# MANUAL WHEELCHAIR PROPULSION:

## TECHNIQUES, POSITIONING, AND EQUIPMENT CONSIDERATIONS

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# FACULTY DISCLOSURE

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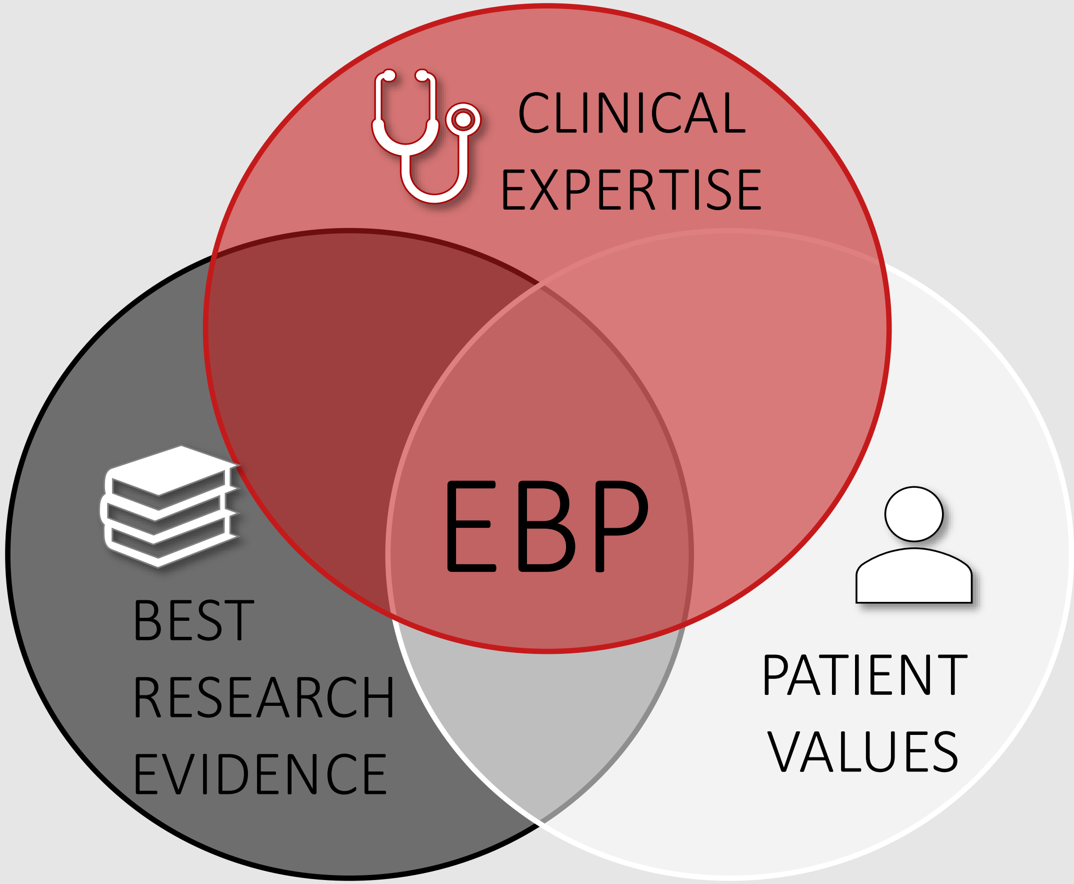
# MOTION COMPOSITES

"LEAD THE EVOLUTION OF MOBILITY FOR BETTER LIVING"

Wishes for Wheels

# EVIDENCE BASED PRACTICE

OUR FOUNDATION




Integrating individual clinical expertise with the best available external clinical evidence from systematic research.
-David Sacket, 1996

# LEARNING OBJECTIVES

BY THE END OF THIS COURSE, PARTICIPANTS WILL BE ABLE TO:

1. Analyze the impact of client ability, musculoskeletal health, and long-term mobility outcomes on the efficiency of different propulsion techniques.

2. Evaluate client positioning and wheelchair configuration to enhance propulsion mechanics, minimize potential for injury, and maximize independence.

3. Apply principles of component selection to customize wheelchair setup to support injury prevention and long-term functional mobility with propulsion.

# WHAT IS PROPULSION

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# WHAT IS PROPULSION

- The method a person uses to move their wheelchair forward, backward, and during turns
- Can be done using arms/hands, feet/legs, or a combination
- Efficiency and technique affect speed, energy use, comfort, and long-term health (e.g., shoulders, posture)
- GOAL: match the wheelchair and propulsion method to the individual's abilities, environment, and daily activities

# TYPES OF PROPULSION

- Arm
- Foot
- Hemi
- Dependent

# ARM PROPULSION


# ARM PROPULSION

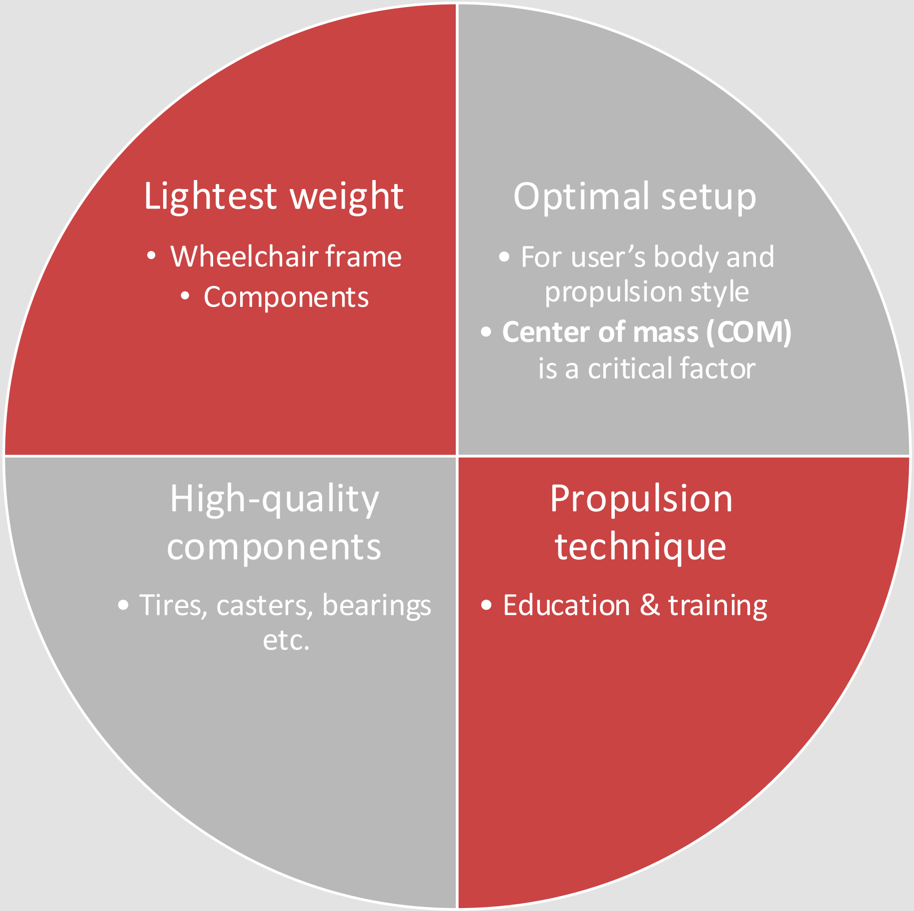
- Using arms and hands typically by pushing on the handrim
  - Most common method of manual wheelchair propulsion
- Energy is applied to the system when arms are in contact with the handrim/tire
  - **How can you be efficient?**
  - Increase the contact time – hand on handrim
- Clients can push on their handrim 2000-3000 times a day!
  - Not just young & active ones
- Consideration: High risk of shoulder pain or overuse injury if not optimized
  - Shoulders are not meant to be weight bearing joints

# RESEARCH & LITERATURE

- High demand on shoulders, wrists, and hands
- Upper extremity pain and strain affects up to 76% of manual wheelchair users
- Risk of overuse injury
  - Shoulder, wrist, elbows
  - Rotator cuff degeneration, shoulder impingement syndrome, tendonitis and bursitis, carpal tunnel syndrome
- Most research is on people with SCI

# RESEARCH & LITERATURE

- A lighter wheelchair ***can*** improve efficiency and reduce strain, but the optimal configuration includes a combination of ideals across multiple aspects.
  - Lightest weight
  - Optimal set-up
  - High-quality components
  - Propulsion technique



# PHYSICAL CONSIDERATIONS FOR ARM PROPULSION

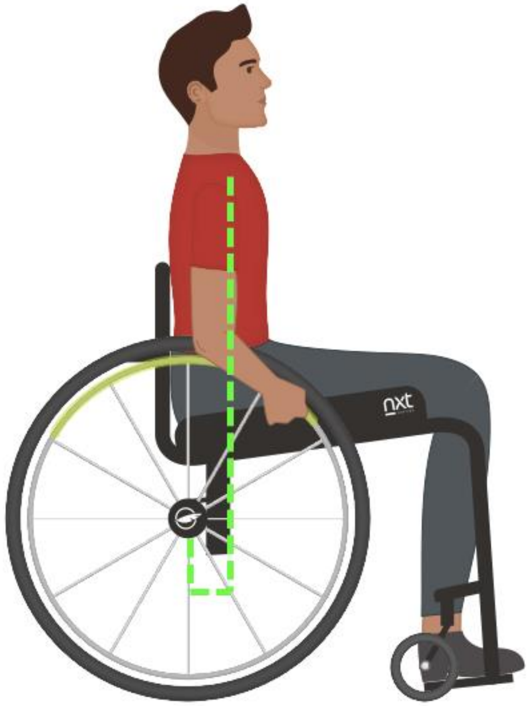
- **Power Phase**: Shoulder flexion, internal rotation → Elbow extension → Wrist/finger flexion
- **Recovery Phase**: Shoulder extension, external rotation → Elbow flexion → Wrist/finger extension & rest
- **Trunk & Core**: Stabilizes posture for efficient force transfer → Provide stability so arm motion translates effectively into wheel motion
- **Efficiency**: Comes from long, smooth strokes with less abrupt force

# OPTIMAL POSITIONING

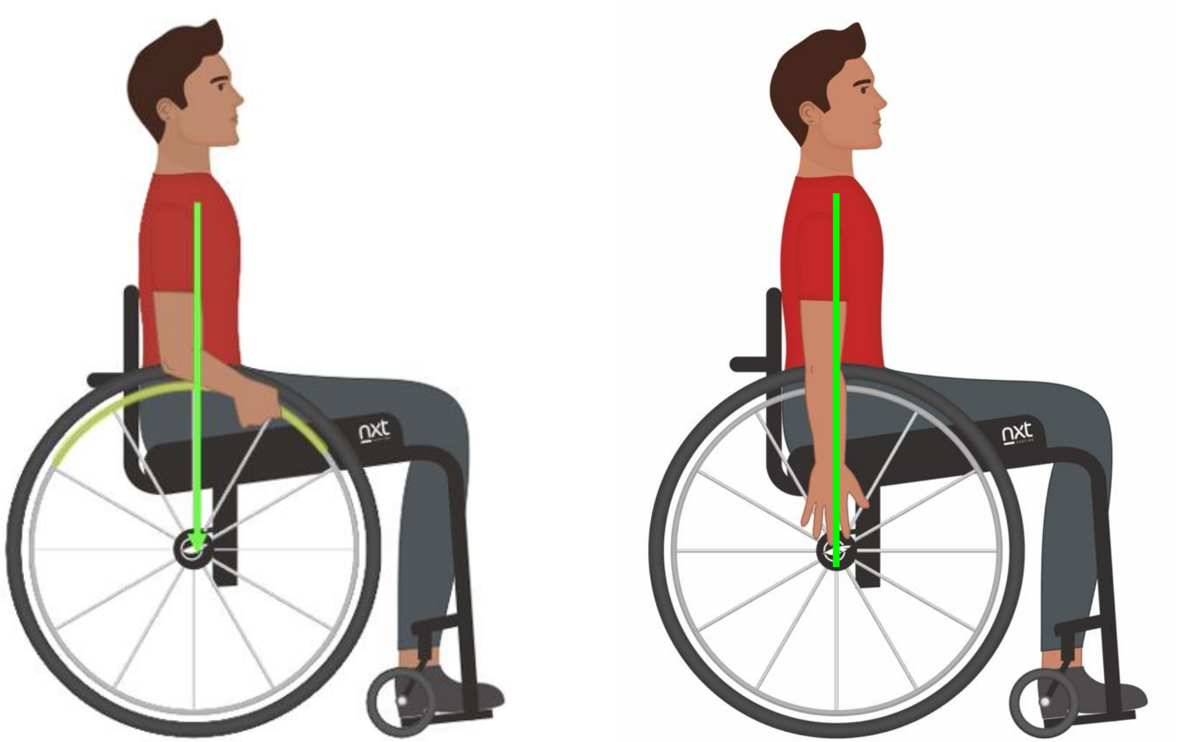
- Rear wheel set up
  - Dictates arm & elbow positioning
  - Allows better contact with more of the handrim
  - Important for all populations
    - Don’t forget the geriatric client
- Two ways to achieve this optimal positioning
  - Rear wheel size
  - Positioning of wheels within the frame

# HORIZONTAL REAR AXLE POSITION

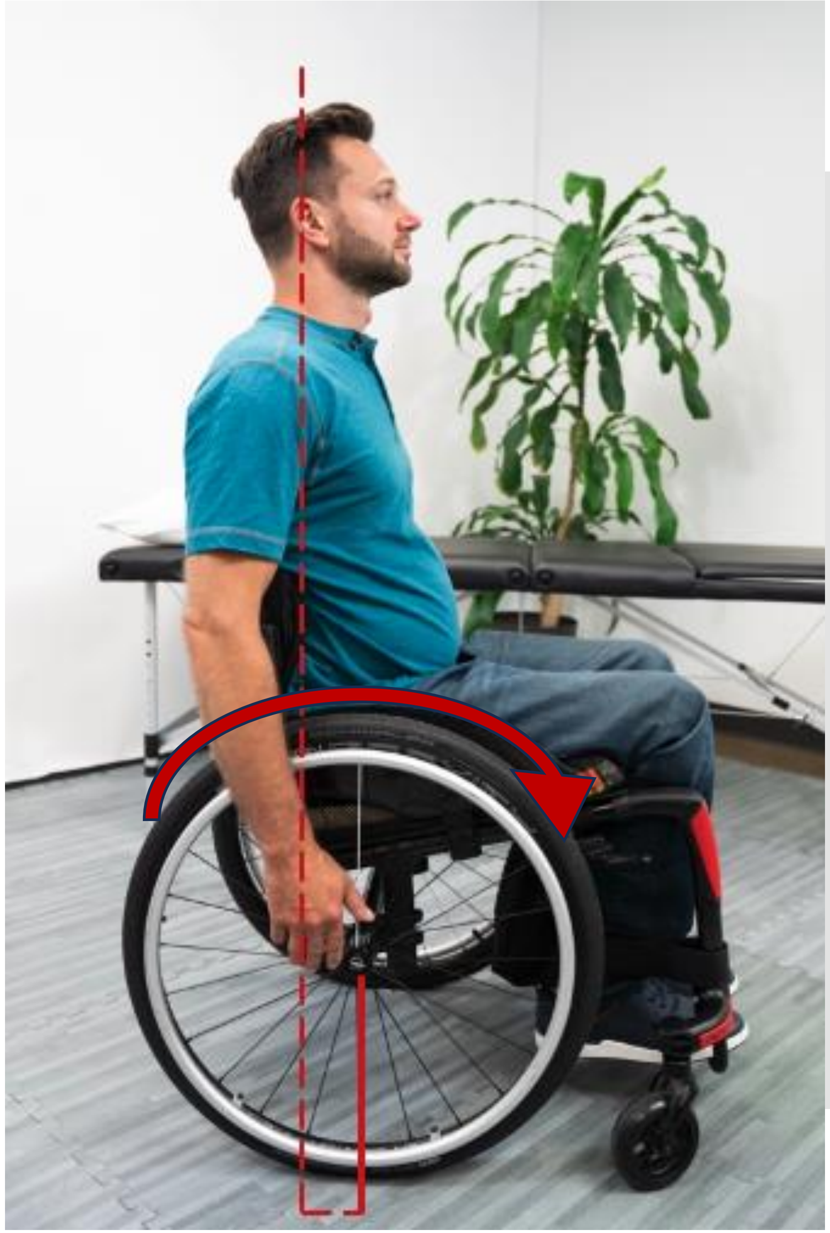
- Horizontal axle position = Center of gravity (COG)
- Move the rear wheel as far forward as possible without compromising the stability of the user
- Axle at or in front of the shoulder
- Axle position is USER Specific



REARWARD HORIZONTAL AXLE POSITION



OPTIMAL HORIZONTAL AXLE POSITION

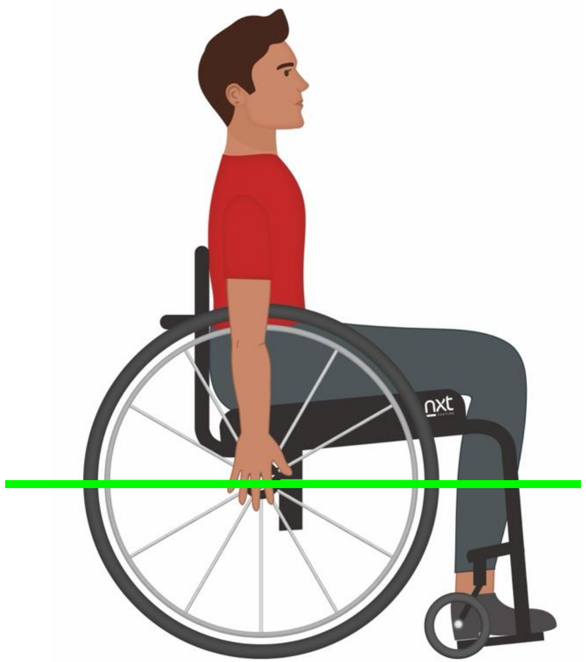


# FORWARD AXLE POSITION

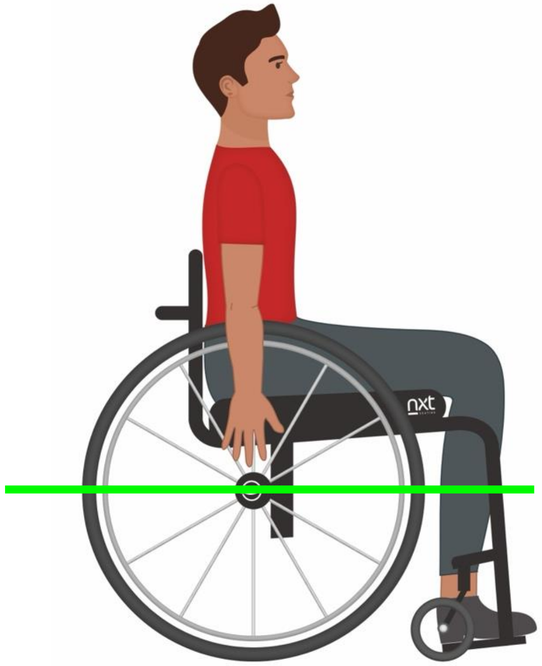
- Allows access to the full wheels for long active phase on push rim
- Allows for use of multiple muscle groups for endurance and power

# VERTICAL REAR AXLE POSITION

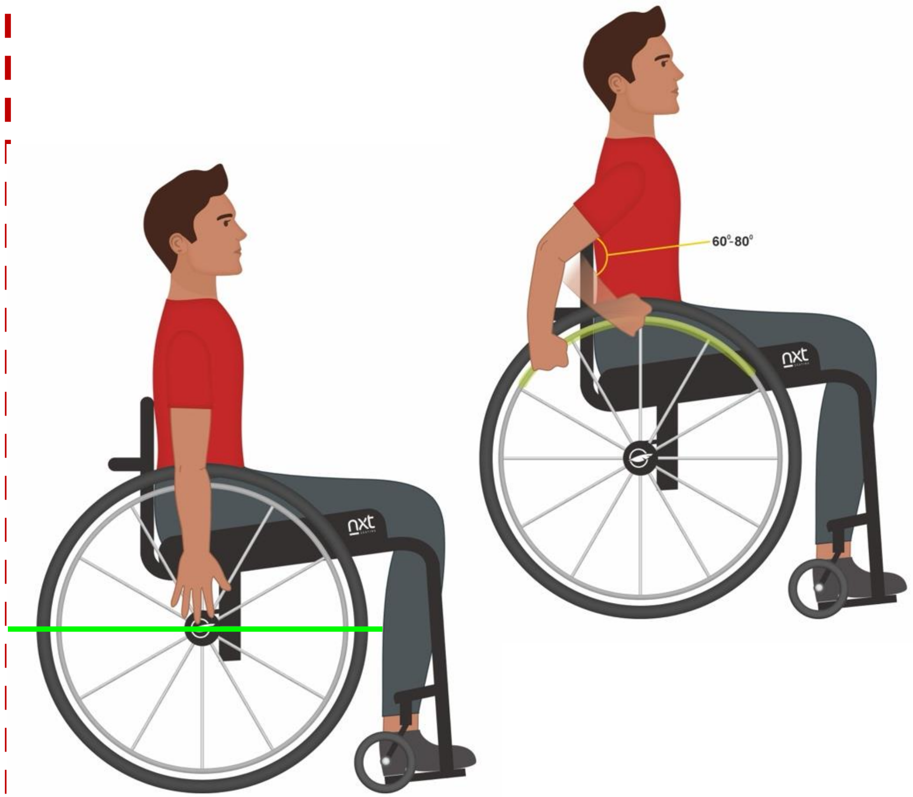
- Angle between the arm and forearm between 100-120°
  - 60-80° of elbow flexion when the hand is on the top of the pushrim
- Middle finger touches the center of the axle with arms hanging
- Can be difficult to optimize with some clients




EXCESSIVELY HIGH AXLE POSITION




EXCESSIVELY LOW AXLE POSITION



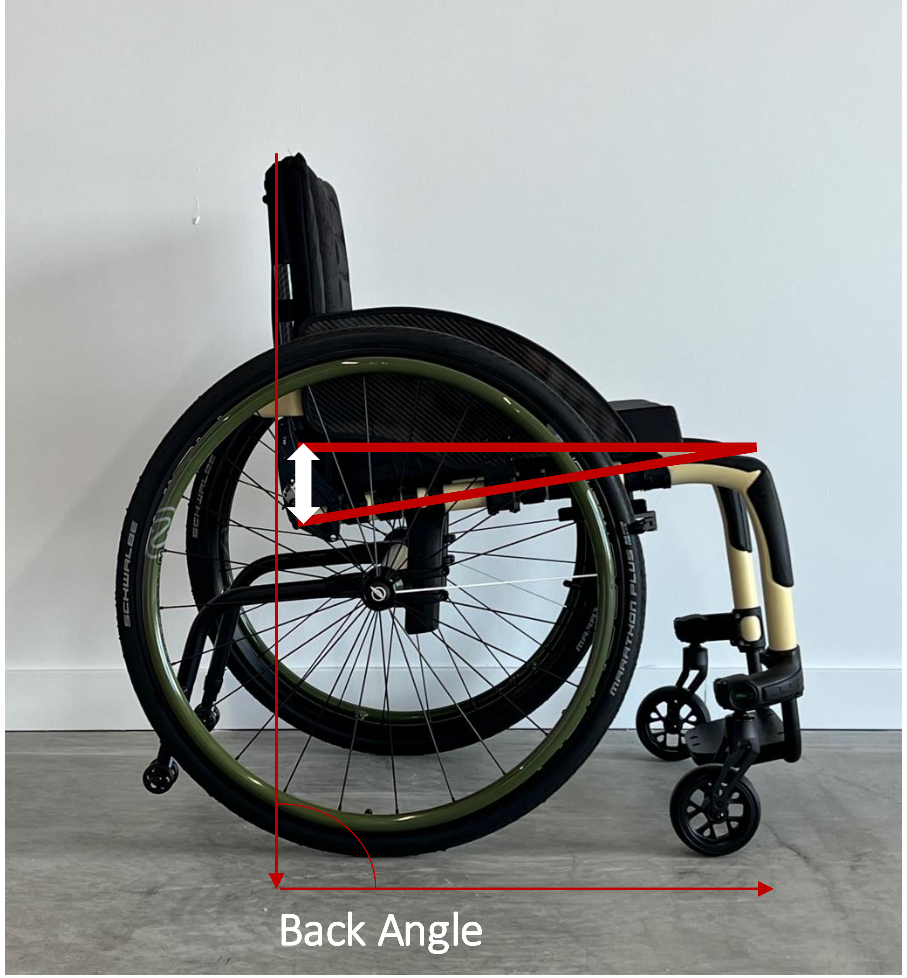

IDEAL POSITION


# PRACTICAL APPLICATION

- LIMITATIONS TO ACHIEVING OPTIMAL POSITIONING
  - Transfer height
  - Environment
    - Environmental surface heights too low (tables, counters, etc.)
    - Clearance (knee & ground)
  - Seating surface heights
  - Safety with forward COG
- TROUBLE SHOOTING
  - Modify seat to floor height
    - Rear or both front & rear
  - Modify rear wheel size

# IMPACT OF REAR SEAT TO FLOOR HEIGHT

1.5” DIFFERENCE




3” DIFFERENCE

# IMPACT OF OPTIMAL CONFIGURATION

# WHEELCHAIR MODEL CONSIDERATIONS

## FRAME HEIGHT

- Can you achieve optimal STFH
- Consider future adjustment up or down

## VERTICAL ADJUSTABILITY

- Can you achieve optimal STFH
- Increments for modification: 1”, 0.5”, ¼”, infinite

## HORIZONTAL ADJUSTABILITY

- As forward as possible without compromising safety
- How far forward can it go
- Increments for modification: 1”, 0.5”, ¼”, infinite

## CASTERS & REAR WHEELS

- Will dictate STF heights
- Will impact maneuverability
- Rear wheel: impact arm positioning

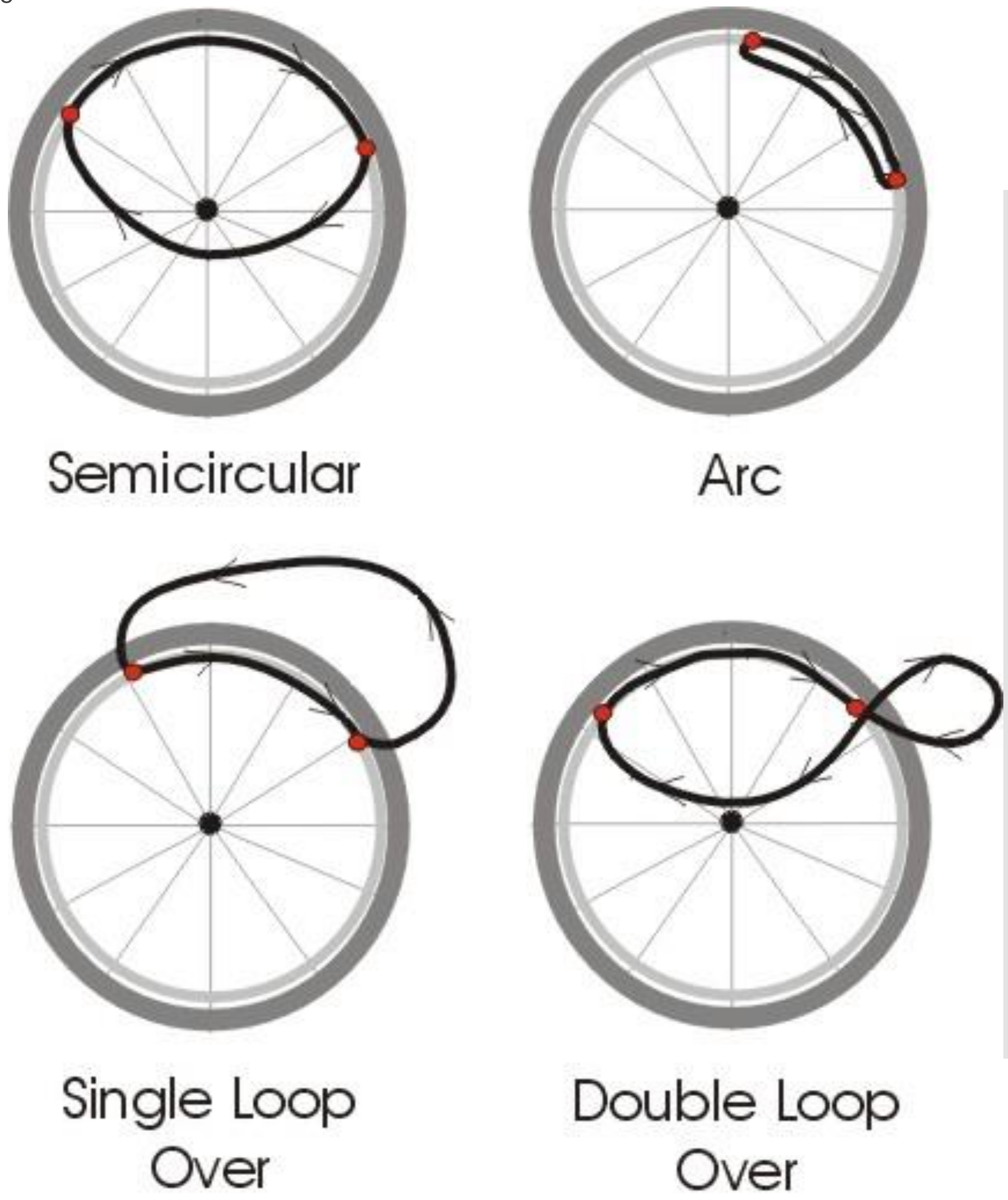
## SEATING SYSTEM

- Seat cushion: Height will impact positioning in the frame and user interacting in the environment
- Back support: should not impact shoulder ROM, PSIS support

## HANDRIM SELECTION

- Material
- Shape
- Size
- Spacing

# TECHNIQUE:
## PROPULSION PATTERNS




- 4 main upper extremity propulsion patterns
- Vary in efficiency depending on the situation
  - Functional Goal
  - Environment

# SINGLE LOOP OVER

## ACTION

Hands grab the handrim, push down and then rise above the hand rim during recovery phase

## PRACTICAL APPLICATION

Crowded environments

## RISK

Shoulder over use with elevation

# SINGLE LOOP OVER PROPULSION

# DOUBLE LOOP OVER

## ACTION

Hands grab the handrim, push down, then let go with wrist flicking and drop below the hand rim during the recovery phase

## PRACTICAL APPLICATION

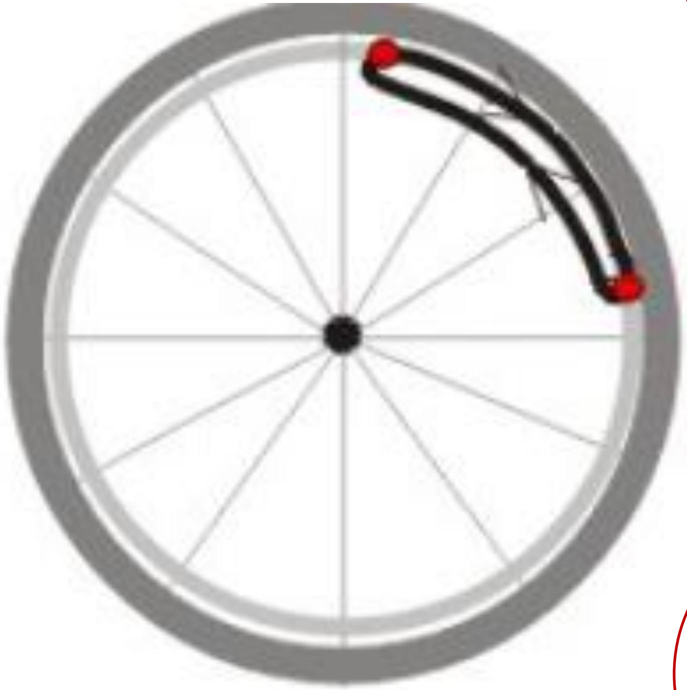
Fast starts, when on rough terrain, carpet etc.

## RISK

Wrist overuse – carpal tunnel

# DOUBLE LOOP OVER PROPULSION

# ARCING



## ACTION

The hand does not leave the handrim during this style leading to a slow down during the recovery phase

## PRACTICAL APPLICATION

Inclines

## RISK

Overuse injury due to inefficiency, most inherent pattern people will choose – risk of never getting more efficient

# ARCING PROPULSION

# SEMICIRCULAR

## ACTION

Hands grab the back of the handrim, push forward and drop below the hand rim during recovery phase

## PRACTICAL APPLICATION

Most efficient for everyday use

## RISK

Minimized on all aspects

# SEMICIRCULAR PROPULSION

# FOOT PROPULSION

# FOOT PROPULSION

- Moving a wheelchair with the lower extremities using one or both feet
- Energy is applied to the system when foot is in contact with the ground
- Uses larger muscle groups
  - Typical weight bearing joints
  - Removes the high risk of upper extremity strain
  - More efficient and less effortful than hand propulsion
- Optimal postural alignment and positioning is just as important for foot propulsion

https://www.youtube.com/watch?v=rKy7-npLXAg

# POPULATION

Common among older adults

Clients with limited UE strength or mobility

Previously ambulatory clients

- Prefer foot propulsion due to familiarity with using their LEs for movement

Clients with good hip/knee ROM, ankle mobility, and gluteal strength

# RESEARCH & LITERATURE

- Under-researched topic
- Most studies use able-bodied subjects
  - Due to co-morbidities
- Lowering seat to floor height improves propulsion speed and reduces effort
- Anterior tilt (3-6°) facilitates more effective foot propulsion, hip & knee flexion ROM and user comfort

# PHYSICAL CONSIDERATIONS OF FOOT PROPULSION

**Power Phase**
- Hip/knee extension
- Ankle plantarflexion
- Foot pushes forward

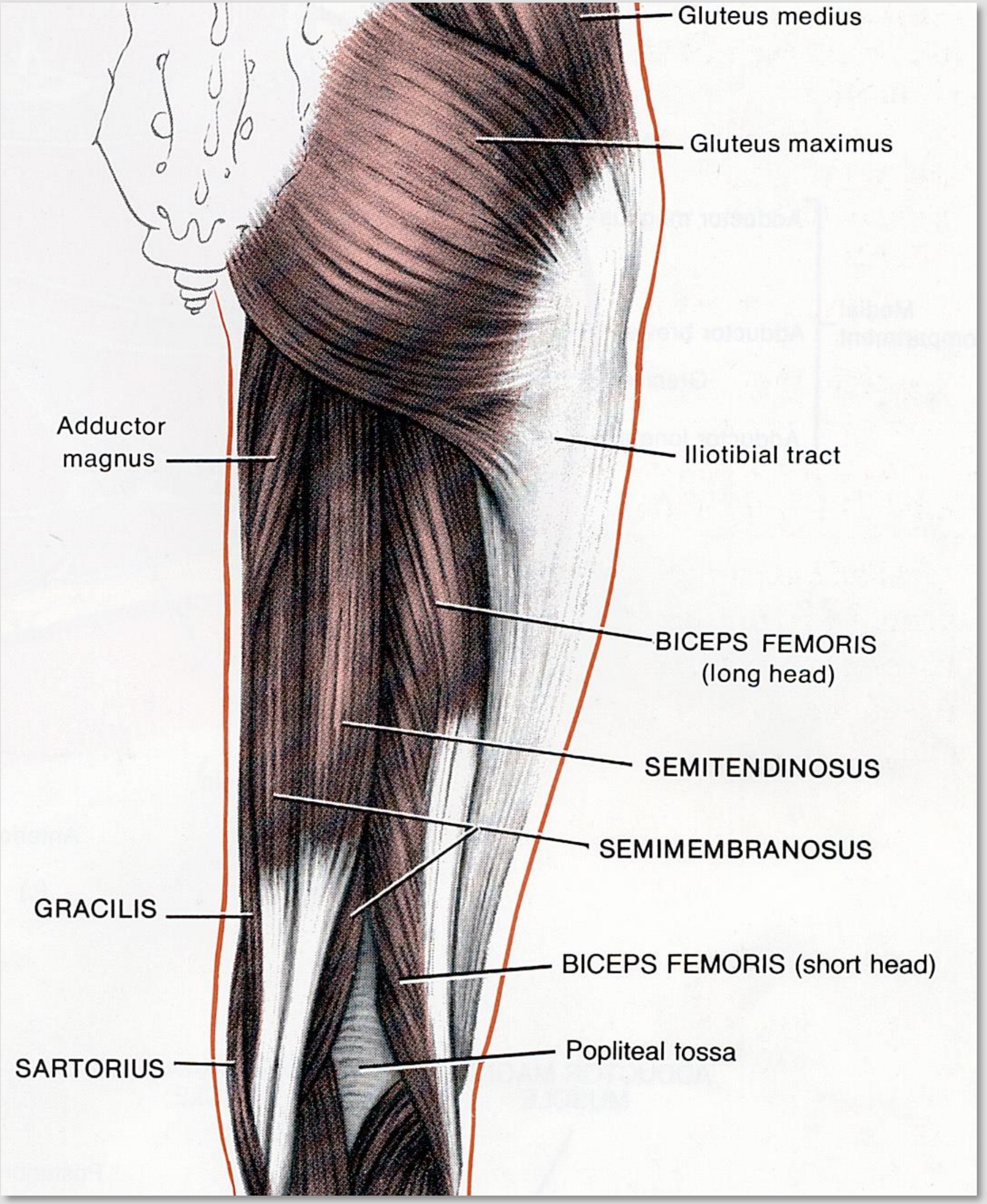
**Recovery Phase**
- Hip/knee flexion
- Ankle dorsiflexion
- Foot swings back to start

**Trunk & Core**
- Maintain upright posture and prevent sliding forward
- Provide a stable base to transfer force from LEs into chair movement

**Efficiency**
- Motion is alternating (like walking in place)
- Efficiency depends on seat height (low enough for foot contact, high enough for clearance) and smooth coordination of hip–knee–ankle movement

# IMPACT OF THE LOWER EXTREMITIES

- Strongly influence pelvic mobility
- Example: Tight hamstrings
  - Affect the amount of isolated hip flexion
  - May promote sacral sitting
- MUST be considered for back support selection



# OPTIMAL POSITIONING

- SEAT DEPTH
  - Maximize posterior thigh support
  - Allow for optimal power & recovery phases
  - Posterior buttocks to popliteal fossa minus 1-2”
- SEAT TO FLOOR HEIGHT (STFH)
  - Lowering STFH improves propulsion speed and reduces effort
  - Finished front STFH 1-2” lower than lower leg length
    - Compensates for the extra distance needed to achieve heel strike

# OPTIMAL POSITIONING

- ANTERIOR SEAT SLOPE
  - 3-6°
    - ➔ 1-2” on an 18” seat depth
  - Pair with optimal support surface
    - Reduce risk of posterior pelvic tilt
    - Minimize increased pressure on coccyx & ITs

$$\text{Seat Slope (degrees)} = \arctan\left(\frac{Hr - Hf}{D}\right)$$

# POSTERIOR V. ANTERIOR SEAT SLOPE

| Posterior Seat Slope | Anterior Seat Slope |
|---|---|
| • Elevates knees and shifts pelvis rearward<br>• Reduces foot contact on the ground | • Facilitates better foot/ground contact |
| • Increases risk of forward sliding | • Improves postural alignment |
| • Limits hip and knee ROM | • Enhances propulsion mechanics |
| • Compromises postural stability<br>  • Posterior pelvic tilt → kyphosis | • Reduces forward sliding and sheer |
| • Reduces propulsion efficiency<br>  • Increased energy expenditure | |

# PRACTICAL APPLICATION

- LIMITATIONS TO ACHIEVING OPTIMAL POSITIONING
  - Transfer height
  - Environment
    - Environmental surface too high (tables, counters, etc.)
    - Ground clearance of footplates
  - Positioning with footplates
  - Seating surface heights

# PRACTICAL APPLICATION

- TROUBLE SHOOTING
  - Center of Gravity
    - Common mistake is placing COG in a rearward position
      - Arms not being used
      - Age biased
      - Increases weight on the casters decreasing efficiency
  - Modify rear wheel size as needed
    - Larger diameter wheel facilitates maneuverability
    - Smaller diameter wheel can accommodate lower STFHs
  - Footwear
  - Backwards
    - Larger muscles used for power phase

# WHEELCHAIR MODEL CONSIDERATIONS

## FRAME

- Can you achieve optimal STFH
  - Consider future adjustment up or down
- Removeable hangers
- Will they be a dependent user in the future

## VERTICAL ADJUSTABILITY

- Can you achieve optimal STFH
- Increments for modification
- 1", 0.5", ¼", infinite

## HORIZONTAL ADJUSTABILITY

- How far forward can it go
- Increments for modification
- 1", 0.5", ¼", infinite

## CASTERS & REAR WHEELS

- Will dictate STFHs
- Will impact maneuverability

## SEATING SYSTEM

- Seat cushion: sufficient buttock well, pre-ischial shelf, cover considerations
- Back support: PSIS support

# OTHER PROPULSION STYLES

Motion U

# HEMI PROPULSION

*https://youtu.be/kQ3cvQNuCPQ?si=2qbBFDHI_1D3pEbt*

*https://youtu.be/4WAlixzQRT4?si=ZVz5MKbVrsbS-Y4y*

# HEMI PROPULSION

# HEMI PROPULSION

## WHAT IS IT?

- To propel using one hand and one foot, typically on one side of the body

## POPULATION

- Often hemiplegia, paralysis or weakness on one side of the body

## RESEARCH

- Similar movement patterns are seen in able-bodied and wheelchair users

## OPTIMAL POSITIONING

- Utilizing principles from both arm and foot propulsion

## LIMITATIONS

- There is always a compromise between upper and lower extremity set-up
- Propulsion efficiency is often slower and more fatiguing

## TROUBLESHOOTING

- When compromising – favour the stronger extremity

## WHEELCHAIR

- Removeable hangers
- One arm drive
- Wheel lock extension/Unilateral wheel-lock
- Pay attention to asymmetrical seating needs: Trunk/core fatigue is common due to high stabilization demand
- Handrim – because of only using one hand

## TRAINING

- Apply both principles of arm and foot propulsion training

# DEPENDENT PROPULSION


*https://www.youtube.com/watch?v=QIeLHZ7djj0*

# DEPENDENT PROPULSION

## WHAT IS IT?

- When a caregiver/attendant propels the wheelchair

## POPULATION

- User who is unable to achieve a successful or efficient propulsions stroke with upper or lower extremities

## WHEELCHAIR

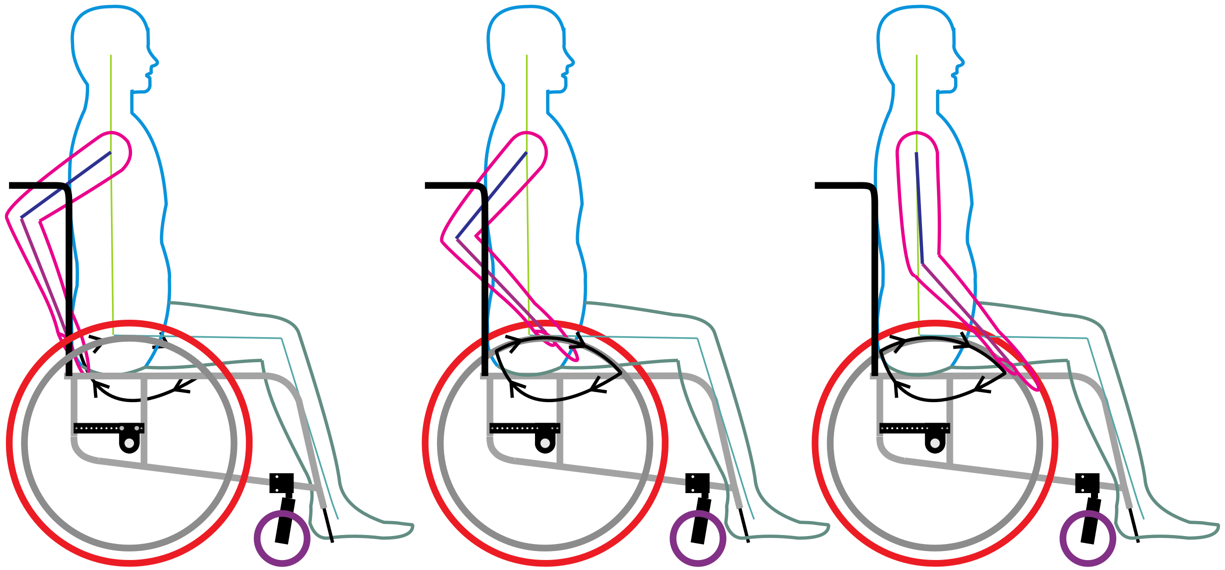
- Attendant wheel lock
- Wheel size can enhance or limit maneuverability
- Ensure optimal seated posture
- Center of Gravity
  - Efficient propulsion for attendant
  - Smaller wheelbase for maneuverability
- Appropriate height/style of push handles across all caregivers

## TRAINING

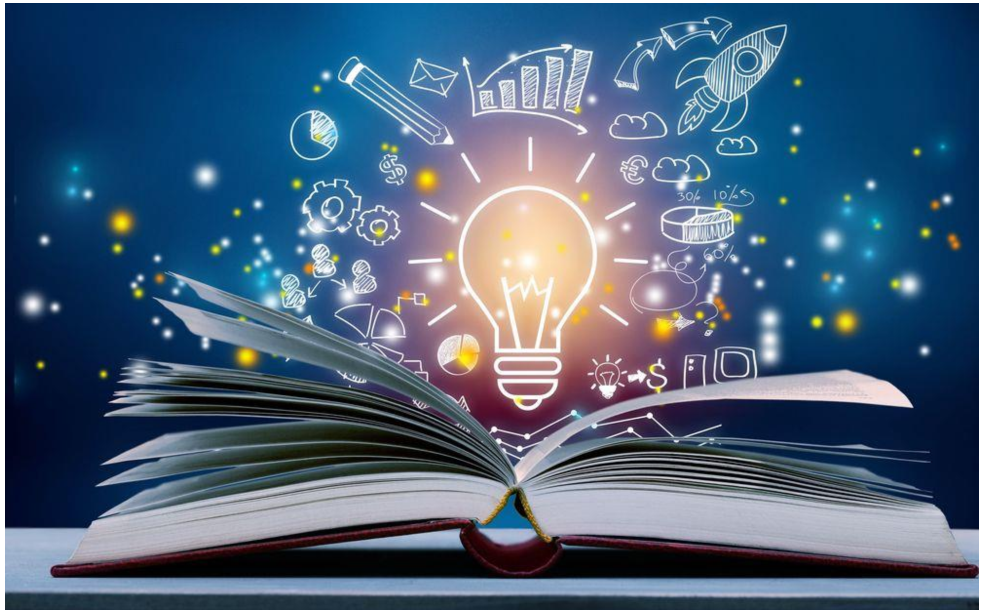
- Assess caregiver(s) propelling user within the wheelchair

# PROPULSION TRAINING

- **TEACH PROPULSION STYLE**
- Educate on risks of propulsion styles
- Assess overall WC Skills
  - Level surfaces
  - Up/down ramps
  - Carpet
  - Turning
  - Wheelies



# WHAT YOU NEED TO KNOW



- You do have to teach the most efficient pattern
  - Just because they move does not mean it is the best way
  - Practice yourself
  - Be creative; people learn differently
- Experienced users will self-select the most advantageous pattern in difficult situations (i.e., ramps)
- Consider a propulsion training in plan of care

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# WHEELCHAIR PROPULSION TEST

**Wheelchair Propulsion Test (WPT)© Version 1.0 Form**

Subject # : ____________________. Date: ___________. Time: ___________Test # ___

| Recorded Data* | |
|---|---|
| 1. Able to successfully complete the 10m distance? | Yes ☐ No ☐ |
| 2. Direction of travel | Forward ☐ Backward ☐ |
| 3. Limbs contributing to propulsion, steering or braking (tick all that apply) | Left: Hand ☐ Leg ☐<br>Right: Hand ☐ Leg ☐ |
| 4. Limb monitored for timing propulsion cycles (tick one limb) | Left: Hand ☐ Leg ☐<br>Right: Hand ☐ Leg ☐ |
| 5. Time (to nearest second) | _______ s |
| 6. Total number of propulsive cycles (to nearest full cycle) | _______ cycles |
| 7. If using one or more hands for propulsion in the forward direction, during the *contact phases*, did the subject generally begin the contact between the hands and the hand-rims behind the top dead center of the rear wheel? | Yes ☐ No ☐<br>Not applicable ☐ |
| 8. If using one or more hands for propulsion in the forward direction, during the *recovery phases*, did the subject generally use a path of the hands that was predominantly beneath the hand-rims? | Yes ☐ No ☐<br>Not applicable ☐ |
| 9. If using one or more *feet for propulsion* and going forward, did the subject make initial foot contact with the knee flexed less than 90° from full extension and finish with the knee flexed more than 90° (or the opposite if going backward)? | Yes ☐ No ☐<br>Not applicable ☐ |
| 10. Comments: (e.g., position on seat, trunk and arm posture, hand grip, foot contact, consistency, need for training, footwear, equipment worn, wheelchair issues) | |

| Derived Wheelchair-Propulsion Data* | |
|---|---|
| 1. Speed: 10m / ______ # seconds = | ______ m/s |
| 2. Push frequency (cadence): _____ # cycles / ______ # seconds = | _____ cycles/s |
| 3. Effectiveness: 10m / _____ # cycles = | ______ m/cycle |

*Directions on next page.

Tester signature: ____________________ Tester name (print): ________________


| Derived Wheelchair-Propulsion Data* | |
|---|---|
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*Directions on next page.

Tester signature: ____________________ Tester name (print): ________________


Propulsion Test

https://wheelchairskillsprogram.ca/en/

# MAKING SENSE OF IT ALL

- Consider frame style carefully based on functional goals and abilities
- Pay attention to configuration details
- Integrate propulsion assessment & training into wheelchair service provision
- Identify concerns for follow up or further clinical intervention
- Provide your clients with the best opportunity for positive outcomes!

Handouts

# Thank You!

For more information contact:

Education@MotionComposites.com

# REFERENCES


- Bossuyt, F. M., Boninger, M. L., Cools, A., Hogaboom, N., Eriks-Hoogland, I., & Arnet, U. (2020). Changes in supraspinatus and biceps tendon thickness: influence of fatiguing propulsion in wheelchair users with spinal cord injury. Spinal Cord, 58(3), 324–333.https://doi.org/10.1038/s41393-019-0376-z
- Charbonneau R, Kirby RL, Thompson K. (2013). Manual wheelchair propulsion by people with hemiplegia: within-participant comparisons of forward versus backward techniques. Arch Phys Med Rehabil. 2013 Sep;94(9):1707-13. doi: 10.1016/j.apmr.2013.03.001. Epub 2013 Mar 13. PMID: 23500180.
- Hamstra, C. , Jones, D. (2025). Considerations When Working with the Geriatric Population. In M. Lange & J. Minkel (Eds.) Seating and Wheeled Mobility: A Clinical Resource Guide (2nd ed., pp. 493-514). Routledge. https://doi.org/10.4324/978100352637
- Heinrichs, N. D., Kirby, R. L., Smith, C., Russell, K. F. J., Theriault, C. J., & Doucette, S. P. (2021). Effect of seat height on manual wheelchair foot propulsion, a repeated-measures crossover study: Part 1 — wheeling forward on a smooth level surface. Disability and Rehabilitation: Assistive Technology, 16(8), 831–839. https://doi.org/10.1080/17483107.2020.1741036
- Heinrichs, N. D., Kirby, R. L., Smith, C., Russell, K. F. J., Theriault, C. J., & Doucette, S. P. (2022). Effect of seat height on manual wheelchair foot propulsion, a repeated-measures crossover study: part 2 – wheeling backward on a soft surface. Disability & Rehabilitation: Assistive Technology, 17(3), 325–330. https://doi.org/10.1080/17483107.2020.1782490
- Lange, M. L, & Minkel, J. (2025) *Seating and Wheeled Mobility : A Clinical Resource Guide*. Routledge, 2025.
- MacGillivray, M. K., Eng, J. J., Dean, E., & Sawatzky, B. J. (2020). Effects of Motor Skill-Based Training on Wheelchair Propulsion Biomechanics in Older Adults: A Randomized Controlled Trial. Archives of Physical Medicine and Rehabilitation, 101(1), 1–10. https://doi.org/10.1016/j.apmr.2019.07.017

# REFERENCES *continued*


- Tafner Curi, H., de Lima, J., & Chaves Ferretti, E. (2020). Factors related to propulsion efficiency in manual wheelchair users with paraplegia due to spinal cord injury. Brazilian Journal of Occupational Therapy / Cadernos Brasileiros de Terapia Ocupacional, 28(3), 999–1019. https://doi.org/10.4322/2526-8910.ctoAR1935
- da Silva Bertolaccini G, Sandnes FE, Medola FO, Gjøvaag T. (2022) Effect of Manual Wheelchair Type on Mobility Performance, Cardiorespiratory Responses, and Perceived Exertion. Rehabil Res Pract. 2022 Jun 11;2022:5554571. doi: 10.1155/2022/5554571. PMID: 35726217; PMCID: PMC9206577.
- Requejo PS, Furumasu J, Mulroy SJ. (2015). Evidence-Based Strategies for Preserving Mobility for Elderly and Aging Manual Wheelchair Users. Top Geriatr Rehabil. 2015 Jan-Mar;31(1):26-41. doi: 10.1097/TGR.0000000000000042. PMID: 26366040; PMCID: PMC4562294.
- Rehabilitation Engineering & Assistive Technology Society of North America [RESNA] (2022). Position on the Application of Ultralight Manual Wheelchairs [position paper]. Retrieved from: https://www.resna.org/Portals/0/Position%20Papers/RESNA%20Position%20on%20the%20Application%20of%20Ultralight%20Manual%20Wheelchairs.pdf?ver=D1H8hccXxkWkG6D73Gh6WA%3D%3D
- Soleymani, H., & Cowan, R. (2024). Relationship between rolling resistance, preferred speed, and manual wheelchair propulsion mechanics in non-disabled adults. Disability and Rehabilitation: Assistive Technology, 19(5), 1980–1991. https://doi.org/10.1080/17483107.2023.2239297