

Optimizing the Ride: How Manual Wheelchair Configuration Enhances Function

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Learning Objectives

1. Identify three configuration techniques that can be utilized to create stability and function in a manual wheelchair.
2. List components of a custom manual chair which are require for safe, efficient and independent functional mobility.
3. Describe how current research can help to guide appropriate device prescription for successful life-long mobility.

Established knowledge

- ▶ Repetitive Strain Injuries are real.
 - ▶ 3 out of 4 people using manual wheelchairs experience some degree of UE pain and fatigue from propulsion.
 - ▶ Pain can develop very quickly after injury, with 35% to 78% of the individuals reporting that impairments began during the first 6 months to 1 year after injury. (Rice, 2017)
- ▶ We know we want to create the outcome & configuration:
 - ▶ "Provide manual wheelchair users with SCI with a high-strength, fully customizable manual wheelchair made of the lightest possible material."- Clinical Practice Guidelines (PVA)

However...

Are we really optimizing?

Are we really customizing?

Are we really re-evaluating as often as needed?

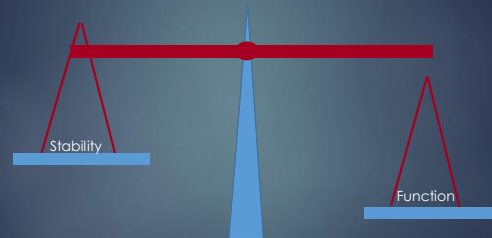
Initial Evaluation

- ▶ Short length of stay
 - ▶ Orthotics, splinting, casting
 - ▶ Medical instability
- ▶ Evaluations based off of program chairs may be sub-par
 - ▶ Lack of demo equipment
- ▶ For clinicians in an inpatient setting, current status is the starting point while at the same time planning for future functional change.

Clinical Struggle

- ▶ We no longer follow a person for a healthy "check-up" to make sure their equipment is working or what we need to adjust
 - ▶ The person may not know a change is needed until they have pain or dysfunction
- ▶ National centers may have a difficult time with follow-up as people often discharge to different states/countries
- ▶ How do we know what "after market" or "upgraded" components really make a difference in a person's function?
- ▶ How do we fill the gap between initial recommendations and knowing when to progress?

Stability vs Function



Stability vs Function

- ▶ Clinicians View:
 - ▶ "What if my patient falls over backwards?"
 - ▶ "My patient says they get scared when the front wheels come off the ground"
 - ▶ "I don't want it to be too difficult to transfer"

Reality: "Function occurs on the verge of instability"

*When a person does not have initial optimization of their wheelchair, this can lead to pain a dysfunction (Dalyan, et al.,)

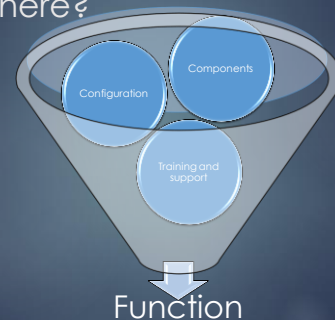
Stability vs Function

- ▶ When to tip the scale towards function?
 - ▶ An optimally set-up chair should not be the exception
 - ▶ Weekly Goal to evaluate seating and mobility (inpatient)
 - ▶ Therapist immersion training
 - ▶ Wheelies are hard and scary when trained on a sub-optimal chair
 - ▶ Goals: how to progress wheelchair skills training (breaking down skills) timeline of skill development.
 - ▶ Group skill training
 - ▶ Take the time to adjust, adjust, and re-adjust

Efficiency vs Effectiveness



But how do we actually get there?



Configuration

MWC Configuration

- ▶ What creates our configuration foundation?
 - ▶ Seat depth/frame depth
 - ▶ Overall Frame Length
 - ▶ Back angle/height
 - ▶ Front frame angle
 - ▶ Vertical COG & Horizontal COG
 - ▶ COM/COG
- ▶ The Person

The Person

- ▶ Posture
- ▶ Body type
- ▶ Pain
- ▶ Comfort
- ▶ Injury level
- ▶ Experience
- ▶ Exposure
- ▶ Environment
- ▶ Pre-morbid complications



Posture

- ▶ Impact:
 - ▶ What happens when it is optimal?
 - ▶ Functional reach is enhanced
 - ▶ Maximize independence with daily activities
 - ▶ What happens when it is suboptimal?
 - ▶ Increased risk of secondary complications
- ▶ Best Practice
 - ▶ Do not wait until an asymmetry becomes non-flexible
 - ▶ Intervene early, educate early
- ▶ When to intervene?
 - ▶ Reports of instability, sliding forward in the chair, increased pain, objective measures of postural change

Body Type

- ▶ Endomorph:
 - ▶ May need lower STF height if large amount of redundant tissue
 - ▶ Tapered back canes
 - ▶ Tapered seat
 - ▶ Camber?
- ▶ Large intra-abdominal girth/longer/heavier legs
 - ▶ More aggressive COG
- ▶ Non-Flexible kyphosis
 - ▶ Open back angle, custom/rigid backrest
 - ▶ Impact on seat depth, caster loading, horizontal COG

Seat Width (Front & Rear)

- ▶ Impact:
 - ▶ What happens when it is optimal?
 - ▶ Improved push efficiency
 - ▶ Postural support
 - ▶ Accessibility
 - ▶ What happens when it is suboptimal?
- ▶ Best Practice:
 - ▶ How to achieve
 - ▶ Most chairs can be spaced wider, unless significant weight change, possibly avoid "growing into a chair"
- ▶ When to reevaluate
 - ▶ Pelvic rotation (too narrow)
 - ▶ Pelvic obliquity (too wide)
 - ▶ Shoulder dysfunction
 - ▶ Decreased accessibility?

Seat Width (Front & Rear)



Seat Depth

- ▶ Impact:
 - ▶ What happens when it is optimal?
 - ▶ Distal thigh support/pressure distribution
 - ▶ LE management
 - ▶ What happens when it is suboptimal?
 - ▶ Skin impairments
 - ▶ Posterior pelvic tilt
- ▶ Best Practice:
 - ▶ How to achieve
- ▶ When to re-evaluate
 - ▶ Feet falling off the footplate forward, pressure on popliteal fossa, posterior pelvic tilt, decreased pressure distribution

Frame Depth

- ▶ Impact:
 - ▶ What happens when it is optimal?
 - ▶ Chair that is balance for each person's anatomy
 - ▶ What happens when it is suboptimal?
 - ▶ Caster loading, anterior instability
- ▶ Best Practice:
 - ▶ How to achieve
 - ▶ Match the bend of the knee (posteriorly)
- ▶ When to reevaluate
 - ▶ Anterior instability

▶ Seat depth is all about maximizing pressure redistribution without interfering with the lower leg.

▶ Frame depth should mirror client proportional to upper leg.



Frame Length

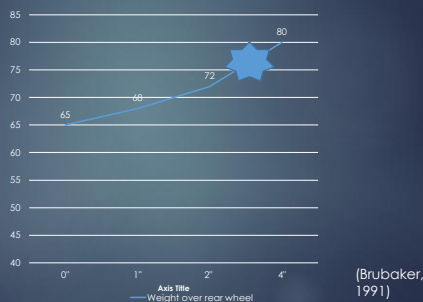
- ▶ Impact:
 - ▶ What happens when it is optimal?
 - ▶ Feet stable and supported
 - ▶ What happens when it is suboptimal?
 - ▶ Loss of anterior stability limited accessibility
- ▶ Best Practice:
 - ▶ How to achieve
 - ▶ Foot placement
- ▶ When to reevaluate
 - ▶ Environmental barriers, foot positioning



Back angle/height

- ▶ Impact:
 - ▶ What happens when it is optimal?
 - ▶ When angle is optimized, height can be lower allowing for improved reach and propulsion
 - ▶ What happens when it is suboptimal?
 - ▶ Person does not feel comfortable, decreased function and participation.
- ▶ Best Practice:
 - ▶ How to achieve
- ▶ When to reevaluate
 - ▶ Facilitating kyphosis

Axle position & Rear Wheel Weight Distribution



Existing Methods to achieve 75-80%

- ▶ Floor Scales
- ▶ FSA floor mat
- ▶ Smart Wheel
- ▶ Balance platform
- ▶ Rate of perceived effort to perform task
- ▶ Skill evaluation
- ▶ Functional outcome measure
- ▶ ?Any other thoughts?

Horizontal COG

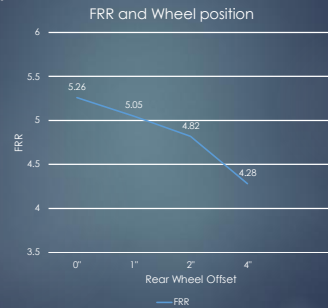
- ▶ Impact:
 - ▶ What happens when it is optimal?
 - ▶ Efficient and effective propulsion
 - ▶ Decreased shoulder strain
 - ▶ What happens when it is suboptimal?
 - ▶ Caster loading
 - ▶ Increased rolling resistance
 - ▶ stability
- ▶ Best Practice:
 - ▶ Start at 1.5" ? 2.5" ? 3.5" ?
- ▶ When to reevaluate
 - ▶ How often is it actually changed on an adjustable chair?

Vertical COG

- ▶ Impact:
 - ▶ What happens when it is optimal?
 - ▶ Stable base
 - ▶ Sit in the chair not on it
 - ▶ What happens when it is suboptimal?
 - ▶ Reaching for the wheels-developing
- ▶ Best Practice:
 - ▶ FSTF: ground clearance and lower leg length (17.5-19")
 - ▶ Rear STF: palm or fingertip to hub
 - ▶ 100-120 degrees of elbow flexion at top of hub
 - ▶ Seat Slope: static and dynamic stability/reaching
- ▶ When to reevaluate?

Components

Rolling Resistance and COG:



What impacts Rolling Resistance

- ▶ Surface interaction
 - ▶ Hard Smooth
 - ▶ Carpet
- ▶ Material of tire
 - ▶ Durometer (hardness of materials)
 - ▶ Solid
 - ▶ Pneumatic with airless inserts (foam)
 - ▶ Pneumatic
- ▶ Tread Profile
 - ▶ Lower tread profile = lower rolling resistance.
- ▶ Weight of Tire
 - ▶ Increased material weight leads to increased deformation.
- ▶ Deformation
 - ▶ Increased deformation = higher rolling resistance.
 - ▶ Solid tires are significantly more affected by load increases.

Material & Type of Tire

- ▶ Impact:
 - ▶ What happens when it is optimal?
 - ▶ Lower rolling resistance facilitates longer coast times, resulting in fewer pushes.
 - ▶ Lower weight decreases initial force to overcome initial inertia, resulting in less force and energy expended by the user.
 - ▶ Improved ride comfort
 - ▶ What happens when it is suboptimal?
 - ▶ Higher rolling resistance requires more push frequency, force and energy expended by the user.
 - ▶ Earlier occurrence of overuse syndrome and entry into club .75.

Material & Type of Tire

- ▶ Best Practice:
 - ▶ Highest Pressure Pneumatic 85-145psi: Justifiable upgrade?
 - ▶ Schwalbe One: Ultra-light, superb traction wet or dry, extremely low rolling resistance, puncture protection.
 - ▶ Schwalbe Marathon Plus: low profile tread, puncture resistance, run-flat.
 - ▶ Higher Pressure
 - ▶ Kenda: 100 - 110psi
 - ▶ Primo HP: 110psi
 - ▶ Primo V-Track: 100psi
 - ▶ High Pressure Pneumatic 80lbs: Typically standard or NCO
 - ▶ High Durometer solid
 - ▶ SHOX 110psi Equivalent
 - ▶ Pneumatic with airless inserts

Schwalbe Marathon Plus



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Composition of wheel

- ▶ Impact:
 - ▶ What happens when it is optimal?
 - ▶ Lower weight = lower initial inertia
 - ▶ Increased stiffness = less energy loss = longer coast distance per push
 - ▶ What happens when it is suboptimal?
 - ▶ Increased force and energy required of user
 - ▶ Less force translated to distance
 - ▶ Increased pain and fatigued

Composition of wheel

- ▶ Best Practice:
 - ▶ How to achieve
 - ▶ Spinerigy Carbon Blade
 - ▶ Weight
 - ▶ Topolino
 - ▶ Carbon Core
 - ▶ Spinerigy SPOX
 - ▶ Super Light Aluminum
 - ▶ Aluminum Spoke
 - ▶ Mag (for the love of god, please don't!)

Sub-Optimal



- Wheel Access
- Frame Length
- Frame Width
- Weight Distribution
- Wheel Type
- Tire Type
- Tread Type
- Caster Type

Optimal



- Wheel Access
- Frame Length
- Frame Width
- Weight Distribution
- Wheel Type
- Tire Type
- Tread Type
- Caster Type

MWC Configuration + Rolling Resistance

- ▶ Rotational inertia
 - ▶ 28% lower with pneumatic, spoke, fwd axle. Lower the inertia, less force needed. (Caspall, 2013)
 - ▶ 3.5" vs 5.25" COG 1.65% lower with forward COG. Even bigger influence when you don't have the right wheel
 - ▶ 1.65% difference COG with best of best
 - ▶ 2.37% difference COG with worst of the worst = 70% difference?
 - ▶ Relook at this.

Clinical Application- Meet Steph



- 20 years old
- C5,6,7 SCI
- Chair concerns: Feet falling off the footplate and dragging
- Difficult to propel long distances
- Unable to load in the car
- Aluminum Adjustable frame
- Power-Assist Wheels
- COG: 0,0"
- FSTF: 19" (lower leg length: 15)
- RSTF 17"
- 17 w x 18 d
- Back height: 18"

Clinical Application

- ▶ When did you know you needed a change to your chair?
 - ▶ "I knew I needed adjustments to my chair when I surrounded myself with other wheelchair users who had been injured longer than I have. They have the experience with several chairs and knew exactly what I would need."
- ▶ How many chairs have you had in 6 years?
 - ▶ "Four. Changes were only made when I would upgrade my chair. The changes slowly got better as my independence grew. I would say that with the level of compact and lightweight of my chair I have become much more independent."

Clinical Application- Meet Steph

- 4th chair
- 6 years post C7 SCI
- Titanium non-adjustable
- 15" w x 16" d
 - Seat taper
- FST: 18"
- RST: 15 ½"
- Back height: 12"
- Loads chair independently
- Smart Drive power assist for distances, carpet, travel, work.



Any advice?

- ▶ Less can sometimes be more.
- ▶ If it's fitted right and it's smaller the chances of having more independence are much greater.
- ▶ I wish I had known that when I was first injured. I thought a big bulky chair would be safer, which it is.
- ▶ But I know now that in order to achieve independence and not hurt my rotator cuff's, a smaller lighter chair is much better.

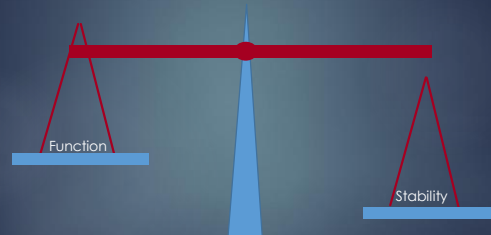
Rider survey results

- ▶ Thank you in advance to all that have taken your time to complete this quick survey. The purpose of this survey is to utilize feedback from people who use manual wheelchairs, or "riders". We will be educating clinicians and suppliers about optimizing wheelchair set-up and want to hear from YOU on what a great fitting chair means and how it can impact your daily tasks.
- ▶ The survey should take between 3 and 5 minutes to complete.
- ▶ TiLite list serve, ROHO, TiLite, Permobil social media, Max Mobility, 2 peer educators social media followers
- ▶ All anonymous but we did receive some emails regarding the survey which we responded to and tried to provide resources when appropriate.
- ▶ Qualtrics Survey system
 - ▶ Participants were volunteers, no incentive provided

Results
coming
soon...

STAY TUNED!!!

Stability vs Function



Training and Support

Training

- ▶ How does great wheelchair skill training combine with great wheelchair set-up?
- ▶ What can you look for to see if you need to adjust a set-up?
- ▶ What might your client/patient be saying to know if you need adjustments?

How do I know when to advance?

- ▶ Seating Identification Tool (SIT) (Miller, WC)
 - ▶ 11 items to cover: skin condition, comfort, positioning, **stability** and mobility
- ▶ Wheelchair Skills Test (WST)
- ▶ FMA
- ▶ Outcome measures
- ▶ 10 m push test/ 100 m push test
 - ▶ Time, number of pushes, fatigue, pain,
- ▶ Seated functional reach
- ▶ Subjective reports of behavior and function

Wheelchair satisfaction and function

- ▶ n=109
- ▶ 1 year post discharge from 8 Dutch SCI specialty centers
- ▶ Measured level of activity with PSAID
 - ▶ 11 item questionnaire: wheeling outside, light housework, yardwork, sports, strength & endurance, caregiver, work/volunteer
- ▶ Correlation between wheelchair satisfaction and PSAID level

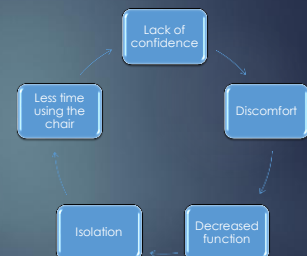


Wheelchair Confidence

- ▶ A person who is confident in their skill set will create challenging goals, seek out the indirect path and recover quickly from set-backs.
- ▶ Individuals with better sporting equipment, report higher confidence
 - ▶ \$50 tennis racquet vs \$300 racquet
- ▶ Confidence and ICF Framework
 - ▶ Part of the body systems because it is influenced by health conditions vs Personal Factors (Sakakibara, 2015).

Wheelchair Confidence

- ▶ Same applies to wheelchair confidence.
- ▶ If a person is not confident in the wheelchair comfort or skills, the functional outcome will be limited
- ▶ How do we achieve this:
 - ▶ Addressing seating needs
 - ▶ Wheelchair skill training
 - ▶ Increase comfort.



Group Influence

- ▶ Effectiveness of Group Wheelchair Skills Training for People with Spinal Cord Injury: A Randomized Controlled Trial (Worobey 2016)
 - ▶ N=79 completed follow-up
 - ▶ 36 participants in wheelchair skills group training
 - ▶ 6 classes held by trainers
 - ▶ 43 active controls in general SCI education
 - ▶ 2 (1) hour education classes
 - ▶ WST-Q and Goal Attainment Scale (GAS)
 - ▶ After one month: WST group improved in skill as well as GAS scores
 - ▶ Higher attendance, bigger improvement

"Group training can improve advanced wheelchair skills capacity and help patients achieve individually set goals"

Impact on QOL

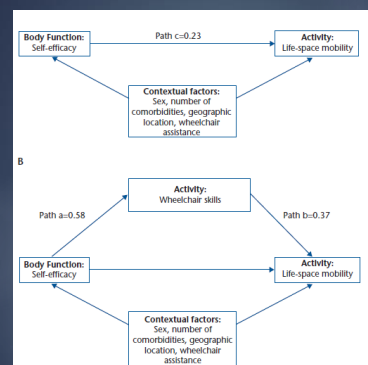
- ▶ n=214 from 6 SCI model centers
- ▶ ≥ 11 months post injury
- ▶ WST performed
- ▶ Higher success rates indicated better perceived health, improved overall satisfaction and community participation
 - ▶ Also influenced by age, gender, level of injury, socioeconomic factors
- ▶ 6 skills determined increased QOL and participation
 - ▶ **Descending a 15 cm (6") curb**
 - ▶ Disassemble chair
 - ▶ Stair negotiation
 - ▶ Stationary Wheelie
 - ▶ 180 deg turn in wheelie
 - ▶ Floor transfer

(Hosseini, 2012)

Impact on Daily Function

- ▶ Life-Space Mobility: "Movement extending from within the home to beyond the town or geographic region"
- ▶ N=123; Adults aged ≥ 50 years of age in Quebec and British Columbia
 - ▶ Used a MWC on a daily basis and had at least 6 months experience
- ▶ Life-Space Assessment:
 - ▶ Frequency of movement: in the home, around the home, in the neighborhood, in town, outside of town
- ▶ WST-Q for wheelchair skills
- ▶ Self-Efficacy had a "statistically significant influence" Life-Space Mobility
- ▶ ***this was almost entirely related to wheelchair skills***

(Sakakibara, 2014)



(Sakakibara, 2014)

So what can you do?

- ▶ Skill training, problem solving, life skills, community mobility
- ▶ Video feedback
- ▶ Peer Education and Mentors
- ▶ Community Group Skills day

Summary

- ▶ Combining fit through configuration = maximal functional outcomes
- ▶ Reducing rolling resistance through components and chair set-up
- ▶ Enhance training and education
- ▶ Provide resources
- ▶ Re-evaluate as much as you can and a small change can make a difference.
- ▶ Each person has individual needs and may not know they are at an efficiency disservice until it is too late.

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Thank you!!

- ▶ Questions? Comments?
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