Manual Wheelchairs: Set-Up & Propulsion Biomechanics

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This is the fifth slide lecture in a series of eight lectures that are intended to provide an overview of the wheelchair mobility and seating evaluation process. The lecture series contains:

• Seating Biomechanics
• Wheelchair Seat Cushions
• Pressure Mapping
• Wheelchair Backs
• Manual Wheelchair Set Up & Propulsion Biomechanics
• Rehabilitation Technology Suppliers & Clinicians
• Service Delivery
• Strategies for Effective Documentation
Abstract and Presenter Bio-sketch

- Mark Schmeler is the Director of Clinical Services at the Center for Assistive Technology. He has many years of front-line clinical experience in seating and mobility with individuals with complex seating needs.
- Mary Ellen Buning is a research associate in the Rehabilitation Science and Technology Department with interest in AT education, service delivery and functional outcomes that result from AT devices and services.
Outline

This presentation will cover the following:

- Categories of Manual Wheelchairs
- Repetitive Strain Injuries
- Propulsion Biomechanics
- Adjustability & Set-Up
Wheelchair Categories (Medicare)

- Standard (K0001)
- Standard Hemi (K0002)
- Lightweight (K0003)
- High Strength Lightweight (K0004)
- Ultra Lightweight (K0005)
- Rigid “Sport” Ultralites
- Reclining
- Tilt in Space

The Health Care Finance Administration (HCFA) is the Federal Agency that administers Medicare. HCFA regulates Medicare but many private insurance companies follow HCFA’s lead.

Wheelchairs are given a code by HCFA so that one computer can talk to another computer. These are often referred to as “K codes.” The system is designed so that HCFA either finds the criteria in the therapist’s documentation that will allow them to pay for it or not allow them to pay for it.

There are additional “K” categories for other kinds of durable medical equipment (DME) but these are the ones for standard wheelchairs.
The standard wheelchair is also called the “depot” wheelchair. It is at the bottom of the pile!

In order for a manufacturer’s wheelchair to fall into this category it must meet the listed criteria.

This kind of wheelchair is very useful in an airport for transporting a passenger but in reality there is no way that it is suitable for everyday use. It is too heavy and has no adjustablility.
High Strength Lightweight (K0004)

- Lifetime Warranty on frame
- Weight: <34lbs.
- Seat Width: 14”, 16”, or 18”
- Arm Style: fixed or detachable
- Seat Depth: 14” or 16”
- Seat Height: >17” & 21”
- Back Height: sectional or adjustable 15” to 19”
- Footrests: fixed or detached

K0002 and K0003 wheelchairs are a lot like K0001 with some small variations but... K0004 tend to cost about $1000. It is lighter but not enough to make a functional difference. The standard widths given above are narrower than is standard. Most people today fit into a 22” seat... Americans are heavier. Even airlines are having a problem with this factor.

This type of wheelchair can come lower to the floor for easier propulsion by foot and for increased ease in transfers.

This wheelchair is the same as k0001 with a little more adjustability. However, it costs 2x as much to purchase one. It probably doesn’t cost this much to manufacture but HCFA sets the price and manufacturers comply.

*This is the opposite of the incentive offered for the drug industries.* **
In our opinion this should be the K0001 chair!
The weight is functionally different for this wheelchair. This would have the greatest impact for the user if they are on hills or at great distances.
This chair is a lot more adjustable
However, it is priced at 4x the cost of the k0001
The manufacturers are not allowed to set the price, HCFA sets the price.
Rigid “Sport” Ultralites

- Rigid Frame
- Very Light
- Adjustable

There is no real code for this wheelchair because HCFA thinks that no one would really need a wheelchair like this.

One big difference which this wheelchair is the rigid frame. As you propel a folding frame wheelchair there is a little flex in the frame. This means that not all of the energy from the user’s arms is going into propulsion; some is going into flexing the frame.

This wheelchair is using the same principle that is used with mountain bikes which are light weight, rigid and have shock absorbing frames.
Recline and tilt are different. Recline is when you change the seat to back angle. Tilt is when you change the orientation in space.

Recline is cheaper. It makes it easier for patient management. Gives ROM., catheterize, transfers.

Disadvantage = shear. Also, it takes person out of alignment. As you return to upright, then the body is forced back the opposite way. Reclining promotes extensor tone and that can be disruptive. Yet, ironically, that is one reason that you can use to justify getting funding for a recliner.

Tilt allows gravity to work in your favor so that shoulders go back, gives a passive stretch for neck and shoulders, repositions pelvis into the back of the chair, reduces tone, and gives some pressure relief. Greater than 45 degree tilt is not proven to be as effective as is needed for reducing pressure on the ischium or lumbar spine. But it does allow pressure to be varied.

Disadvantage, the frame for a tilt chair doesn’t fold so not easy to take apart and put into a trunk. More expensive. A few thousand $ more. Teach your funding source why one is needed over the other.
Repetitive Strain Injuries in MWU’s (Boninger, 1999)

- Shoulder Pain - 20 to 100% of MWU’s
  - rotator cuff tears
  - aseptic necrosis
- Wrist Pain - 30 to 70% of MWU’s
  - carpal tunnel syndrome
  - many are clients asymptomatic for CTS but have nerve transmission abnormalities.

A lot of research at the University of Pittsburgh is centered around this issue of repetitive strain and over use injuries related which is related to long term wheelchair propulsion in wheelchairs that are not optimally set up for the user.

If you have been an active wheelchair user then you are very likely to develop shoulder pain due to repetitive strain injuries.
Implications of Repetitive Strain Injuries for MWUs

- Require costly medical interventions
- Unable to perform ADL’s with lost of productive time and dependence on others.
- Disruption in roles & routine
- Drastic changes in lifestyle
  - Forced to switch to powered mobility
  - Modifications to living environments

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This is very understandable when you realize that arms were not designed for wheelchair propulsion. The shoulder problems come from using shoulders as a weight bearing joint. Also people who swing and hang for transfers. Many people are not symptomatic and then have a rather rapid onset of symptoms.

The medical intervention (surgical repair) is expensive and interferes with the performance of ADLs (bathing, transfers, dressing and everything else).

A beginning problem will often lead to reoccurrence especially if the client returns to the same lifestyle. Orthopedists are often not tuned into the issues of wheelchair users.

Transition to power mobility. The change to a power wheelchair is often an emotionally difficult step to make. It brings increased dependency. All kinds of accessibility and transportation issues need to be reconsidered.
If you are going to efficiently propel a manual WC then the shoulder should be in vertical alignment with (or slightly in front of) the axle of the wheel. In poorly fitted wheelchairs, the shoulder is significantly forward of this line which leads to muscles imbalance and overuse... and eventually overuse injuries.

When the axle is in the correct position then you will use 2 sets of muscles, and this keeps things in balance.

Need to be able to reach as far back as possible on the rim of the wheelchair so that you have a pushing stroke that has two parts (flexion and extension) rather than just one.
The first part of the movement is grasping the rim just behind the apex of the curve.

When the hand grasps the rim behind top dead center (TDC) then stronger muscles can be recruited to create forward propulsion. This results in fewer strokes.

In the slide on the right, with hand placement far behind TDC then there is danger of damaging the joint capsule of the shoulder through the effects of the combined movement of internal rotation and shoulder extension.
At mid phase in pushing, the hand should be vertically aligned with the shoulder.

The hands are in an optimal position for exerting forward force on the wheelchair pushrims.

In the slide on the right the wrists are forced into extreme radial deviation.
Aft Phase of the Stroke

• Triceps/Shoulder Depressors

In the end phase of the stroke the hands go further down the rim thus completing the stroke with maximum efficiency. The maximum amount of force is exerted.
Appropriate Wheelchair Set-Up Prevents Upper Extremity Problems

- Shoulder position relative to real axle is positively correlated with median nerve dysfunction.
- Shoulders should be set in front of the user at rest to decrease stroke frequency, increase contact angle, increase the angle of initial contact, and reduce the rate of loading on the hand.
  – (Baldwin, Boninger, Koontz & Cooper, 1999)

Care should be taken in setup and prescription to avoid potential damage. People who use manual wheelchairs have an increased chance of developing repetitive stress injuries (RSI).

This research is reported in the ‘99 RESNA Proceedings. Long Beach, CA. p 373-375.
An active young person with an SCI is easily recommended for this kind of wheelchair. But it is the 80 year old person without the strength and flexibility that can benefit the most from it. They are the ones who get the wheelchair without the lightness and adjustability! This doesn't make sense!

Ultralights have less rolling resistance because because most of the user’s energy goes into forward propulsion and is not lost in the flexing of the wheelchair frame.
Seat Width

- Wheels should be close enough to the body to allow efficient propulsion.

Width of the wheelchair has strong influence on good access to the rims. It should be wide enough to provide lateral stability. Not so wide that it interferes with propulsion. Generally the frame should be as snug as possible to the body which creates efficient alignment and helps with propulsion. Often the long term care residents want room in the sides of their wheelchair for tucking in their possessions.
Camber

- Rims come closer to body.
- Smoother pushing motion.
- Increases lateral stability.
- Environmental issues.

Camber means the wheels are angled in toward body at the top and out at the bottom.
- This makes for a better angle for efficient pushing.
- Adds stability and efficiency in sports and athletics.

The drawback is that it creates access issues because the wheelchair becomes wider and has more difficulty in interior environments.
Seat Height

- Hand should be able to reach the rear axle of the wheel.

Should not be so high that the arms go into bad position.
Axle Position

- Move axle plate as far forward as is comfortable/safe

This adjustability can help with both forward and backward and up and down position of the large wheels. This is another reason why everyone should have a K5 wheelchair.

This Otto Bock wheelchair has a lot of adjustability. Just to show the irony of the HCFA coding system, the company has to fill in several of the holes designed to give the wheelchair adjustability so that the chair can be coded as a k0004. However, they can be knocked out so that you get the full adjustability of a k5.

The most efficient position is to move the axle as far forward as can be tolerated. However this makes the chair “tippier” which concerns some users. This can be counter acted through use of anti-tippers.
Seat Angle

- Provide a good propulsion base

Increasing this seat angle is called “dump.”
Increasing the degree of rearward slant helps to lock in the pelvis in position.
If there is too much dump it can create excessive pressure on the ischial tuberosities.
If excessive extensor tone is a problem, then increasing the dump can break up extensor tone.
Backrest

• Should not interfere with arm movement

If you have back support make sure that it has not caused limited ROM (range of motion) in shoulder blades or in shoulder rear flexion.
Seat to Floor Height

- Lower seat height allows for foot propulsion

Using the lower extremities to propel the wheelchair is better than using your arms from a biomechanical point of view. Tall chairs with a thick cushion can add to this problem. It adds to a sense of stability when your feet are on the floor. This is another advantage of the K0005 wheelchair. It allows you to raise and lower the seat height as well as change the seat angle.

Foot propulsion tends to pull people out of the wheelchair seat especially if it is positioned too high or too low. This can be counteracted with a seatbelt or with increased seat to back angle.

Adjustable wheelchairs are very cost effective in long term care. They can be recycled for another client and provide them with customized seating which can lead to increased function.
Performance of selected lightweight wheelchairs on ANSI/RESNA tests

  1. Compares the durability, stability, and cost effectiveness of three different lightweight wheelchair models.
  2. Compares the results from this study to those published for ultralight and institutional depot wheelchairs.

At HERL (The Human Engineering Research Lab at the University of Pittsburgh) they smash wheelchairs and test them from a structural perspective to the maximum of their durability.

They put the WC through a series of tests which are supposed to simulate 5 years of wheelchair use. They repeat the test until the wheelchair gets a class 1, 2, or 3 failure (catastrophic).

In this study they compared the test results.
Research Findings Cont’d

- The three models of lightweight wheelchairs tested are substantially similar and their fatigue lives are significantly ($p<.05$) lower than rehabilitation wheelchairs.

Excellent results for lightweight wheelchairs.
Research Findings Cont’d

- Ultralight rehabilitation wheelchairs are the most cost effective over the life of the wheelchair, costing 3.4 times less (dollars per life cycle) than depot wheelchairs, and 2.3 times less (dollars per life cycle) than the lightweight wheelchairs tested in this study.

- Rehabilitation wheelchair gives 78 cycles per dollar
- Lightweight wheelchair gives 112 cycles per dollar
- Ultralight wheelchairs give 263 cycles per dollar.

You get more than 3 times the value from a k0005, plus it is easier to propel and more adjustable. In our current system, we buy the cheaper wheelchair and get only 1/3 of the value. Currently, a k0005 wheelchair has a full retail cost = $1800. If HCFA was smart they would require a wheelchair manufacturer to produce just 1 kind of adjustable lightweight wheelchair. This would allow them to keep their manufacturing costs lower. It would also make it easier for the supplier to keep and inventory. It would be ideal to combine the k0004 and k0005 into one category.

That would mean there could be a fleet of wheelchairs in a nursing home that could meet the needs of any client. Better equipment could lead to happier residents and lower direct service costs.
Review Questions

- How does the wheelchair set up affect the musculo-skeletal system during wheelchair propulsion?
- How can the wheelchair back affect manual wheelchair propulsion?
- What does the research say about the “life-cycle” cost of light weight wheelchairs?
Suggested Readings

- Check the resources at Wheelchair University at:
  http://www.wheelchairnet.org/WCU/wcu.html

- Check out the Application Guidelines for the Wheelchair Standards at:
  http://www.wheelchairnet.org/ProdServ/Docs/WCN_PVAGuide.html

- Continuing Education opportunities at:
  http://www.wheelchairnet.org/WCU/Departments/WCEd.html