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

Free Wheelchair Mission Chair
(www.doitfoundation.org

Correct posture?
CORRECT FITTING OF A WHEELCHAIR
Correct anatomical and wheelchair positions

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

Correct body position

Correct wheelchair position

Figures from (Mayall, 1995)

Wheelchair Foundation Chair
(www.kidswithoutborders.com)
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 donor 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.
CORRECT FITTING OF A WHEELCHAIR
Cushioning and positioning

Pressure Sores
(Close eyes if squeamish)

Figures from (Mayall, 1995)
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

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 ½ max muscle force and ¼ max muscle speed
  • Optimal efficiency and max power output do not occur together → Engage more muscles for more power

UROP: Mario Bollini
Previous work: Power output measured from different drive systems

Conventional chair
\[ P_{\text{out}} = 26.5W \]
(van der Linden, et al, 1996)

Lever-powered tricycle
\[ P_{\text{out}} = 39.3W \]
(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

\[ \eta P_{\text{human}} = \eta T_{\text{human}} \omega_{\text{human}} = P_{\text{out}} = F_{\text{resist}} V_{\text{device}} = F_{\text{resist}} R_{\text{wheel}} \omega_{\text{wheel}} \]

\[ \frac{\omega_{\text{wheel}}}{\omega_{\text{human}}} = \text{Gear Ratio} \]

Tune through design dictated by environment calculated

February 24, 2009
Upper body biomechanics data

(Shigley, Mischke, 1996)

<table>
<thead>
<tr>
<th>Fifth-percentile arm strength (N) exerted by sitting men</th>
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<tbody>
<tr>
<td>(1)</td>
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<tr>
<td>------</td>
</tr>
<tr>
<td>elbow flexion (deg)</td>
</tr>
<tr>
<td>Left</td>
</tr>
<tr>
<td>180</td>
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<td>150</td>
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</tr>
<tr>
<td>90</td>
</tr>
<tr>
<td>80</td>
</tr>
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</table>

Single arm energy output

\[ T \ (Nm) \]

\[ F \]

\[ 48.3 \]

\[ 2\pi/3 \]

\[ 56 \]

\[ \theta \ (rad) \]

\[ 2\pi/3 \]

\[ 5\pi/6 \]

\[ 27J/stroke^* \]

Conventional wheelchair propulsion

\[ \times 2\% \] error from van der Linden, et al, 1996

\[ T \ (Nm) \]

\[ 76.3 \]

\[ F \]

\[ 59.1 \]

\[ \theta \ (rad) \]

\[ 2\pi/3 \]

\[ 5\pi/6 \]

\[ 35J/stroke \]

Opposed handrim-wheel rotation

February 24, 2009
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
**Geartrain performance**

Difference between chair velocity ($V_{Chair}$) and hand velocity ($V_{Hand}$)

\[
\frac{V_{Chair}}{V_{Hand}} = \frac{D_{CR} R_W}{D_{FW} L}
\]
LFC DEVELOPMENT
Lever sizing

Pushing power at peak efficiency, young male: **19.6W @ 51N and 0.38m/s**
Max pushing force at slow speed (both hands), 50% male: **356N**

Power balance at peak efficiency:

\[
\eta P_{in} = P_{out} \Rightarrow \eta P_{human} = \eta F_{hand} V_{hand} = P_{drag} + P_{rolling} + P_{gravity}
\]

\[
\eta F_{hand} V_{hand} = C_D \frac{1}{2} \rho_{air} A (V_{chair})^3 + mg (V_{chair}) \left[ \mu \cos \theta + \sin \theta \right]
\]

Force balance at peak force:

\[
F_{Resist} = F_{Rolling} + F_{Gravity} = mg \left[ \mu \cos \theta + \sin \theta \right]
\]
LFC DEVELOPMENT
Off-road testing

θ = 17.6°
Uncertainties in strength

$$\sigma_p = \frac{\sigma_y}{n_s}$$

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

Uncertainties in Loading

$$F_p = \frac{F_y}{n_L}$$

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

$$n_{total} = n_s n_L$$

For machines that can cause injury or death, $$n_{total}$$ 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=tMmiN6M7GXs&feature=PlayList&p=AE40D5B0BDD7EE81&playnext=1&index=9
EXAMPLE
Estimating stress in wheelchair axle during tip-over

Load = 670N

Axle
($l_a = 17\text{mm}$, $d_a = 16.4\text{mm}$)

Frame

Wheel
($d_w = 660\text{mm}$)

Length to chair center
($l_f = 203\text{mm}$)

$\theta = \text{tipping angle}$

$F_{\text{Reaction}}$
EXAMPLE
Stress in cantilevered Cannondale front shock
• 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 (March 3rd, 7-8:30pm???) 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)