**How Do People Actually Use Their Manual Wheelchairs, and What Really Matters?**

**What Does A Wheelchair User Really Want?**

To a manual wheelchair user, a high-performance machine = a high \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ machine

How Do We Measure Efficiency?

“Work” required can be used as measure of efficiency

When a **force** causes a body to move, work is being done on the object by the force.

**Work** is the measure of energy transfer when a force (*F*) moves an object through a distance (*d*).

Formula for work Work = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ X \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Machines**

Six Types of Simple Machines - even complex machines are composed of a combination of simple machines

A machine can make a tough job easier

A wheelchair is a wheel and axle machine -that provides a mechanical advantage -to make mobility easier

The most efficient machine results in the least amount of work

**Mechanics of a Wheelchair**

When we consider mechanical system level performance of a wheelchair, we are concerned with:

**Factors that influence propulsion effort:**

**Inertia** – a body at rest tends to stay at rest, and a body in motion tends to stay in motion (in a straight line) –

unless \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

3 Types of Inertia

1-Translational – straight line across a surface

2-Rotational – associated with a rotating wheel

3-Turning/Yaw – the resistance of something moving in a straight line to a force compelling it to turn left or right – wants to continue in a straight-line motion and must have a force exerted to ‘make’ it turn.

Inertia is impacted by: Mass - the amount of matter in something, commonly referred to as ‘weight’.

**Friction** - the resistance that one surface or object encounters when moving over another

2 Types of Frictional energy losses for a wheelchair

1-Rolling Resistance – the frictional force that slows down a rolling wheel

2-Scrub - the frictional force that occurs at the tire-surface interface during turning

Feel it – press the ball of your foot/shoe into the floor, and spin your foot

Friction is ever present - we need friction to move about, but how much is too much?

Two components involved in propelling a wheelchair: the wheelchair + the human operator

**Wheelchair Machine Factors**

The wheelchair as a machine has an inherent mechanical efficiency, and there is nothing that the user can do to improve it – only detract from its efficiency

**What factors might affect the inherent efficiency of this machine?**

1- **Mass**: The total mass/weight *of the wheelchair* and its components **excluding** the end user

NOT system mass: the total mass/weight of the wheelchair and its components **including** the end user

2-**Wheels and Tires**:

The characteristics of the selected drive wheels and caster wheels, bearings and tires.

For example: inflation/pressure, diameter, width, stiffness/durometer, bearing efficiency, tread, shape

3-**Wheelbase**: The position of the drive wheels and caster wheels including their ability to be adjusted.

CG adjustment and weight distribution

-CG adjustment is a reflection of the placement of the center of gravity (system mass) over the rear wheels

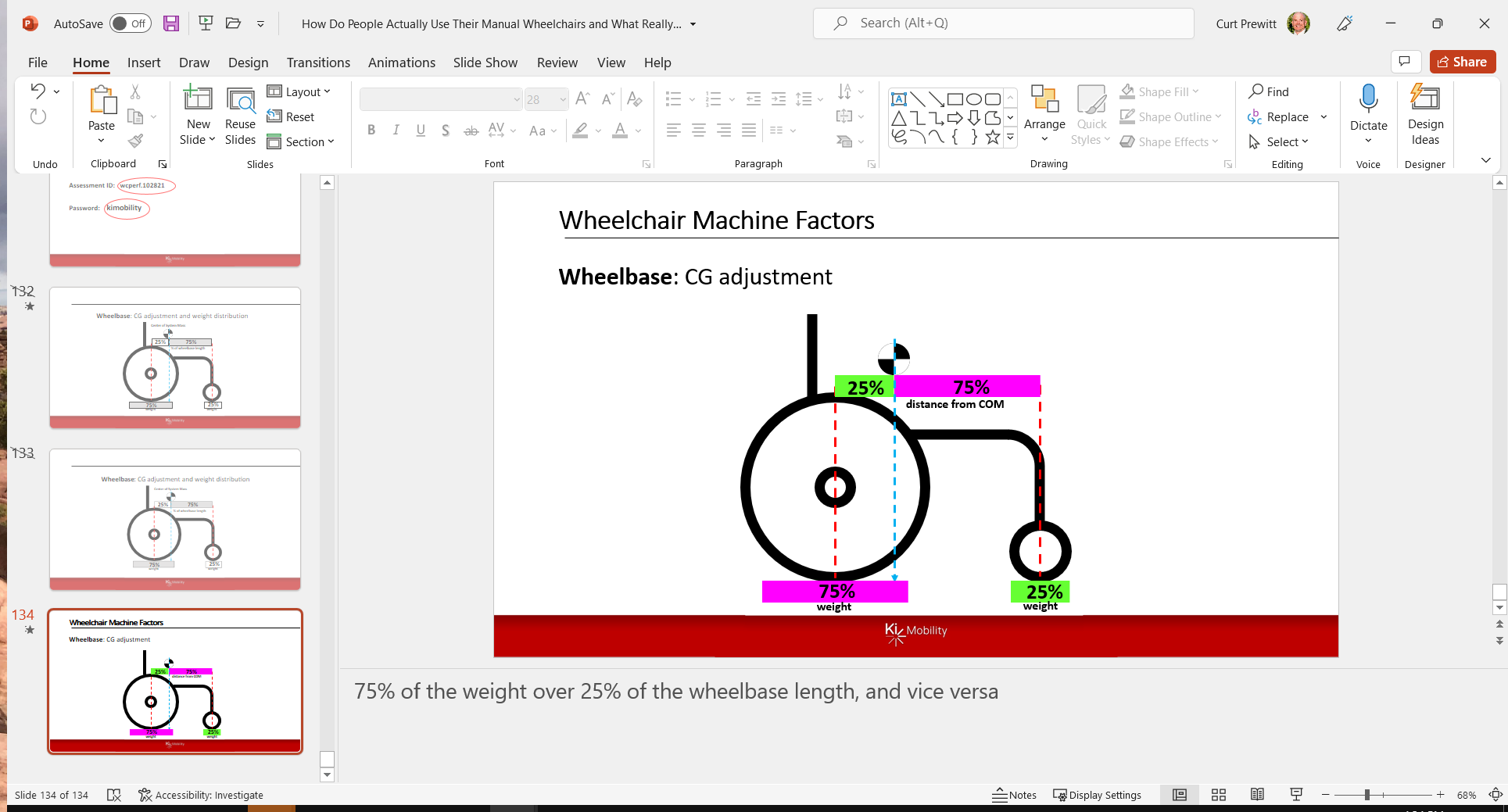
-CG is placement of the rear wheel axle, forward or back, and will relate to user stability/balance.

Weight distribution is a reflection of where the center of gravity is placed relative to the distance between the rear wheels and the casters (this is wheelbase). It can relate to the fore/aft placement of the rear wheel axle, **or** placement/adjustment of the front wheels.

Formula for weight distribution:

With a vertical line from the center of system mass (wheelchair and user combined) to the floor, the distance forward of that line, *as a percentage of the wheelbase* (horizontal distance from center of rear wheel to center of front wheel) is inversely proportional to the *percentage of system mass* (weight) over the rear axle, and vice versa.

For example, with a 75% weight distribution, 25% of the length of the wheelbase is behind the vertical line of the center of system mass (i.e. 75% of the weight is over the rearward 25% of the wheelbase), and 75% of the length of the wheelbase is forward of the vertical line from center of system mass, with 25% of the weight over it.



4-**Design**: The characteristics of the frame and components excluding the wheels and tires *as prescribed*.

Includes the materials and how they were used to make the wheelchair.

One characteristic of design is flexure – any ‘flex’ or give in a wheelchair is lost propulsion energy

**Complexity of Research on wheelchair propulsion cost**

Having the 2 components involved in wheelchair propulsion, the wheelchair + the operator, makes research on propulsion cost difficult, due to the inconsistent human operator

**Research Complexity Solved**

Anatomical Model Propulsion System (AMPS)

Wheelchair propelling robot; Mimics human weight distribution

Allow propulsion torque repeatability without the inconsistency of a human operator involved

**Research Study:** Impact of Mass and Weight Distribution; Sprigle and Huang, 2015 (AMPS study)

MWC propelling robot; measured propulsion torque costs

**Results:**

**Acceleration:**

Straight: System Mass change of 12.3 lb had a greater influence during acceleration

(wheelchair mass difference in the ultralightweight category are ounces, or 1 or 2 pounds – not 12+ pounds)

Turning: Weight distribution > impact than adding 12.3 lb, muted on carpet

**Steady State:**

Straight: Weight distribution > impact than adding 12.3 lb

Turning: Weight distribution > influence than adding 12.3 lb , muted on carpet

**Research Study:** Manual Wheelchair Use: Bouts of Mobility; Sonenblum, Sprigle and Lopez, 2012

28 Adults who use MWC for primary mobility; data logger on MWC to record movement activity

**Results:**

Mean Daily Use

1.95 km (~1.2mi); 58 min/day; 96 bouts/day; 63% of bouts <30sec, <13m, <.5m/s

In other words, they don’t go far, they don’t go fast, but they do turn a lot.

**Research Study:** Influence of Operator & Wheelchair Factors; Lin and Sprigle, 2019

Looked at WC factors of System Mass (WC + person), Weight Distribution, Frictional Loss in straight & turns

Operator Factors of Shoulder Position, Aerobic Capacity, Propulsion Strength

**Results:**

Weight Distribution was the Only significant contributor within wheelchair factors

Shoulder Position was the Only significant contributor within operator factors

**Research Study:** Measurement of Rolling Resistance and Scrub; Sprigle, Huang and Misch, 2019

Rolling resistance and scrub torque measured on a wide variety of drive wheels and casters

On different surfaces and different applied loads

**Results**:

There is no perfect caster for all surfaces.

Shifting more load onto the drive wheels is the most effective means of reducing resistance

**Lifting, Can Users Determine Difference in Mass?**

wheelchair users were asked to lift chairs with different masses onto a plinth, or load into a vehicle

They could not reliably tell the difference of a 1kg (2.2 lb) difference in chairs

If all things are equal, shouldn’t you choose the lightest chair?

Yes, But, to be equal they would have to be

-The same design (same size, same model, same specifications/same components, etc.)

-The same wheelbase and weight distribution

-The same wheels and tires

**Take Away**

Role of Clinician and ATP:

To work with user to identify and prioritize seating & mobility needs for the INDIVIDUAL!

Needs could include:

Postural Stability

Correction or Accommodation of Asymmetries

Pain/Sitting tolerance

Skin Protection

Durability

Ease of Transport

Environment of Use…

**Take Away**

What Would Lead You to Choose One Ultra-Lightweight Wheelchair Frame Over Another?

Unique features, component choices

or

Adjustability – of Wheelbase, of Seat Angle, of Back Angle

**Wheelchair Machine Factors** - - What can we do to affect the inherent efficiency of this machine?

**What Really Matters?**

Based on what we know right now,

1 Weight Distribution – Critical

2 Wheel & Tire Selection – Definitely Important

3 Design – More research needed, but less so than 1&2

4 Mass - More research needed, but less so than 1&2

Extra work required to propel a MWC with 1 lb added to mass = 2L bottle floor to table \_\_\_x/day

-To propel a MWC with soft roll caster instead of 5” std caster = 2L bottle floor to table \_\_\_x/day

More research is ongoing. Stay tuned for more. . .