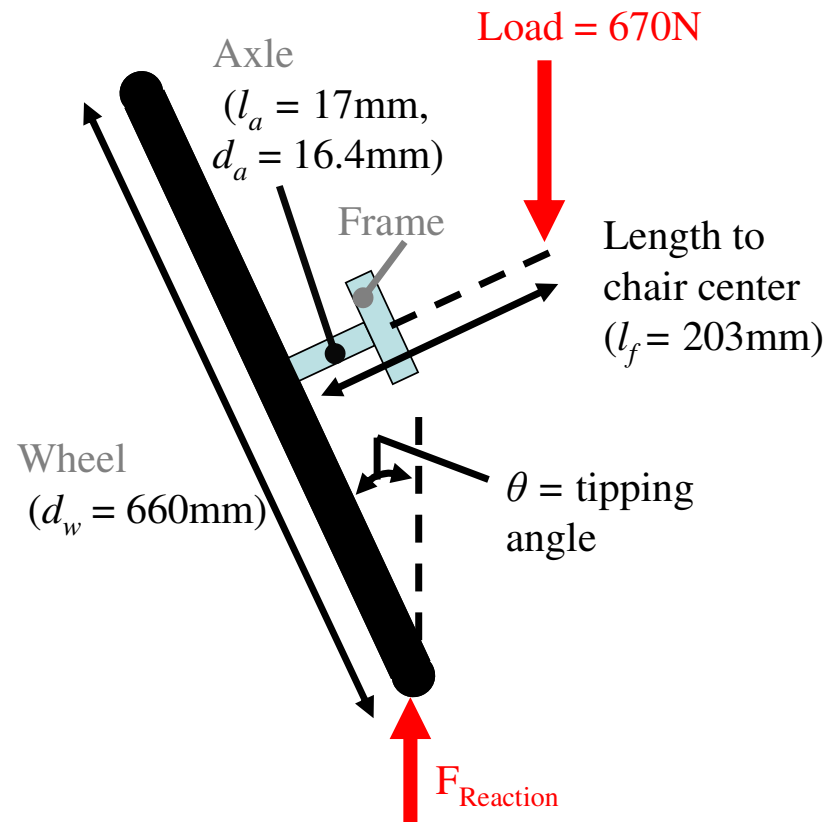
<http://www.youtube.com/watch?v=cikuW8zZqZE&mode=related&search=>

February 21, 2008



## EXAMPLE

### Estimating stress in wheelchair axle during tip-over







## EXAMPLE

### Stress in cantilevered Cannondale front shock



February 21, 2008





## **HOMEWORK**

- **Reading from Positioning in a Wheelchair**
- **Have first group meeting, define Functional Requirements and project scope, and send to Mentors and Community Partners for Review**
- **Pick first presentation day (Feb 27<sup>th</sup>, 7-9pm???) will present strategies then**



## CLASS ACTIVITY

### Measuring human power output

**Next class: Meet in 1-005 lab**

**Break into teams of 4 to 5, get a mobility aid from 3-446, and go to tunnels in basement**

#### **Tasks:**

- **Measure the rolling resistance of your team's mobility aid and calculate the coefficient of rolling friction**
- **Measure your **MAX** mechanical power output on a flat surface for each person in the group (must travel at least 50 feet). Can use rolling start to negate transient effects.**
- **Estimate the angle of one of the tunnel ramps (you can do this mathematically and/or experimentally – don't just eyeball it)**
- **Measure each group member's mechanical power out while going up a ramp. (Note: one wheelchair team should go up backwards)**