MAXIMIZING PROPULSION EFFICIENCY IN MANUAL WHEELCHAIRS:
PRACTICAL STRATEGIES

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ALPINE | OCTOBER 4, 2024

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FACULTY DISCLOSURE

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- Physical Therapist
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- Current Clinical Education Specialist, Motion Composites
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- Grew up in MO → MU Grad → GO CHIEFS & TIGERS
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GREETINGS FROM MOTION COMPOSITES
INDUSTRY AWARDS

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2014 2015 2016 2017 PROFIT 500 CANADA'S FASTEST-GROWING COMPANIES

2010 AWARD HARDING INNOVATIVE PRODUCT CSMC

2013 AWARD HARDING INNOVATIVE PRODUCT CSMC

2014 AWARD HARDING INNOVATIVE PRODUCT CSMC

2016 AWARD HARDING INNOVATIVE PRODUCT CSMC

mobility product award 2022

Motion Composites Wins 3 Mobility Product Awards 2022 - Motion Composites

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MOTION COMPOSITES
MISSION, VISION & VALUES

"LEAD THE EVOLUTION OF MOBILITY FOR BETTER LIVING"

"BECOME EVERYONE'S FAVORITE MOBILITY COMPANY BY OFFERING INNOVATIVE PRODUCTS AND THE MOST RESPONSIVE SERVICE"

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EVIDENCE BASED PRACTICE

OUR FOUNDATION

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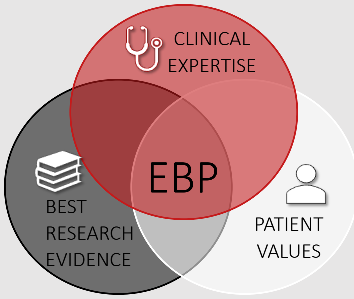

Integrating individual clinical expertise with the best available external clinical evidence from systematic research.
-David Sacket, 1996

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LEARNING OBJECTIVES

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

1. Differentiate three aspects of manual wheelchair design and configuration that will influence propulsion efficiency.
2. Analyze three key points of manual wheelchair configuration their impact propulsion efficiency.
3. Implement two techniques to assess manual wheelchair propulsion on level surfaces.

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WHAT IS PROPULSION EFFICIENCY?

- Propulsion
  - the action of driving or pushing forward
- Efficiency
  - (especially of a system or machine) achieving maximum productivity with minimum wasted effort or expense

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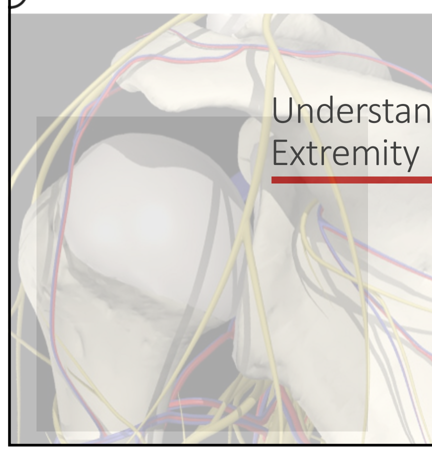

Understanding Upper Extremity Injury

What the evidence tells us:

- Shoulder pain prevalence in manual wheelchair users can be upwards of 70-100%
- Nearly 75% of paraplegics with shoulder pain were suffering from impingement syndrome
- Degree of pain/derangement/disability is directly proportional to age/time since injury
- Shoulders are not designed to be weight-bearing joints

Guidelines/Recommendations

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GUIDELINES & RECOMMENDATIONS

- The Consortium of Spinal Cord Medicine (2005): "Preservation of Upper Limb Function Following Spinal Cord Injury: A Clinical Practice Guideline for Healthcare Professionals."
- RESNA Position Paper (2022): The Application of Ultralight Manual Wheelchairs
- Sawatzky, B. et. al. "The Need for Updated Clinical Practice Guidelines for Preservation of Upper Extremities in Manual Wheelchair Users: A Position Paper." American Journal of Physical Medicine and Rehabilitation, 2014.
- Cowan, Rachel E. Et.al. Impact of surface type, wheelchair weight and Axle Position on Wheelchair Propulsion by Novice Older Adults. Archives, Physical Medicine and Rehabilitation, 2009 July. 90(7): 1076-1083.

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THE CLINICAL GOAL

- Maximize Function
- Maximize/Improve Quality of Life (QOL)
- Minimize fatigue during normal daily activities
- Delayed onset or prevention of UE injury/dysfunction

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CONSIDERATIONS FOR IMPROVING EFFICIENCY

MANUAL WHEELCHAIR SELECTION & TRAINING

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START WITH FRAME BASICS

FOLDING

- What most think of when they hear wheelchair, most common
- Typically, more weight
- More moving parts, less efficient
- Statistically chair of choice

RIGID

- Typically, lighter weight
- Rigidity improves efficiency
- More built-in adjustability
- More responsive to user input
- Easy to transport*

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FOLDING FRAME STYLE HAS AN IMPACT

- Rigidity = less flex/movement in a frame which is more energy efficient
- Components of the folding frame design:
  - 2 x side frames
  - 1 x cross brace
  - Attachment of the cross brace
  - Seat saddles
- What details do we want to look for?

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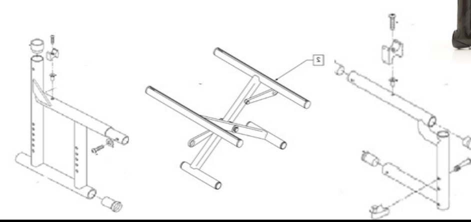
SIDE FRAMES

- Reduce potential for movement
- Less moving parts/bolts that loosen over time
- Lighter weight



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CROSS BRACE

- Distributes weight evenly over the seat
- Reduces or eliminates torsion in the frame (more rigid)

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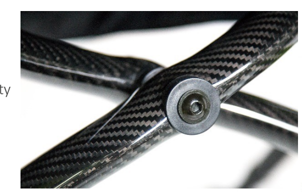
OTHER FRAME COMPONENTS

- Oversized cross brace axles
  - More surface area
  - Stiffens ride; increases frame stability
- Locking seat saddles
  - Increases rigidity
  - Increases overall seat stability



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CHAIR MATERIALS

Typical materials: aluminum, titanium, carbon fiber

Material choices impact:
- Weight
  - Impacts forces at UE during startup/stop & turning
  - May limit functional transport
- Frame flexion/stiffness
  - Increased frame movement means energy is lost
  - Ride characteristics are impacted by materials ability to impact vibration transmitted to user

Impact of material is based on material science and the construction of the frame

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CONSIDER OVERALL WEIGHT

Standard definitions have not kept up with technology
- US Medicare Definition of Ultralightweight = chair that weighs under 30 lbs. without wheels and has an adjustable COG

Folding vs. Rigid: impact of the cross brace

Every option weighs something:
- Armrests and brackets
- Anti-tips and brackets
- Push handles

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PARAMETERS OF WHEELCHAIR CONFIGURATION

ASSUMING APPROPRIATE FRAME DIMENSIONS

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IMPORTANCE OF REAR WHEEL POSITION

THE EVIDENCE

Research shows that vertical and horizontal wheel position one of the most important adjustments to minimize impact on the UE during propulsion

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- Rehabilitation Engineering & Assistive Technology Society of North America (RESNA). 2012. Position on the Application of Ultralight Manual Wheelchairs [position paper]. Retrieved from: RESNA: www.resna.org/resources/position_papers.dot
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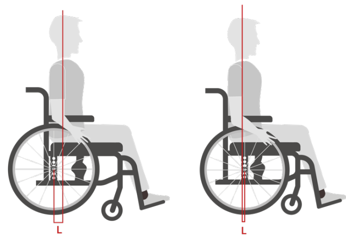
HORIZONTAL AXLE POSITION

- Move the rear axle as far forward as possible without compromising stability of the user
  - At or in front of the shoulder
  - Consider use of anti tips
  - Train clients in wheelies & fall recovery
- Axle position is USER Specific



REARWARD HORIZONTAL AXLE POSITION

OPTIMAL HORIZONTAL AXLE POSITION

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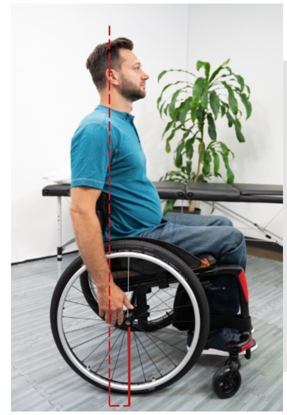
FORWARD AXLE POSITION



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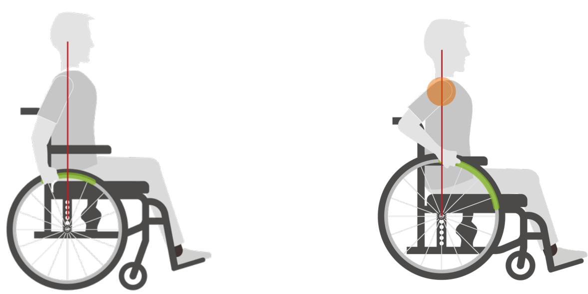
VERTICAL POSITION CHANGES



EXCESSIVELY LOW AXLE POSITION

Path of Propulsion

EXCESSIVELY HIGH AXLE POSITION

Path of Propulsion Shoulder Trauma

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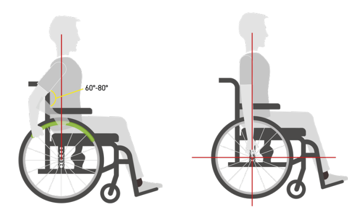
VERTICAL AXLE POSITION

- Angle between the arm and forearm between 100-120 degrees (60-80 degrees of elbow flexion) with hand on top of pushrim
- Middle finger touches the center of the axle with arms hanging
- Can be difficult to optimize with some clients
- Look for:
  - Limited shoulder elevation
  - Reduced extension
  - Decreased external rotation



POSITION TEST 2

Path of Propulsion

POSITION TEST 1

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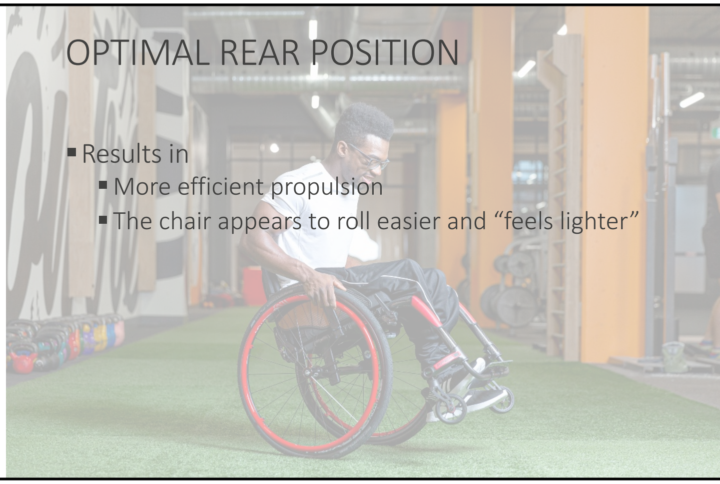

OPTIMAL REAR POSITION

- Results in
  - More efficient propulsion
  - The chair appears to roll easier and “feels lighter”

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REAR WHEEL SELECTION

Weight matters!

Stiffness = increased lateral stability; more efficiency?

Look at wheel movement during turns

Maintenance realities

Spoke wheels require little to no maintenance (user dependent)

Mag wheels warp over time

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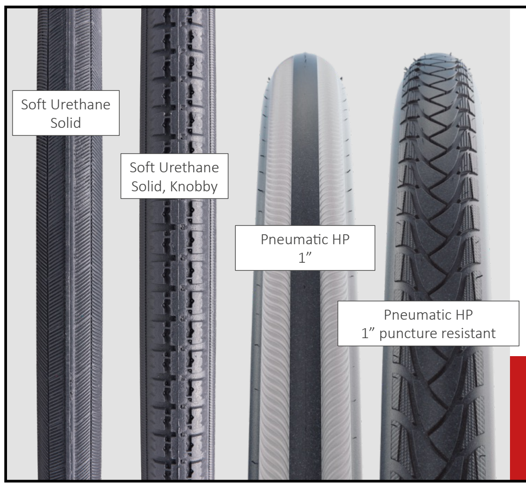

REAR TIRE SELECTION

- The evidence is clear: air filled tires are more efficient
  - At 50% of recommended inflation, an air-filled tire rolls with less resistance than a solid tire. (Sawatzky et. al.)
- The maintenance reality
  - Tires should be checked weekly
  - Inflation needed 1-2x per month
  - New tire technology is puncture resistant
- Educate your client
  - **Give them the responsibility & the choice**

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OTHER CONSIDERATIONS

- Front wheel (caster) selection
- Camber
- Handrims
- Seating and positioning options

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IMPORTANCE OF FUNCTIONAL TRAINING & EDUCATION

DON'T STOP WITH CONFIGURATION

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Education is Key!

- Educate caregivers and users
- Set expectations for equipment maintenance
- Teach proper set up and propulsion technique
  - Assess propulsion on initial evaluation
  - Identify deficiencies and establish plan of care
  - At delivery:
    - Maximize configuration and set up
    - Continue propulsion instruction

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PROPULSION TRAINING

- Identify type of propulsion stroke
- Educate on upper extremity preservation
- Assess overall WC Skills
  - Level surfaces
  - Up/down ramps
  - Carpet
  - Turning
  - Wheelies

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PROPULSION PATTERNS

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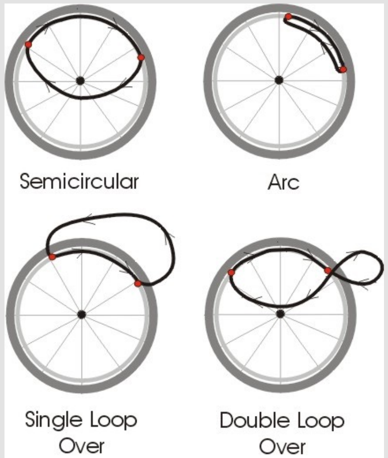
IDENTIFY PROPULSION PATTERNS

- Identify the current pattern
- Give instructions on most efficient movements
- Practice/re- evaluate
- QUESTION: Which propulsion method do you think is the most efficient for traveling across flat terrain?



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SINGLE LOOPING OVER PROPULSION

Single looping over propulsion: the hands rise above the hand rim during recovery phase

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DOUBLE LOOP OVER

Double looping over propulsion: the hands rise above the hand rim, then cross over and drop below the hand rim during the recovery phase.

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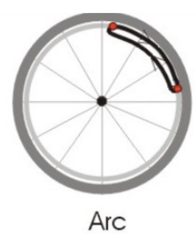
ARCING



Arcing: The third metacarpophalangeal (MP) follows an arc along the path of the hand rim during the recovery phase

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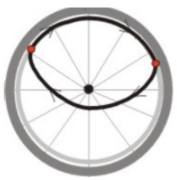
SEMICIRCULAR



Semicircular

Semicircular: the hands fall below the hand rim during recovery phase

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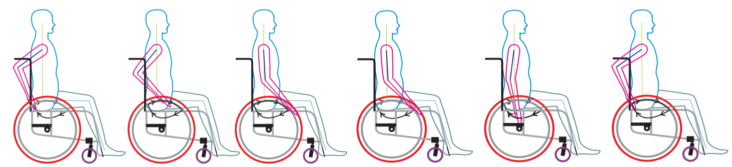
PROTOCOL

- 10 m on level surfaces
- 10 m on carpet
  - Count number of strokes
  - Determine velocity
  - Observe pattern
- Up ADA ramp
- Figure 8
- Wheelies



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WHAT YOU NEED TO KNOW

You do have to teach the most efficient pattern

- Don't assume they know 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 ☐ Right: Hand ☐ Leg ☐
4. Limb monitored for timing propulsion cycles (tick one limb)	Left: Hand ☐ Leg ☐ 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 ☐ 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 ☐ 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 ☐ 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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3. Effectiveness: 10m / _____ # cycles =	_______ m/cycle

*Directions on next page.

Tester signature: ____________________ Tester name (print): _________________

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INTEGRATING INTO CLINICAL PRACTICE

BACK TO REALITY

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CONSIDER CLIENT SPECIFIC INDICATIONS

- History of UE pain/dysfunction
- Reports of fatigue during the day
- Decline in independent mobility
- Diagnosis driven changes in function
- Caregiver abilities and needs*

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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 delivery process
- Identify indications for follow up or further clinical intervention
- Provide your clients with the best opportunity for positive outcomes!

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KEYS TO OPTIMIZING PROPULSION

1. FRAME SELECTION
2. PROPULSION TRAINING
3. CONFIGURATION

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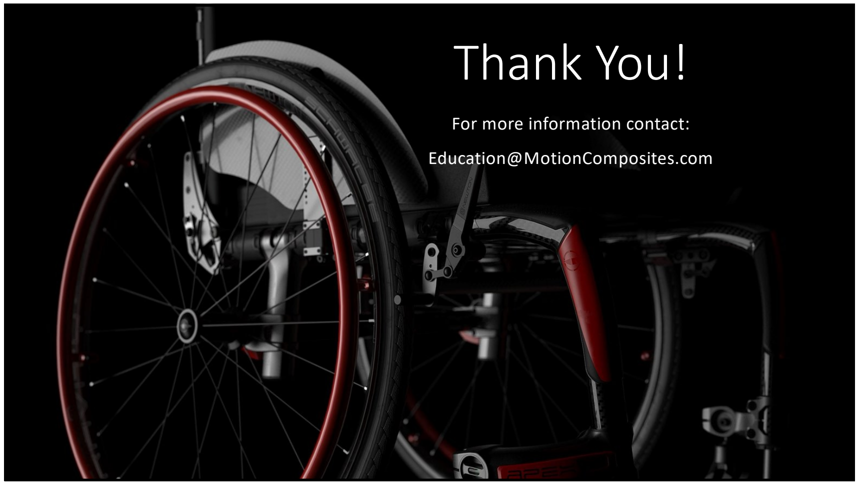

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RESOURCES

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RESOURCES

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