Optimizing a Wheelchair

Taking Advantage of the Technology to Get Best Outcomes, Now and In the Future

PRESENTED BY

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Ki Mobility
Better by Design

Manual Wheelchairs: The Science that Should Be Driving Your Clinical Choices

This Presentation is Part of a Series

1. How Do People Actually Use Their Manual Wheelchairs, and What Really Matters?
2. The Impact of Wheels and Tires on Wheelchair Propulsion Efficiency
3. Optimizing a Wheelchair: Using the Technology to Ensure Ongoing Success

Why are we tackling this subject matter?

Manual wheelchair evaluation and prescription is complex

requires understanding the wheelchair and the factors that impact its performance, the user and the factors that impact user function, as well as the interaction between the user and the wheelchair.

Evidence-Based Practice

What is Evidence-Based Practice?

Evidence-Based Practice

"Evidence-based medicine is the integration of best research evidence with clinical expertise and patient values"

(Sackett, 1996)

A philosophy of providing health care that is guided by the integration of client factors and values, clinical expertise and best available research evidence.

Evidence-Based Practice

"Evidence-based medicine is the integration of best research evidence with clinical expertise and patient values"

(Sackett, 1996)

EBP lives at the intersection of client factors & perspectives, clinical expertise, and best research evidence

Evidence-Based Practice

Client Factors and Perspectives

Values, Priorities, Expectations

- Efficiency of Propulsion
- Postural Stability
- Correction or Accommodation of Asymmetries
- Pain/Sitting tolerance
- Skin Protection
- Durability
- Ease of Transport
- Accommodate Environment of Use

Unique to each individual, based on their personal and cultural circumstances

Often individuals come to us with a similar list of concerns, but their goals and priorities are UNIQUE based on their view of:

Illness, disease, and their causes; their health practices, behaviors, and choices; their family structure and key decision makers,

Evidence-Based Practice

Clinical Expertise

"…we mean the proficiency and judgment that individual clinicians acquire
through clinical experience and clinical practice."
(Sackett, 1996)

Includes requisite knowledge based on:

- Education
- Experience
- Shared encounters
- External clinical evidence from systematic research

What do we mean by clinical expertise? accumulation of information that is available to draw on when we make clinical decisions

Evidence-Based Practice

Clinical Expertise

Requisite knowledge must be kept current

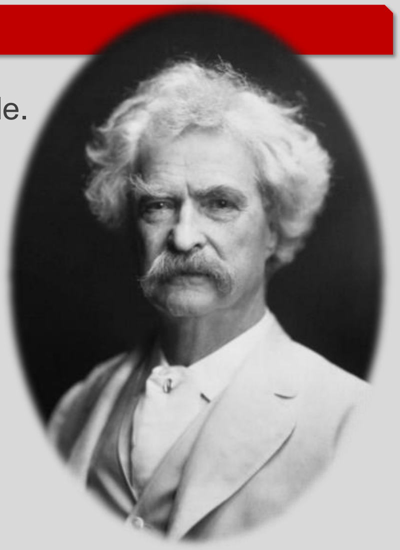
“Tribal knowledge” passed down may not be supported by scientific evidence

Evidence-Based Practice

Clinical Expertise

"It ain't what you don't know that gets you into trouble. It's what you know for sure that just ain't so."

-Mark Twain



need to validate the information we use to make clinical decisions

Evidence-Based Practice

Best Research Evidence

Current

Stand up to critical appraisal

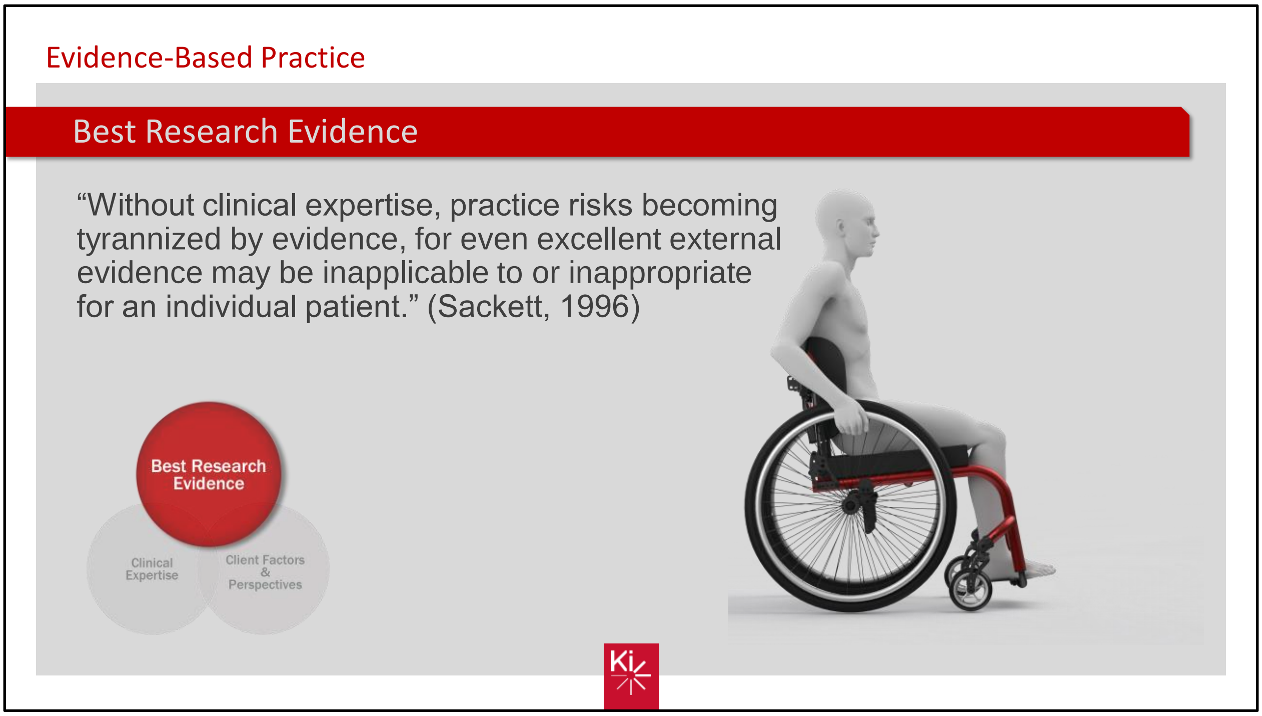
Answer clinical question

Combine with clinical expertise

Current: on average it takes 17 years for research evidence to reach clinical practice

there is bad research out there, need to be able to recognize

needs to answer the clinical question we are asking and be looked at through the lens of our clinical expertise



Even Sacket, a pioneer of EBP, stressed that evidence in the wrong context can result in poor clinical decisions

Evidence-Based Practice

Best Research Evidence

"Without clinical expertise, practice risks becoming tyrannized by evidence, for even excellent external evidence may be inapplicable to or inappropriate for an individual patient." (Sackett, 1996)

For example, if we just put as much of the system weight over the rear wheels as we can, because research says this is a good way to improve propulsion efficiency, but we don't consider whether this is a SAFE thing to do, we could wind up with a problem. . . This is why research evidence must be combined with client factors and clinical expertise

Wheelchair Machine

A Wheelchair is a Machine

It provides a mechanical advantage to make mobility easier

In our first presentation we discussed that a wheelchair is a machine that provides a mechanical advantage to make mobility easier for the user

Wheelchair Machine

The wheelchair as a machine has an inherent mechanical efficiency

- There is nothing that the user, ***in the act of propelling it***, can do to improve it

We discussed that as a machine, each wheelchair has an inherent mechanical efficiency

Wheelchair Machine

What can be done to affect the inherent efficiency of this machine?

- Wheelbase Adjustment
- Wheel and Tire selection
- Seating Adjustment

We identified 3 factors that do impact the efficiency of a wheelchair, and therefore predict performance

Wheelchair Machine

What can be done to affect the inherent efficiency of this machine?

- **Wheelbase Adjustment**
- Wheel and Tire selection
- Seating Adjustment

However, we've previously identified some factors that can improve the efficiency of the machine
The first presentation focused on what research has identified as the most impactful of those factors: Wheelbase adjustment, which we will be discussing today

Wheelchair Machine

What can be done to affect the inherent efficiency of this machine?

- Wheelbase Adjustment
- **Wheel and Tire selection**
- Seating Adjustment

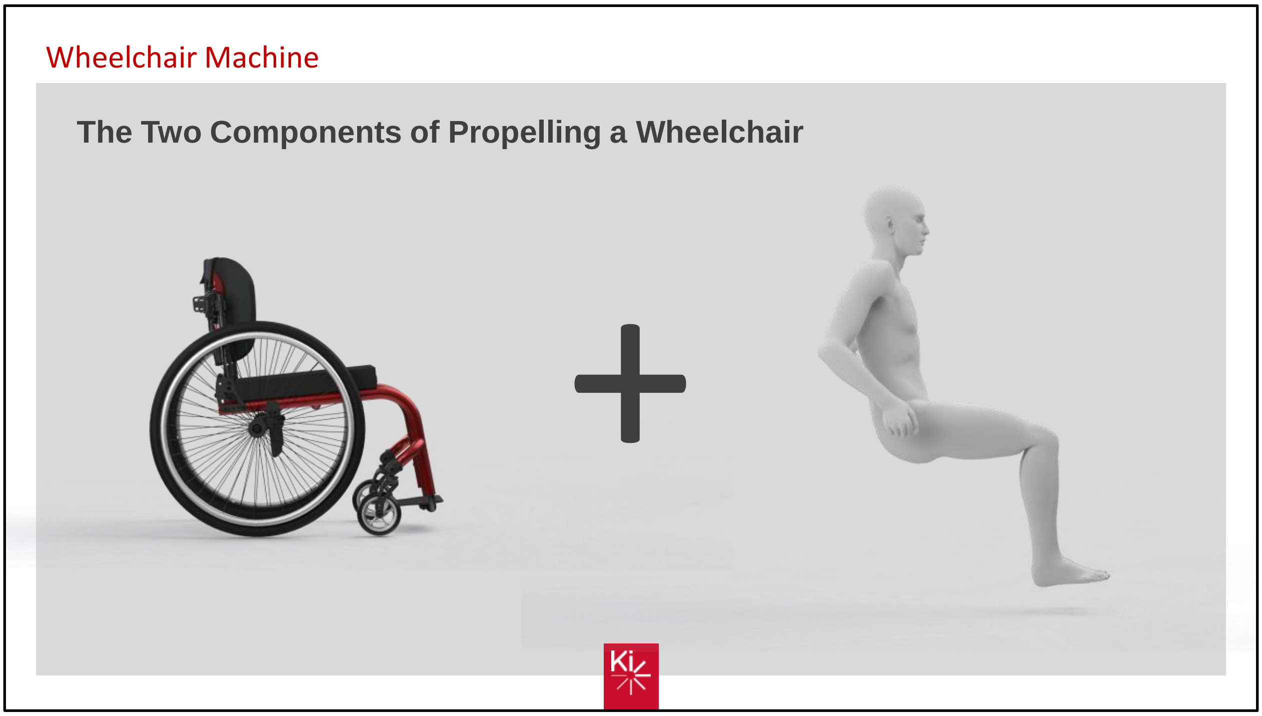
The second presentation of the series focused on the impact of wheel and tire selection

Wheelchair Machine

What can be done to affect the inherent efficiency of this machine?

- Wheelbase Adjustment
- Wheel and Tire selection
- **Seating Adjustment**

Today we are discussing the optimal set up of an individual wheelchair, taking into consideration the needs and capabilities of the user.



The first two presentations of this set focused on the wheelchair as a machine,

But, there are two components to propelling the wheelchair – the chair, and the user

The impact of the issues like wheelbase, and wheel and tire selection must be considered in the context of each individual user, so today's presentation is going to flip the script. . .

Wheelchair Machine

Today's presentation is going to flip the script, and look at the user. . . in relation to the wheelchair. In other words, how do we optimally set up the machine to match the USER's needs?

Role of the Wheelchair for the User

Dissatisfaction and Abandonment of Wheelchairs

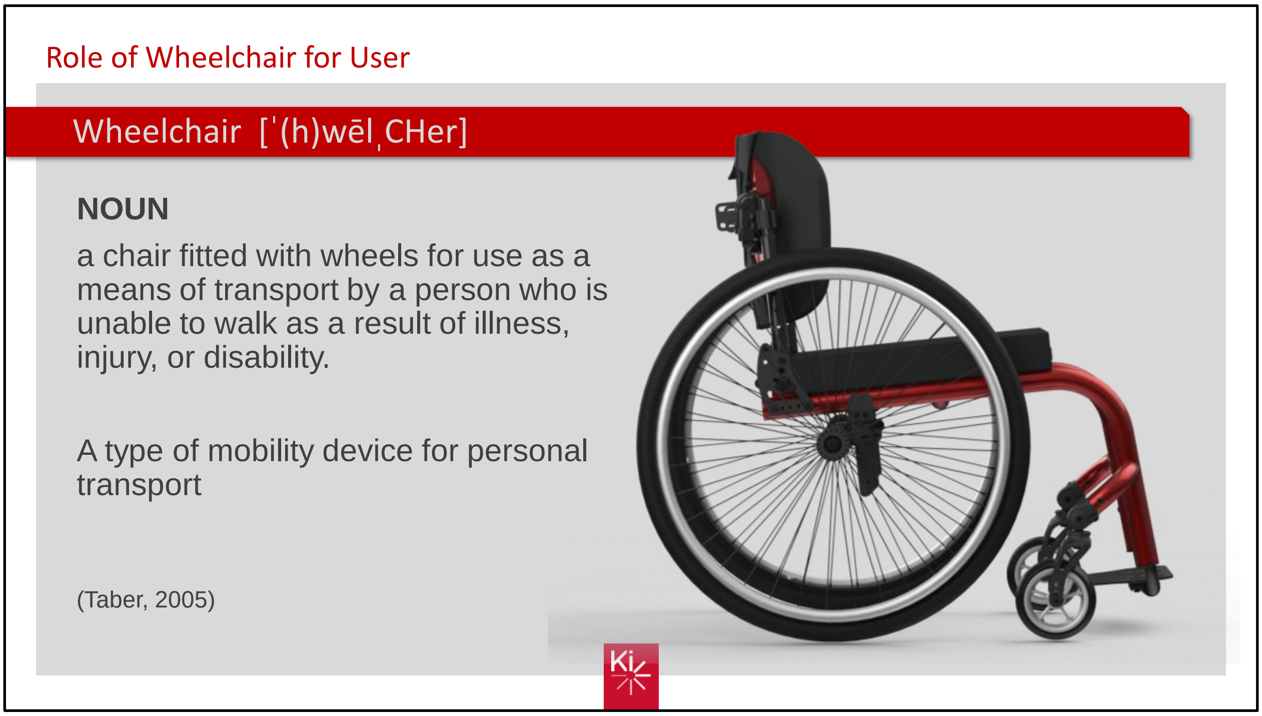
Dissatisfaction with, abandonment of, mobility equipment is high

Why?

- Lack of user opinion in selection (Phillips & Zhao, 2010)
- Improper fit to the user and to tasks the user wishes to undertake (Scherer & Galvin, 1996)
- Myth that "a user's assistive technology requirements need to be assessed just once" (Scherer & Galvin, 1996)

What can we do to address it?

Why do we need to consider the user? We've already discussed that setting up the MWC is a complex task.
Historically, there is evidence that as an industry there is room for improvement-
we may not have always done a good job of employing the principles of EBP



There’s a lot we can do to address this dissatisfaction, but first, let’s consider that even the definition of wheelchair calls it a mobility device, a means of transport.

We need to broaden the definition of the role that the chair plays for a user, because so often there is a tendency to view a wheelchair primarily as a mobility device.

This is a definition from a medical dictionary, and it says nothing about function or participation. . .

All this contributes to a focus on the propulsion of the device, particularly in the ULWC class of chairs. Even reimbursement coding often refers to the chair by its weight, not by configurability or adjustability, and this can set a tone for how they’re perceived.

Lightweight; high-strength lightweight; Ultralightweight; (Heavy Duty or Extra Heavy Duty speak to mass of the user)

Role of Wheelchair for User

Hold on - I am not suggesting that we should ignore the role of the wheelchair as a mobility device - - We need to ensure that everyone involved in the prescription process is fully considering the larger context of use – not JUST mobility.

Role of Wheelchair for User

(Sonenblum, Sprigle, & Lopez, 2012)

With that in mind, we need to focus on how people use their manual wheelchairs.
Consider a study done on how users move about in their chairs in everyday life
Researchers used a data logger to monitor subject activity

discovered that users were in movement only about 10% of the time in their chairs (58 min out of 10 hours up in chair)

doesn't mean that they're not involved in any activity the other 90% of the time. They are functioning, doing tasks, etc. They need it to work when they're mobile, but they also need it to work for all the rest of the function they do when they're not propelling. . .

Methods:
28 Adults who use MWC for primary mobility, Age Range: 22-67 y/o, 27 ULW/1 standard MWC User Years: Average 9 yr. (1.5-36 yrs.), Data logger

on wheelchair to record movement activity

Role of Wheelchair for User

Individuals who use wheelchairs do much more than propel from wheelchair

- For many, it is the position from which they perform all ADLs

We need to take into consideration all of the other activities user does from the chair. Understand the activities, the environment in which they need to do them, their goals and expectations, etc. Should sound familiar – it’s Evidence Based Practice. . .

Role of the Wheelchair for the User

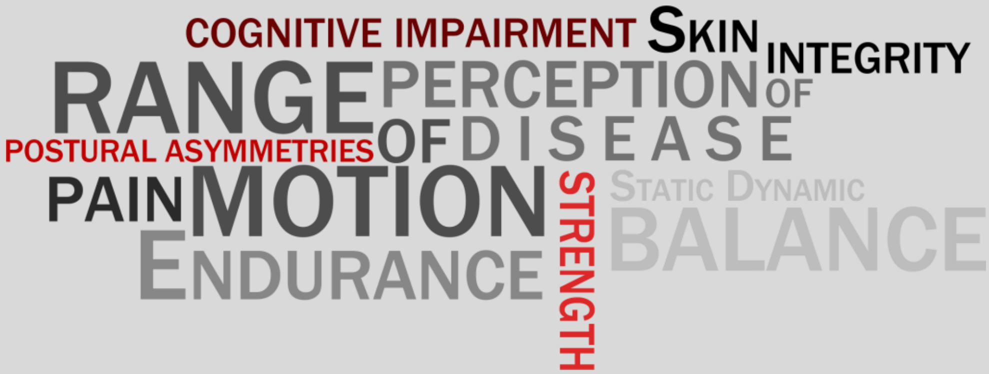
How Do We Approach the Prescription Process?

1. Body Function & Structure
2. Activity & Participation
3. Environmental & Personal Factors

So, where do we start?

How Do We Approach the Prescription Process?

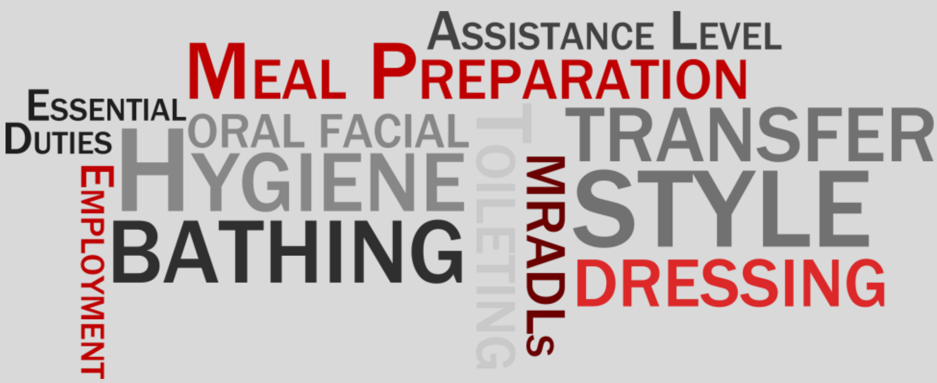
Body Function & Structure



In addition to the primary disease, illness, or injury we need to consider… all these things listed – as well as their potential for functional improvement, or decline, in each of these areas

How Do We Approach the Prescription Process?

Activity & Participation



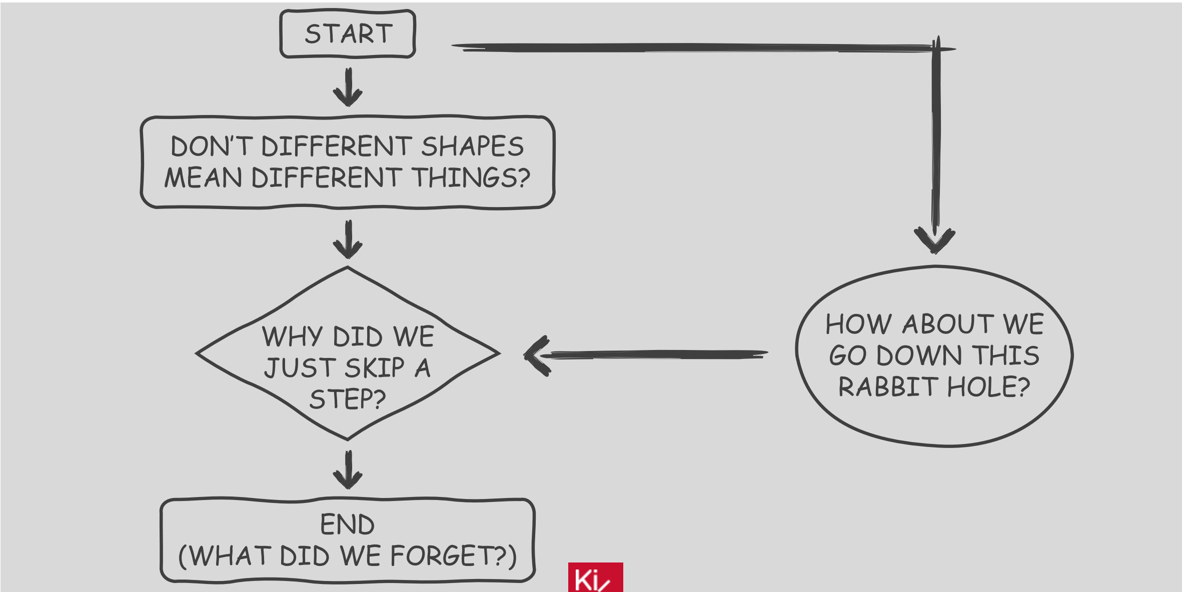
We need to gather information about their activities of daily living and how they perform activities – and often this must be done without actually seeing the environment or even the activity actually being performed

How Do We Approach the Prescription Process?

Environmental & Personal Factors

We need to understand environment and the psychosocial context within which their activities and mobility are performed

How Do We Approach the Prescription Process?



Yikes, there's a lot to consider there . . . Wouldn't it be nice if there was a straightforward flow chart/decision tree?
It doesn't exist, BUT we can return to EBP

How Do We Approach the Prescription Process?

Return to Evidence-based Practice

set appropriate goals, apply our clinical expertise to evaluate physical and functional needs

anticipate potential changes,

apply research evidence

How Do We Approach the Prescription Process?

Establish a Foundation Posture

We cannot consider

- functional activities
- wheelchair propulsion

until postural stability has been addressed

The purpose of the presentation today is not to move through evaluation process

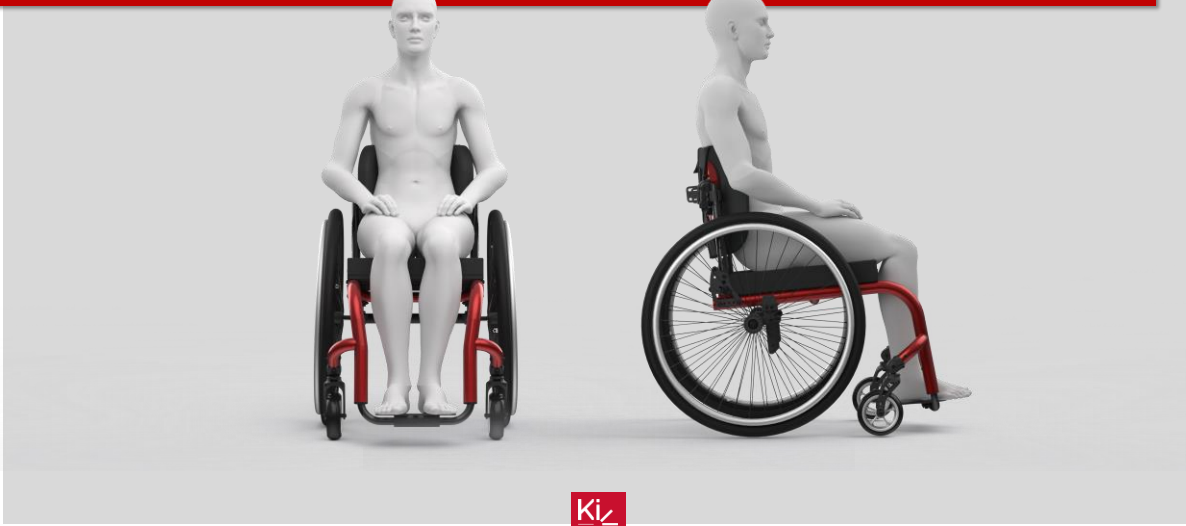
Rather, it is to focus on how to optimize the set up of a wheelchair

taking into consideration the user’s postural needs and capabilities

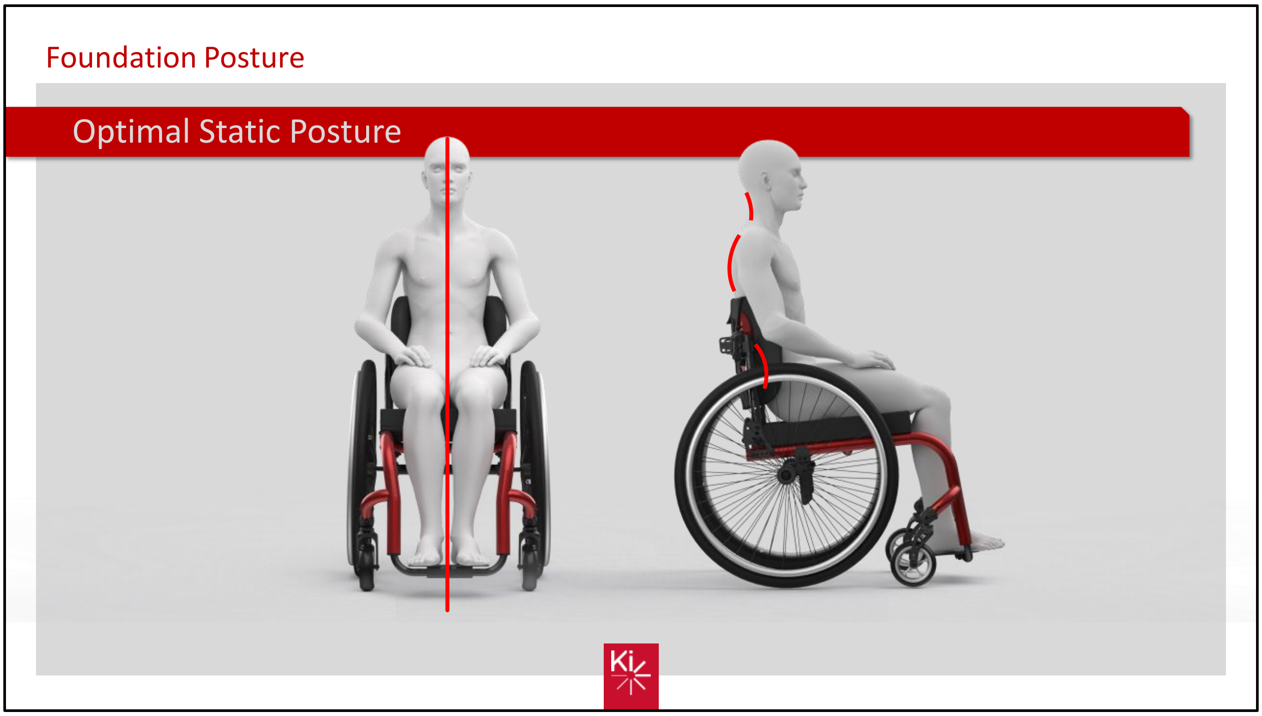
To do this, we need to establish the user’s baseline position for function, because there’s no way to be efficient in movement until you’re stable

Foundation Posture

Optimal Static Posture



Optimal static posture: Most neutral alignment one can maintain with least amount of energy-our basis for movement



For someone who has progressed through normal postural development and has no impairments, Optimal Static Posture may look like the images here on the screen

From a frontal view, we would expect to see symmetry, left and right sides as mirror images,

From a lateral or side view, we would expect to see neutral upright head posture, neutral pelvic alignment (no ant. or post. tilt), normal spinal curves, etc.

Optimal Static Posture

An individual's neutral alignment is dependent on:

- Range of motion
- Strength
- Muscle imbalances
- Endurance
- Muscle tone
- Lifestyle/habits

For those requiring a wheelchair, optimal static posture/foundation posture may look very different. Their alignment may be affected by the presence and predominance of many of these issues. . . Their ROM, Their mm tone, etc. They may consciously, or unconsciously seek out positions of comfort or stability to accommodate for limitations due to these influences. Our bodies adapt to stress and repetition, and can reinforce movements or positions that can lead to the formation or worsening of postural asymmetries.

This presentation does not allow the time to address methods of evaluation, but the determination of an **individual's** neutral posture should be thoroughly assessed

Static Postural Control

In order to maintain static postural control, an individual needs to be able to maintain a position of balance

We need to determine how to setup the chair for the individual's foundation posture

Balance = the ability to control opposing forces so that they are equal or even (either static or dynamic)

- Static balance = when the body is at rest or completely motionless
- Dynamic balance = when all the applied & inertial forces acting on the moving body are in balance, resulting in movement with unchanging speed & direction

Dynamic Posture

Dynamic posture is person's alignment during activity

Once we have established the foundation posture, or that static posture. . .

Then we can look at dynamic posture

Dynamic Postural Control

Dynamic posture is person's alignment during activity

Requires ability to maintain **Center** of **Gravity** (**CG**) over a constantly changing **B**ase **of** **S**upport (**BoS**)

For able bodied individuals

when walking or running,

Dynamic Postural Control

Dynamic posture is person's alignment during activity

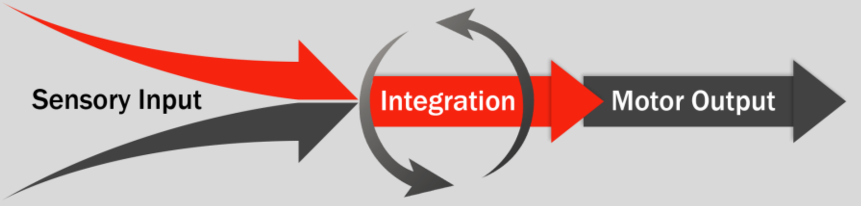
For an individual who uses a wheelchair, requires maintaining a changing **CG** over a fixed **BoS**

For an individual who uses a wheelchair,

requires the ability to maintain a changing CG over a relatively fixed BOS

Dynamic Postural Control

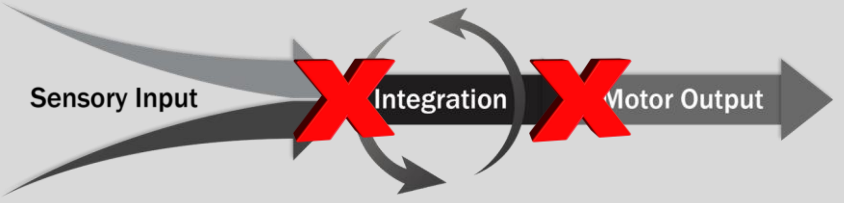
Dynamic postural control requires integration of sensory input for motor output



Things like our vision, proprioception, tactile sensation

Dynamic Postural Control

Dynamic postural control requires integration of sensory input for motor output



For individuals with disabilities, there is often a break in this chain

Dynamic Postural Control

Let’s consider this for an individual with an SCI.

J lifting a pen.

Not a heavy object, but for him it is a two-handed task,

require assistance from his left hand

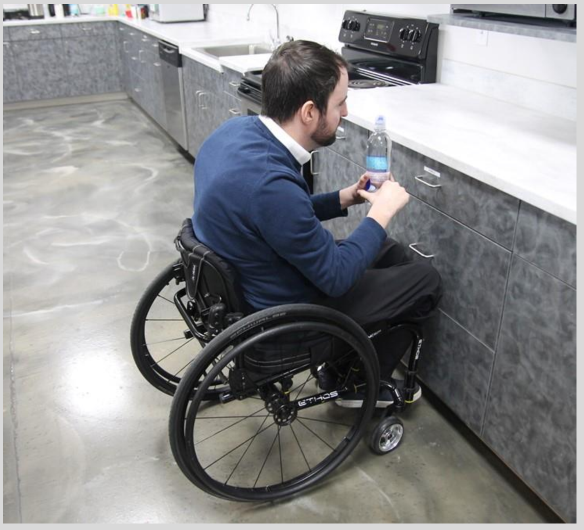
needs to stabilize his trunk by placing his arm on the counter

Dynamic Postural Control

Here he still is resting his left arm on the counter,

could place his left arm down without much change in his posture

Dynamic Postural Control



J lifting a slightly heavier object,

because of limited dexterity it is a two-handed activity

And we can see the impact on his posture – still against backrest, but rounded upper thoracic, forward shoulders and head w/ upper cervical extension, bracing with elbows

Dynamic Postural Control

J lifting a gallon of milk,

more significant postural changes – rounded thoracic spine, pulling away from backrest

need for additional support from his left arm with hand hooked under right knee

Dynamic Postural Control

J actively reaching for an object out of his backpack

shift in his pelvis

hooking of his left arm

Dynamic Postural Control

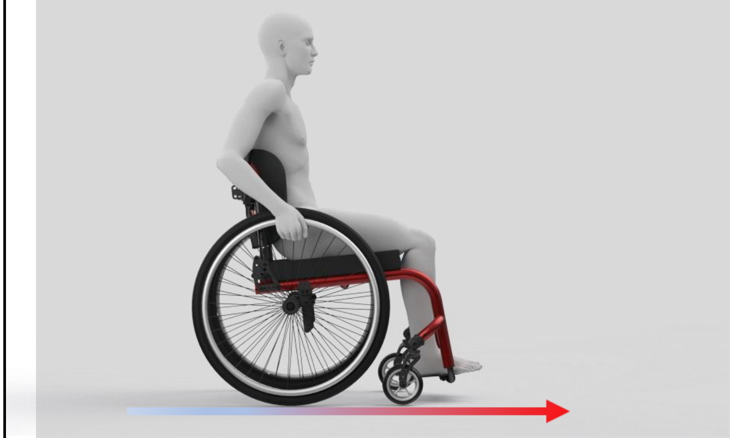
Put stability of posture to the test with dynamic functional activities

- Activities chosen by user

The point here is that once we have determined the chair set up to maintain a stable static posture, then we need to put stability of posture to the test with dynamic functional activities.
They choose – what is it that individual wants or needs to do from their chair? EBP
We need to do this to optimize for the function they need to perform

Dynamic Postural Control

Then we can put stability of posture to the test during propulsion

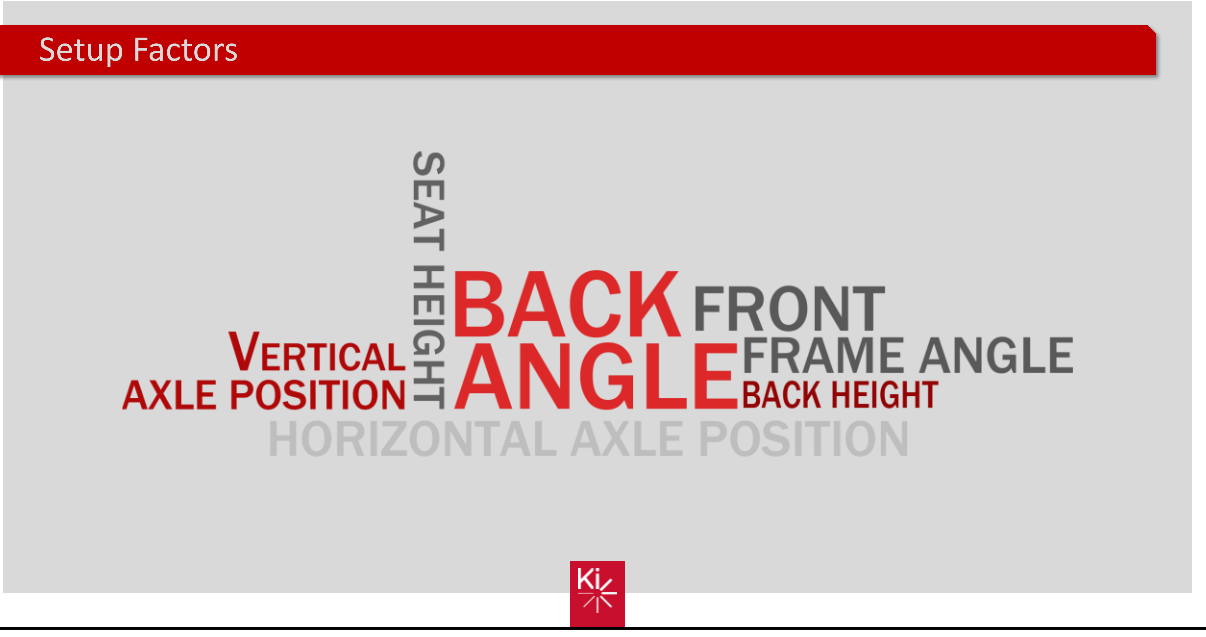


Then, decisions can be made regarding **optimizing** the setup of the wheelchair for mobility.

If we first start with trying to optimize the wc for propulsion, we may wind up with a chair that's not stable enough for the other activities the individual needs to wants to do from their wc

Now that we have established how critical adjustment is to a manual wheelchair, we are going to look at specific aspects of chair setup

There is a lot of research available that focuses on “optimal” setup parameters for many aspects of the chair, Optimizing the Wheelchair Setup



It is important to remember that although the research necessarily isolates these factors, they do not exist in isolation. Each adjustment has an impact on other aspects of the wc configuration. . .

How many of us have tried to make just one quick adjustment, but then it led to a cascade of other effects that needed to be addressed, and before you know, there went lunch time.

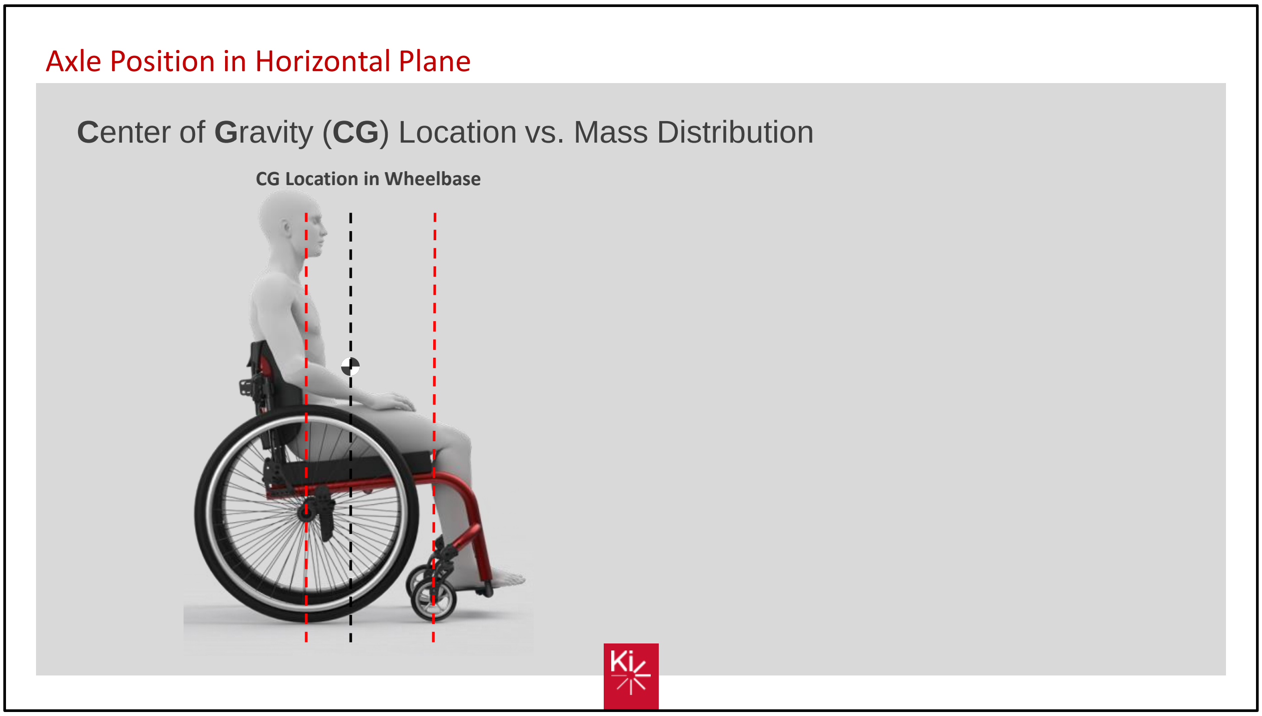
Axle Position in Horizontal Plane

Influences two important aspects of wheelchair mobility

- Stability
- Propulsion efficiency

(Medola, 2014)

Let's look at axle position in the horizontal plane



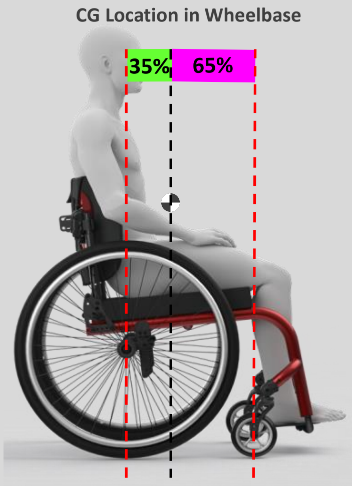
When we talk about CG, most people think about moving the rear axle horizontally,

impacting CG of the system-user and chair combined (illustrated by this dot)

In most cases the rider does dominate this equation/system – in most cases the rider weighs much more than the chair.

Axle Position in Horizontal Plane

Center of Gravity (CG) Location vs. Mass Distribution



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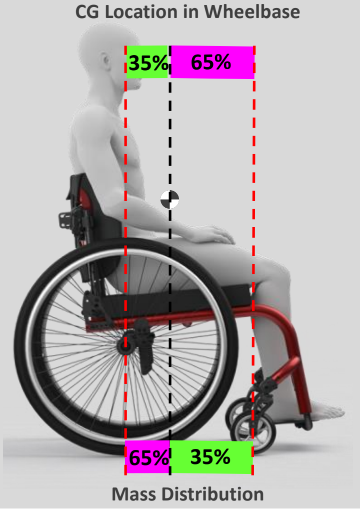
In this example 35% of the distance between the center of casters and the center of the drive wheels is behind the CG and 65% is in front of the CG
35% of the wheelbase is behind the CG, 65% of the wheelbase is in front of the CG

Axle Position in Horizontal Plane

Center of Gravity (CG) Location vs. Mass Distribution

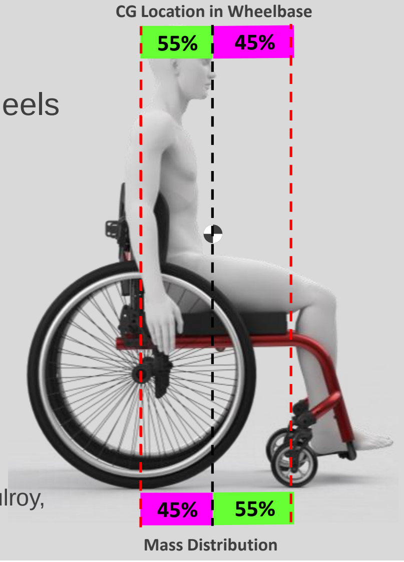


Because there is an inverse relationship between Mass distribution and center of gravity location, in this example 65% of the mass is over the rear wheels and 35% is over the caster wheels.
So 35% of the total wheelbase behind the CG, places 65% of the mass over the rear wheels

Axle Position in Horizontal Plane

More rearward drive wheel position

- Decreases system mass over drive wheels
- Improves rearward chair stability
- Increases rolling resistance
- Decreases user access to drive wheel



(Gorce, 2012, Boninger, 2005, Freixes, 2010, PVA, 2007, Mulroy, 2005, Brubaker, 1986, Slowik et al., 2013)

Remember, because of the inverse relationship between CG location and mass distribution,

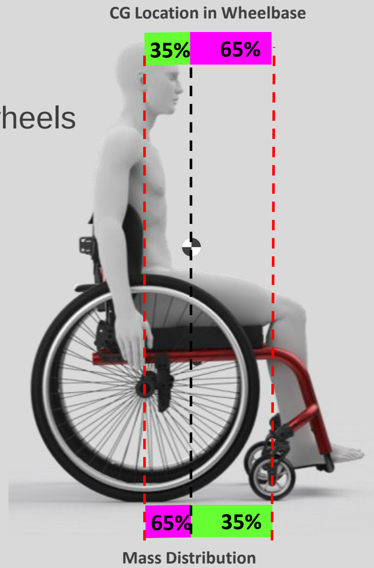
greater the distance from CG to rear axle the less system mass over the rear wheels.
This can increase rear stability, but the tradeoff is increased rolling resistance

Ex. think about what happens when you place too much weight on the front of a shopping cart. How much more difficult is it to turn that cart and maneuver it in the store.

Axle Position in Horizontal Plane

More forward drive wheel position

- Increases system mass over the drive wheels
- Decreases rearward chair stability
- Decreasing rolling resistance
- Increases user access to drive wheel



In contrast , a more forward drive wheel position…

Axle Position in Horizontal Plane

May need to prioritize stability for some users

Even though moving the axle as far forward as possible may seem ideal to increase access for propulsion efficiency, we may need to place it more rearward for stability or safety reasons

image on the left, the user may need to lean back for stability with forward reach

Children often have shorter seat depths than adults, small changes in horizontal axle position greater impact on stability

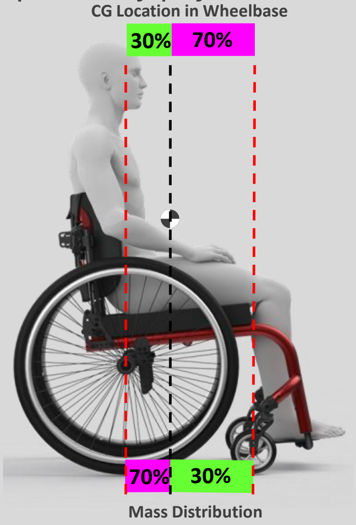
Occupational needs might require greater stability on various terrains and postures. Consider the task at hand, and the environment. If the person in the center is taking photo of something higher, and on a slope, they could become unstable rearward.

Axle Position in Horizontal Plane

For others, you may need to prioritize agility concurrent with their skill level

Axle Position in Horizontal Plane

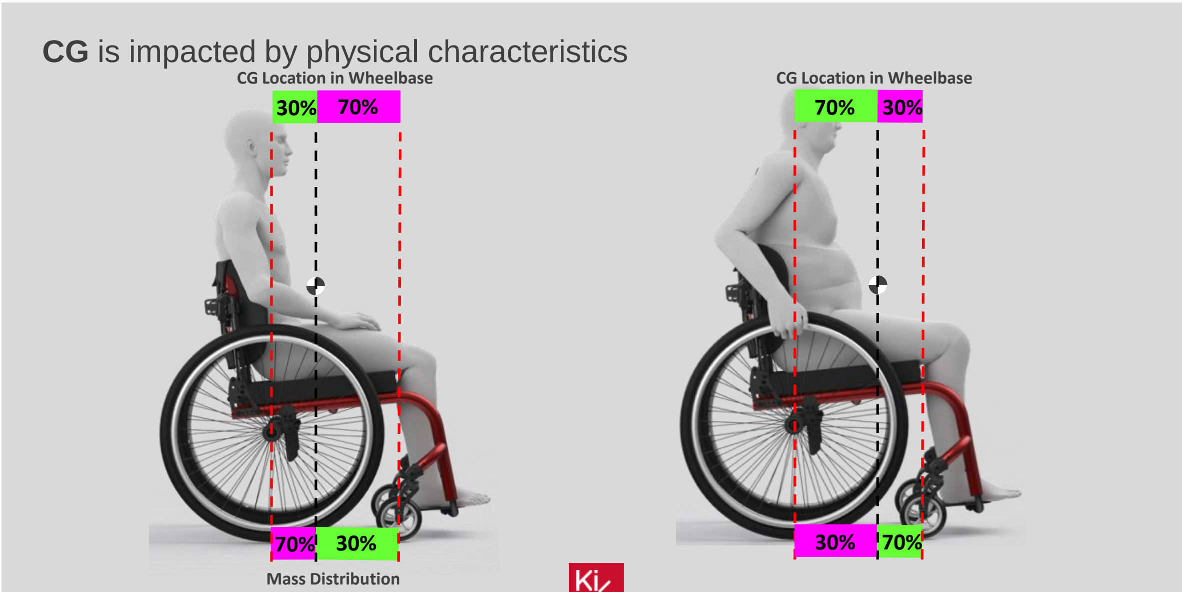
CG is impacted by physical characteristics



We can see changes in stability of a chair with maturity when weight distribution changes.

Ex. young boy to adolescent-carrying more weight in chest and shoulders-now distributing more mass over the rear wheels of the chair

Axle Position in Horizontal Plane

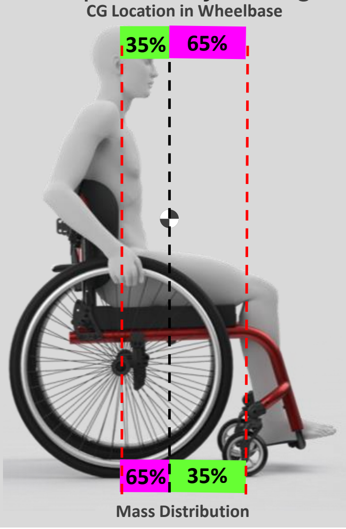


Examples:
weight gain can impact rolling resistance by increasing mass over the casters

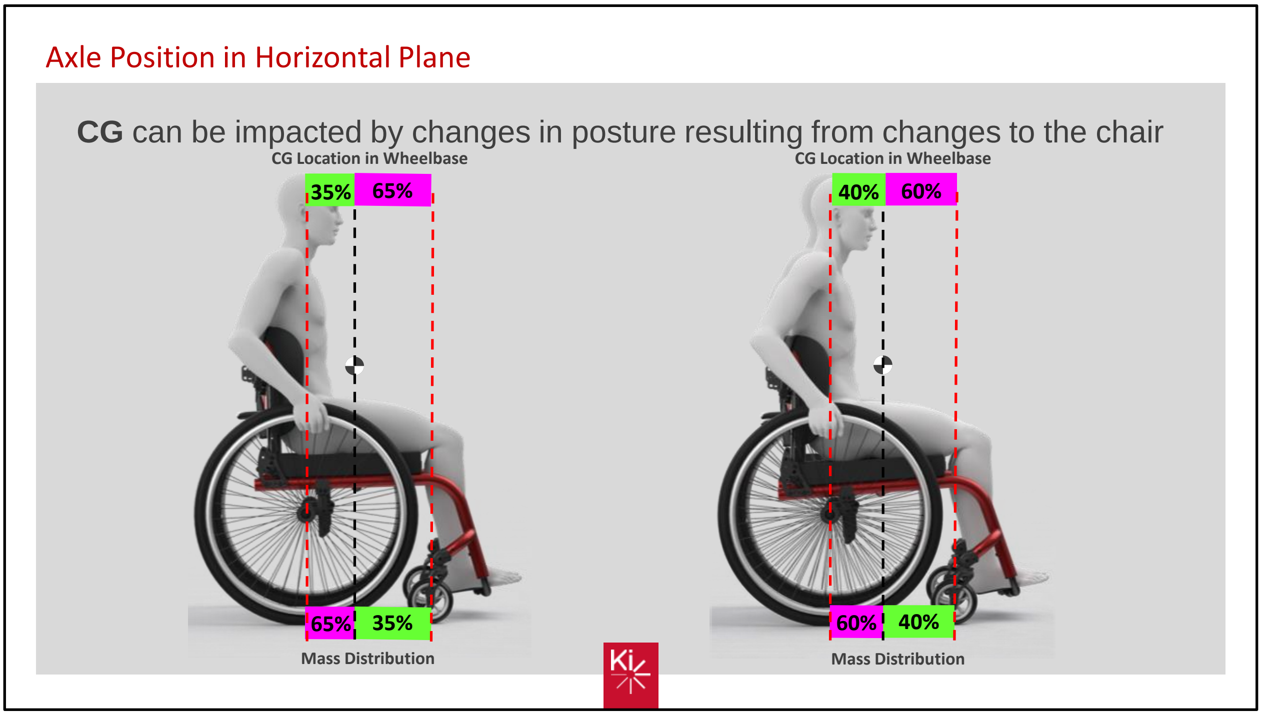
A pregnant user who is further along in her pregnancy

Axle Position in Horizontal Plane

CG can be impacted by changes in posture resulting from changes to the chair



Rogue 4 hand at 12



adding seat slope and closing the back angle

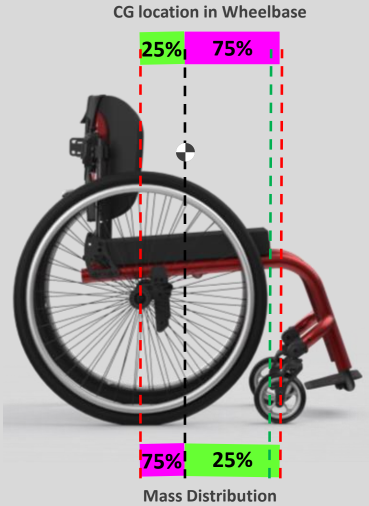
can impact CG without any concurrent change to the rear axle position

Here we changed from 65% to 60% mass over the rear wheels. This may not necessitate a change, but we need to be aware of the cascade of effects that may result from making just a single change, or two.

Rogue 4 hand at 12

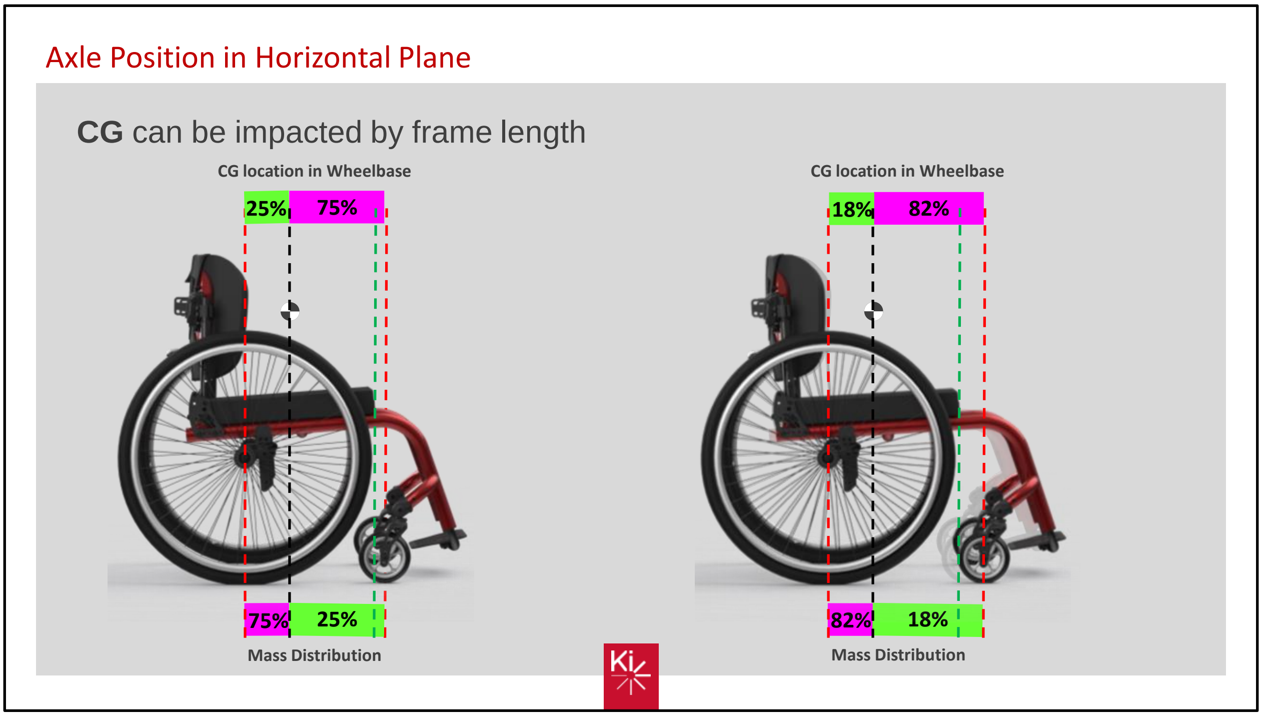
Axle Position in Horizontal Plane

CG can be impacted by frame length



Because the % weight over the drive wheels is inversely proportional to the distance from the center of mass to the casters

changing the frame length has an impact on CG



Increasing the distance to the casters (increasing wheelbase) with the same rear axle position,

results in a greater percentage of mass over the drive wheels

Axle Position in Vertical Plane

Vertical axle position impacts

- Stability
- Propulsion efficiency

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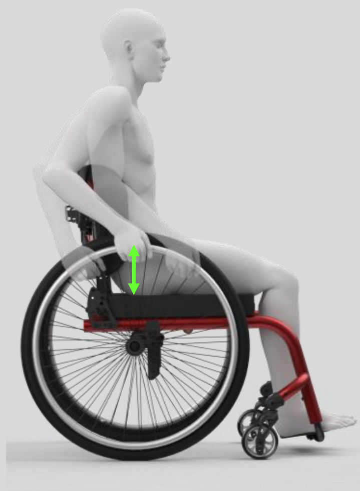
Like horizontal axle position, impacts wheelchair stability and propulsion

Axle Position in Vertical Plane

Rear seat height relative to the drive wheel



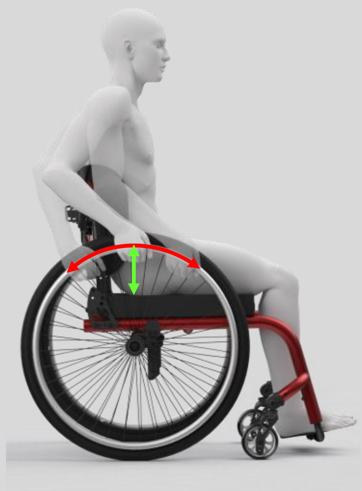
Without concurrent changes in setup,

determines rear seat height relative to the drive wheel

Axle Position in Vertical Plane

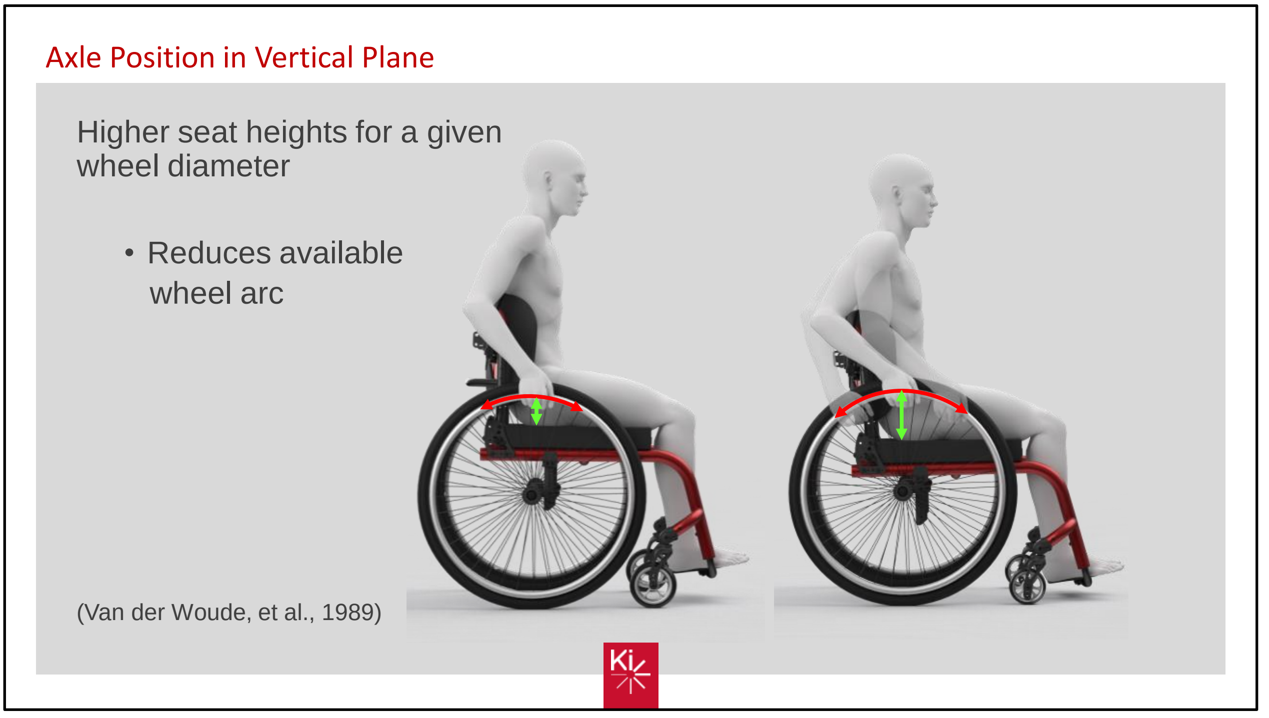
Rear seat height relative to the drive wheel

- Determines available wheel arc for propulsion



(Van der Woude, et al., 1989)

With a set axle position in the horizontal plane



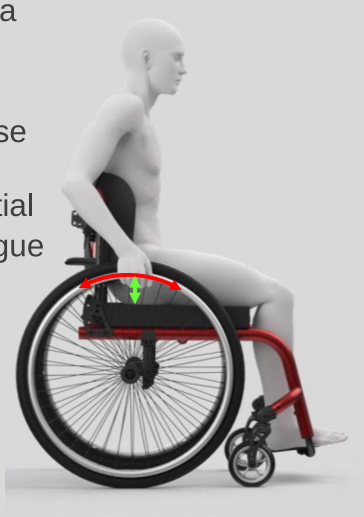
Therefore, having a higher seat height for the same diameter wheel

Will reduce the available wheel arc for propulsion

Axle Position in Vertical Plane

Higher seat heights for a given wheel diameter

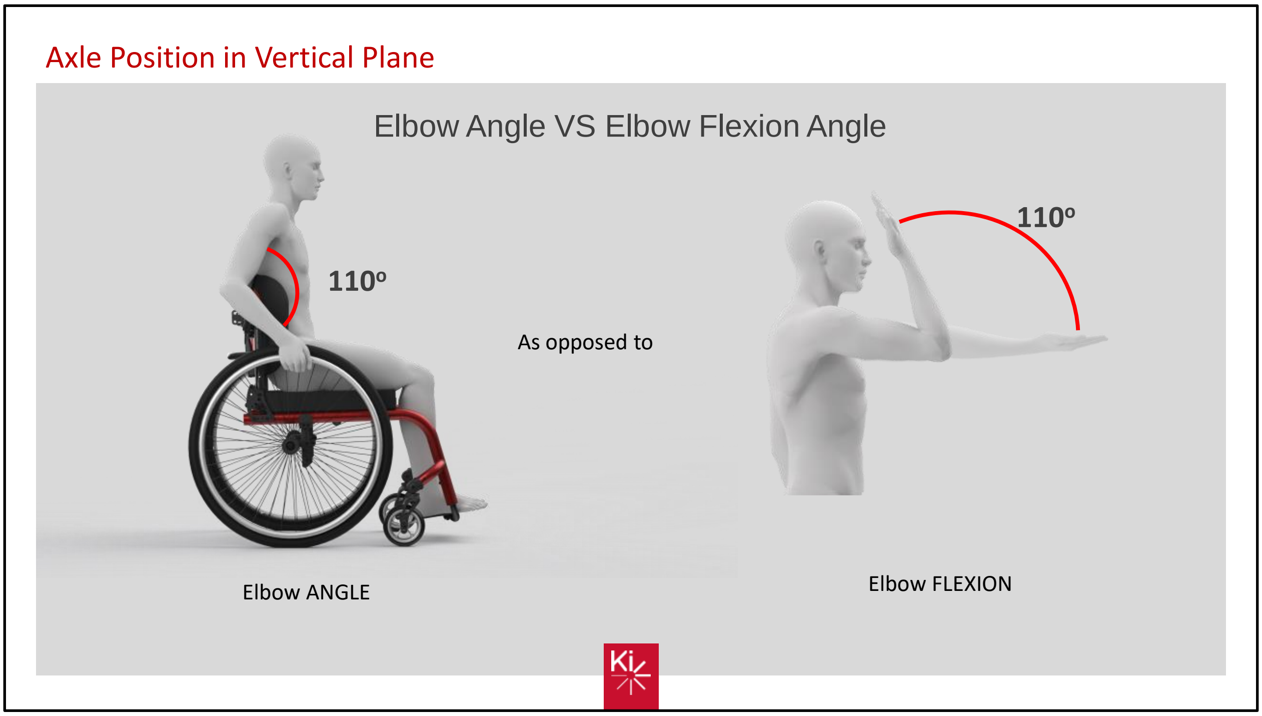
- Shown to increase push frequency
- Increased potential for muscular fatigue



(Boninger, et al., 2000 & Boninger, et al., 2005)

Studies have demonstrated this smaller contact arc results in… increased push frequency, and increased potential for mm fatigue

both of which have been correlated with increased upper extremity overuse injury



Before we talk about optimal UE access to the handrim for propulsion, it's important to differentiate between what research studies refer to as elbow angle and elbow flexion angle

Full elbow flexion is typically 150-160°, with a fully extended (straight) arm as 0°

In contrast, when discussing elbow angle for propulsion, research refers to the angle between the upper arm and forearm with the hand at 12 o'clock on the handrim (which, in this example, is 70° elbow flexion on the other side of 110° of elbow angle)

From Waugh, Guide to Seating Measures

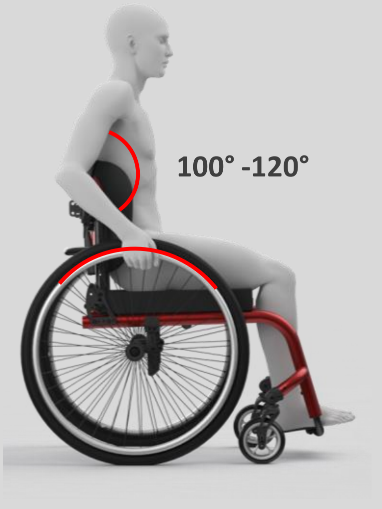
The terms defined in this chapter are measures of a static position rather than goniometric measures of joint range of motion. The methodology for measuring joint range of motion is well established in the medical field, and it is not the intention of the standard or this guide to re-define these measures, but rather to define terms which both describe a static seated posture and also provide measures which more easily translate into corresponding support surface angles for prescription purposes.

Axle Position in Vertical Plane

100-120 degrees of elbow angle when hand is at top of handrim (12 o'clock)

- Maximizes user access to handrim throughout push stroke
- Places shoulder and elbow in most mechanically advantageous positions
- Protects the upper extremity by eliminating harmful ranges for shoulder and elbow

(Van der Woude, et al., 2009, Van Der Woude, et al., 1990, Mejis, et al., 1989)

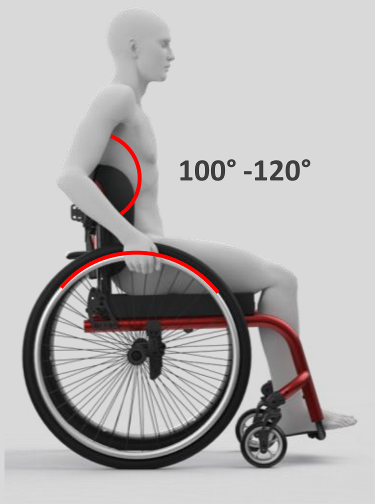


Multiple studies demonstrated that an elbow angle of 100-120° with hand at 12 0'clock on handrim maximizes the available wheel arc

Axle Position in Vertical Plane

100-120 degrees of elbow angle when hand is at top of handrim (12 o’clock)

- Associated with improved propulsion efficiency
- Associated with decreased energy expenditure



(Van der Woude, et al., 2009, Van Der Woude, et al., 1990, Mejis, et al., 1989)

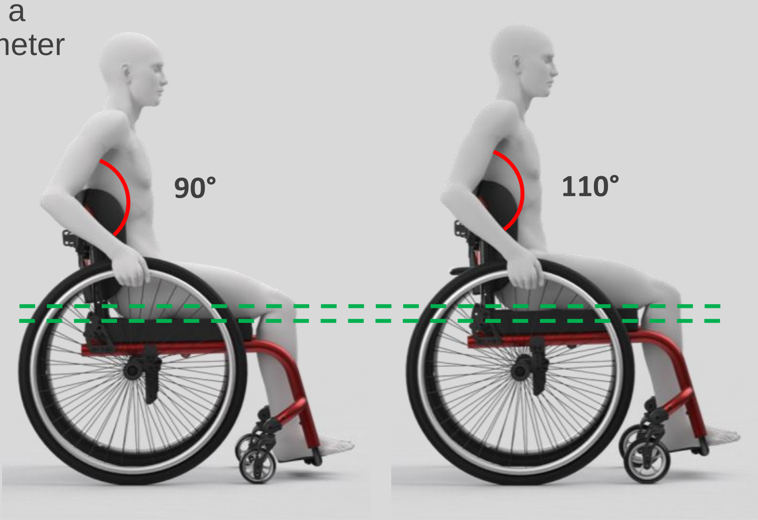
…in other words, fewer, longer push strokes, for a given distance

…Of course, that’s when used with efficient propulsion technique, which is a topic for another presentation

Axle Position in Vertical Plane

Lower seat heights for a given drive wheel diameter

- Less efficient handrim forces
- Less efficient cardiorespiratory parameters



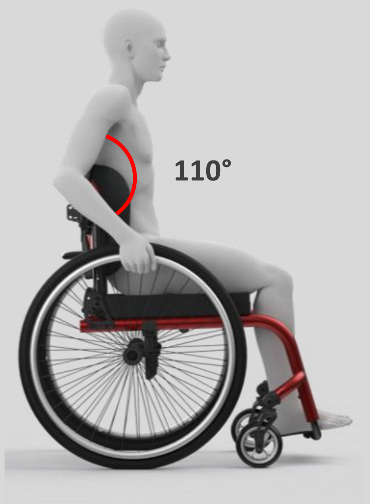
(Van der Woude, et al., 2009)

Seat heights resulting in elbow angles of 80 to 90 degrees (with user holding handrim at top position of 12 o'clock)

correlated with less efficient force production for propulsion, and higher cardiorespiratory demand. This lower seat can result in excess elbow flexion and concurrent shoulder hiking as the hand approaches the high point of the wheel, resulting in increased stresses at shoulder, elbow and even wrist. Resulting in greater risk of injury.

Axle Position in Vertical Plane

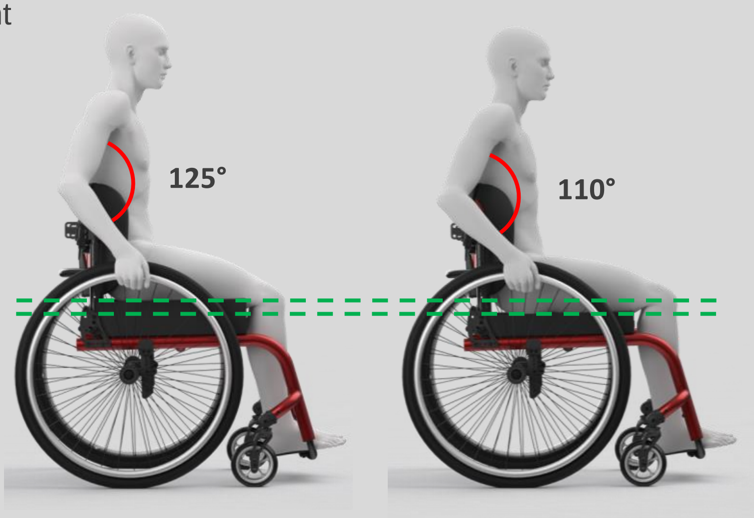
Vertical axle placement can be impacted by seat cushion height



user might have an elbow angle within the 100-120° range on a 2” seat cushion

Axle Position in Vertical Plane

Vertical axle placement can be impacted by seat cushion height

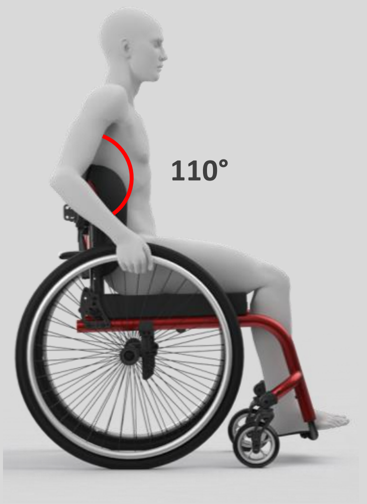


But may have an elbow angle greater than 120° on a 4” seat cushion

Sometimes it may be prudent to plan for the possibility in initial prescription, so you don’t have to modify the chair in other ways if this situation arises. Such as changing overall STF or rear wheel diameter.

Axle Position in Vertical Plane

Vertical axle placement can be impacted by the need for seat slope

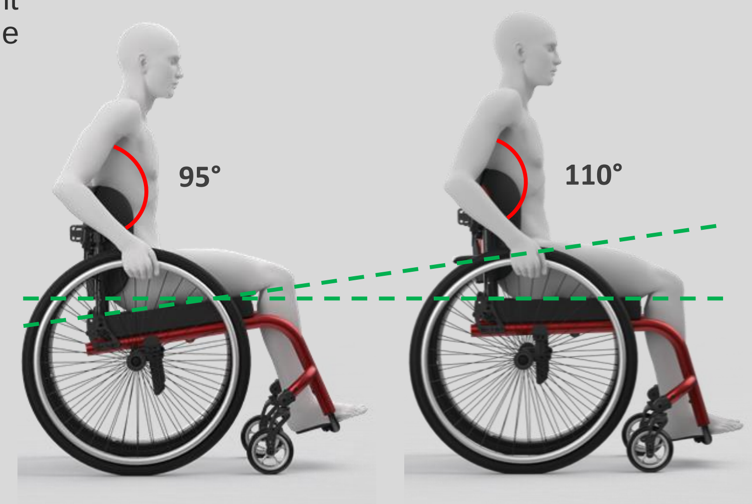


If a user requires the addition of seat slope (ex. to improve trunk and/or pelvic stability),

it may result in a less than optimal elbow angle

Axle Position in Vertical Plane

Vertical axle placement can be impacted by the need for seat slope

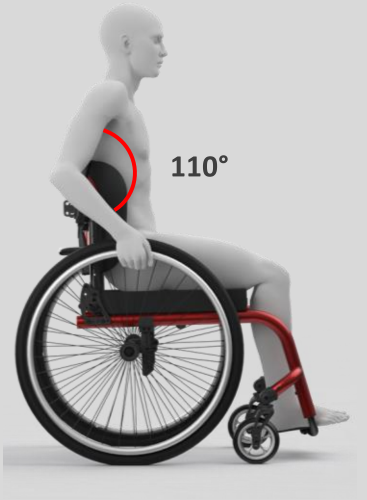


In this case that angle changed from 110 to 95.
Once again, if you anticipate you may need this modification, it may be prudent to plan for this at initial prescription and start with a greater elbow angle,

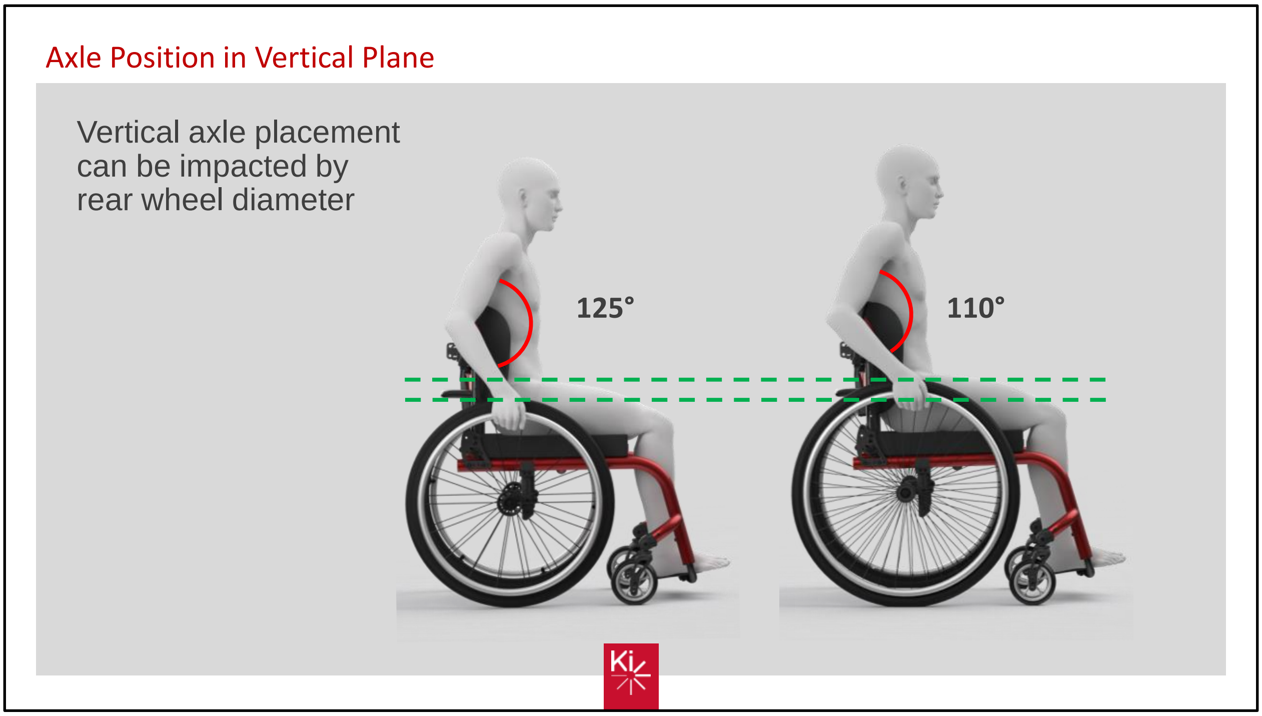
or it may require modifications to the chair later to maintain optimal elbow, Such as increasing overall STF or decreasing rear wheel diameter.

Axle Position in Vertical Plane

Vertical axle placement can be impacted by rear wheel diameter



24” is the standard drive wheel diameter for most adults



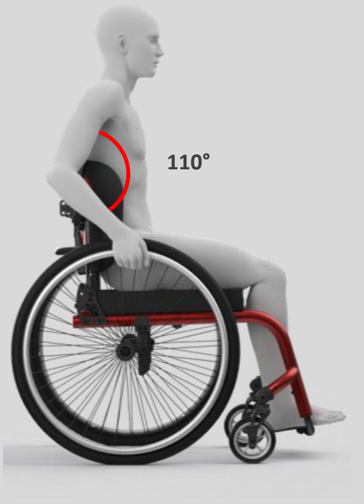
rare to want to decrease rear wheel diameter,

(larger wheels provide more leverage, magnify your pushing force, and help you overcome the force of friction)

“outgrow” their rear wheel diameter (Ex. raising the STFH to accommodate growth for a child), so we may have to change to a larger wheel to put that elbow angle back in that optimal range. In this example, ‘outgrowing’ the wheel resulted in an elbow angle of 125, and putting on a larger wheel put it back to 110

Axle Position in Vertical Plane

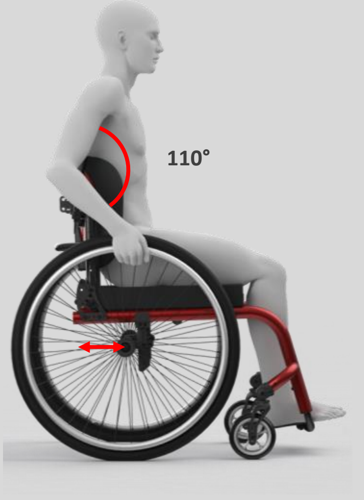
Elbow angle can be affected by other set up choices



Ex. horizontal axle position

Axle Position in Vertical Plane

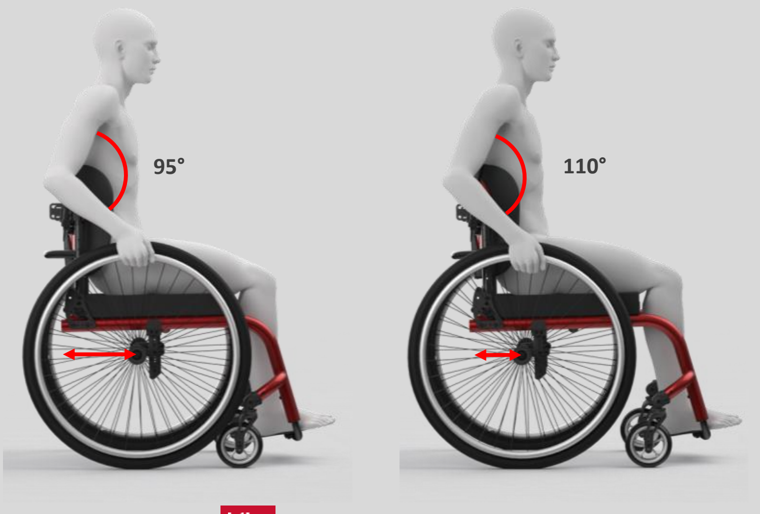
Horizontal axle placement can impact elbow angle



needs to be optimized during the life of a chair

Axle Position in Vertical Plane

Horizontal axle placement can impact elbow angle



moved forward to be accommodate user skill acquisition

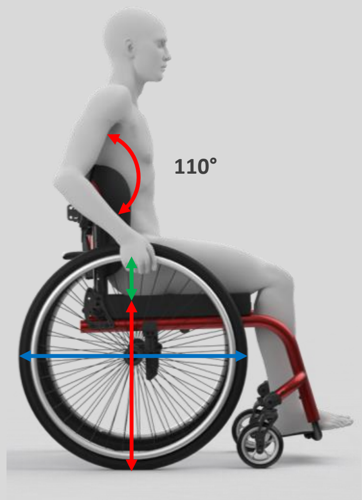
may move the user outside of the optimal elbow angle

Axle Position in Vertical Plane

Formula for Wheel Size

- Measurements needed:
  - Seat to Palm (SP)
    - measured in the desired seated posture
    - with an elbow angle of 110°
  - Rear Seat Height (RSH)
  - Wheel Diameter (WD)

SP + RSH = WD



Taking all this into consideration, we can use this formula to simulate anticipated changes in setup

make sure you have the potential to modify the chair in the future

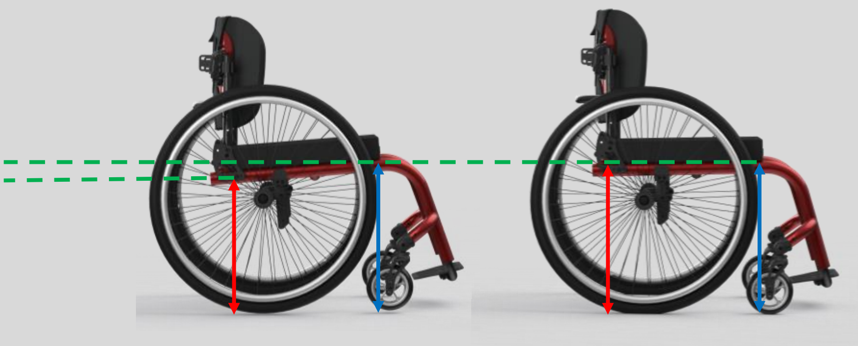
Seat Angle

Often thought of as the difference between Front Seat Height and Rear Seat Height or “Dump”

Let’s talk about seat angle. It’s often thought of as. . .

Seat Angle

Often thought of as the difference between Front Seat Height and Rear Seat Height or “Dump”



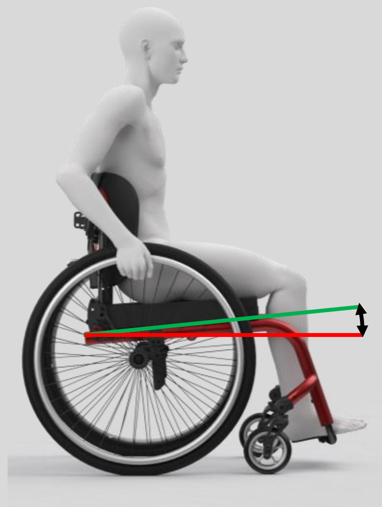
(Ex. 20” FSH -18” RSH= 2” of dump)
A difference in vertical height between two points of reference does not an angle make.

dump <u>is not</u> equivalent to seat angle

Seat Angle

Angle is the figure formed by two rays, sharing a common endpoint

- Seat Inclination relative to the Horizontal Plane

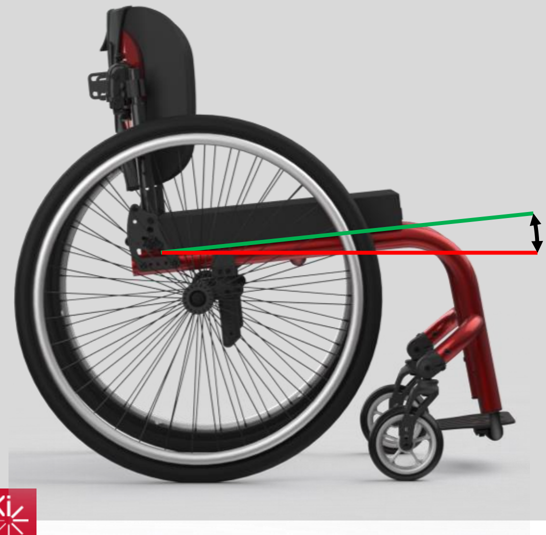


Seat angle is the angle between the green ray (seat inclination) and the red ray (horizontal plane)

Seat Angle

Formula for Seat Angle

- Measurements needed:
  - Front Seat Height (FSH)
  - Rear Seat Height (RSH)
  - Seat Depth (SD)
- FSH-RSH="Dump"
- Dump/SD =sine
- Inverse of sine converted to degrees = Seat Angle



Calculating seat angle is also dependent on seat depth. We have to revisit trigonometry. . .

Clarify that image is not correct for clarity

Seat Angle

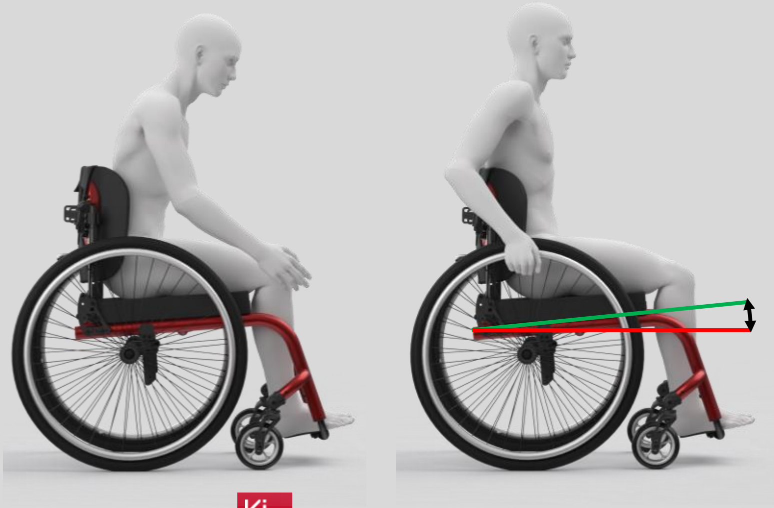
"Dump"	Seat Depth	Seat Angle
0	0	0°
2	14	8.2°
2	15	7.6°
2	16	7.1°
2	17	6.7°
2	18	6.4°
2	19	6°
2	20	5.7°
3	14	12.2°
3	15	11.4°
3	16	10.7°
3	17	10.1°
3	18	9.5°
3	19	9°
3	20	8.6°

David Fagan: if we need to convert this table

Ex. similar to ramp inclination, the longer run, the less steep the rise.

Seat Angle

Can be important to functional stability

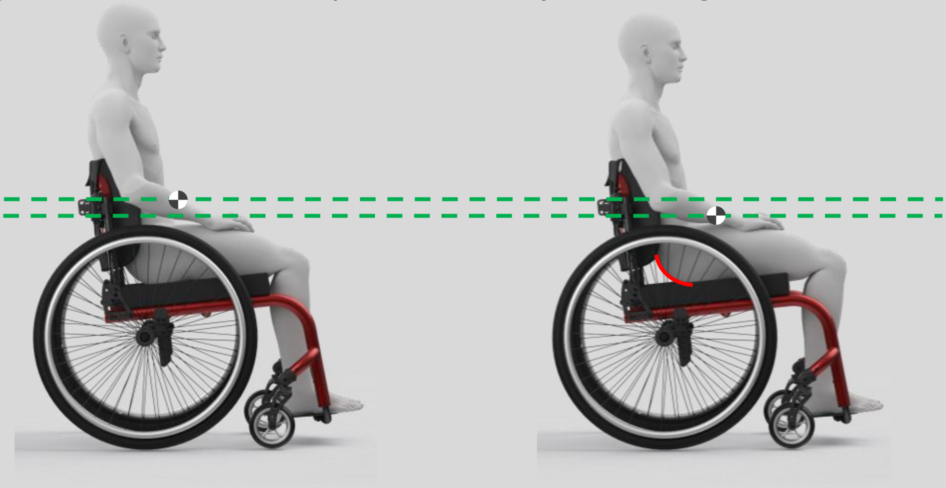


may be added to a chair to providing increased pelvic stability to help decrease sliding

Sometimes to improve forward stability for someone with impaired trunk control

Seat Angle

The higher one's **CG** the more postural stability is challenged



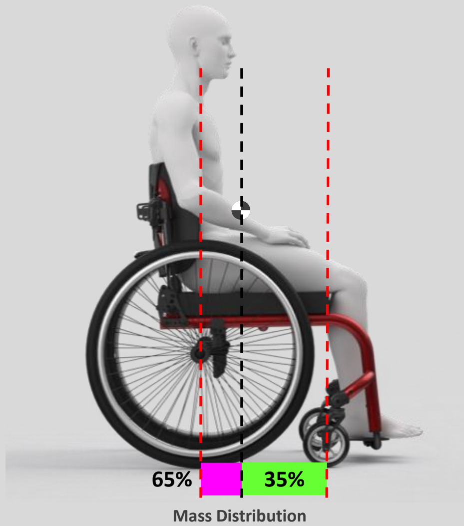
Generally, the higher one's **CG,** the more postural stability is challenged. So, if we feel unstable, or it's taking a lot of work for us to sit, a common reaction is to lower our CG, and in doing so increase our BoS to increase stability.

We commonly see this with wc users when their seating is not set up correctly for their needs

Ex. back angle might be too closed or a seat surface too level, their reaction might be to scoot forward, lowering their CG and increasing BOS

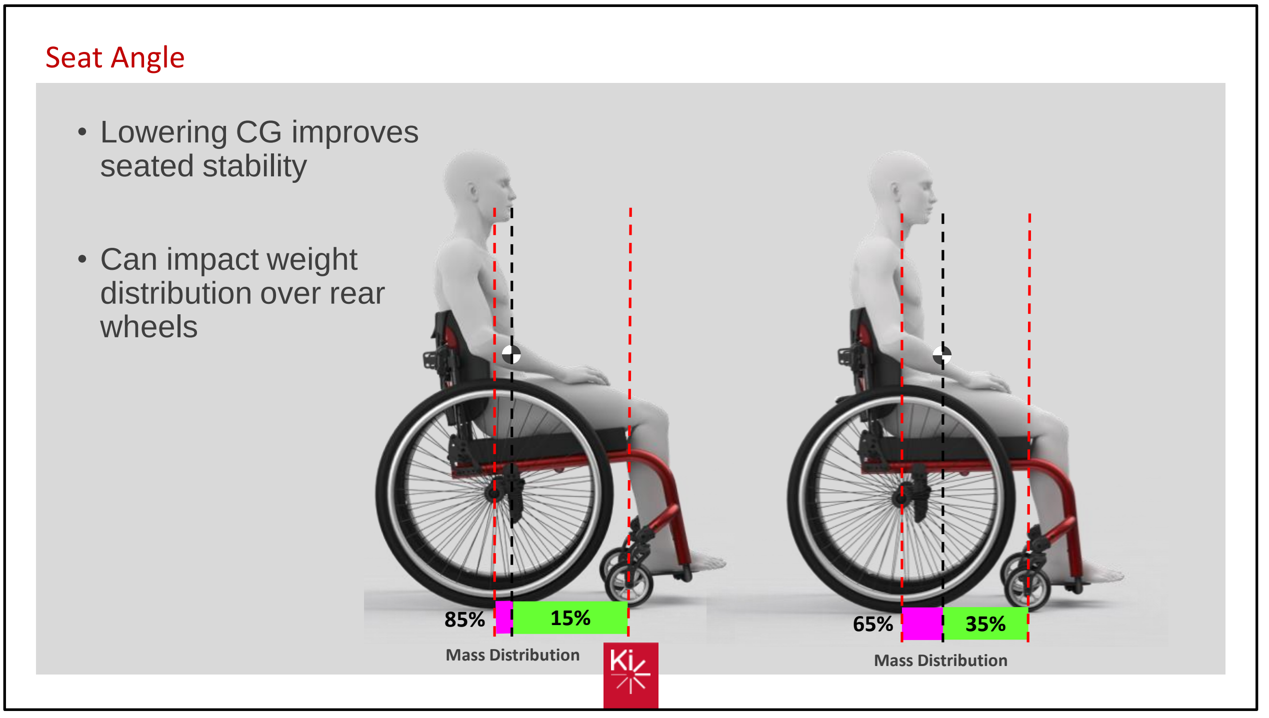
Seat Angle

- Lowering **CG** improves seated stability
- Can impact weight distribution over rear wheels



Lowering CG through dump/seat inclination improves seated stability

But remember, it impacts weight distribution over the rear wheels as well



look what happens when we add seat inclination. In this example, we changed from 65% over DW to 85%

This may in turn require more adjustments to axle and/or back angle

Back Angle

Measurement of back cane angle in relation to seat rail

In reality, with the addition of seating, it is the relative angle of the two support surfaces (backrest and seat cushion)

Back Angle

Like seat angle, often used to facilitate

- Improved seated stability
- Functional use of upper extremities

Ex. If someone is too upright, they may have decreased forward stability,

If the back angle is too open, they may have impaired forward reach

Back Angle

- Can impact access to rear wheels for propulsion
- Can impact weight distribution over rear wheels

In contrast to that forward reach, a more open back angle increases available wheel arc for propulsion,

While closing the back angle decreases the available wheel arc

And of course, this also can impact weight distribution just like many other adjustments

Back Angle

May be altered throughout "life of the chair"

Like all adjustments, this may be altered over time- to accommodate a decline in function, or skill acquisition

Back Angle

May be altered throughout "life of the chair"

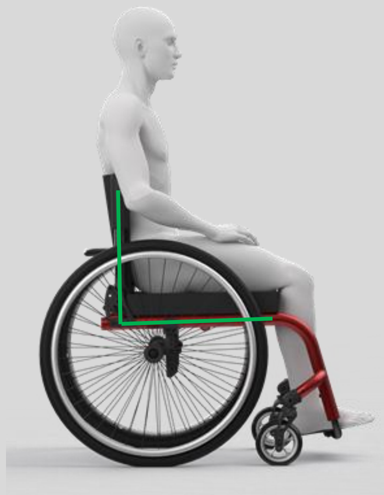
Ex. removal of a TLSO. Because a TLSO may necessitate a more open back angle,

Once it is removed, user may be able to tolerate a more closed back angle

Back Angle

Back Upholstery

- Back Angle

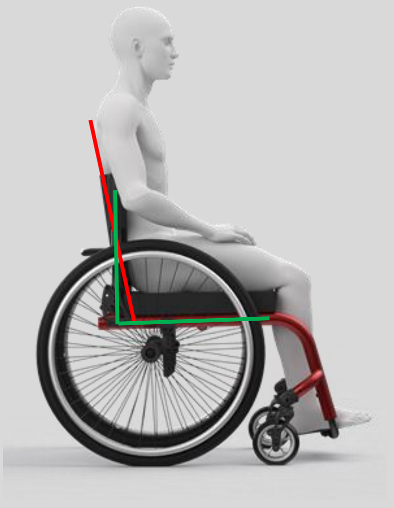


Remember, we said that back angle becomes the angle between the two support surfaces

Back Angle

Back Upholstery

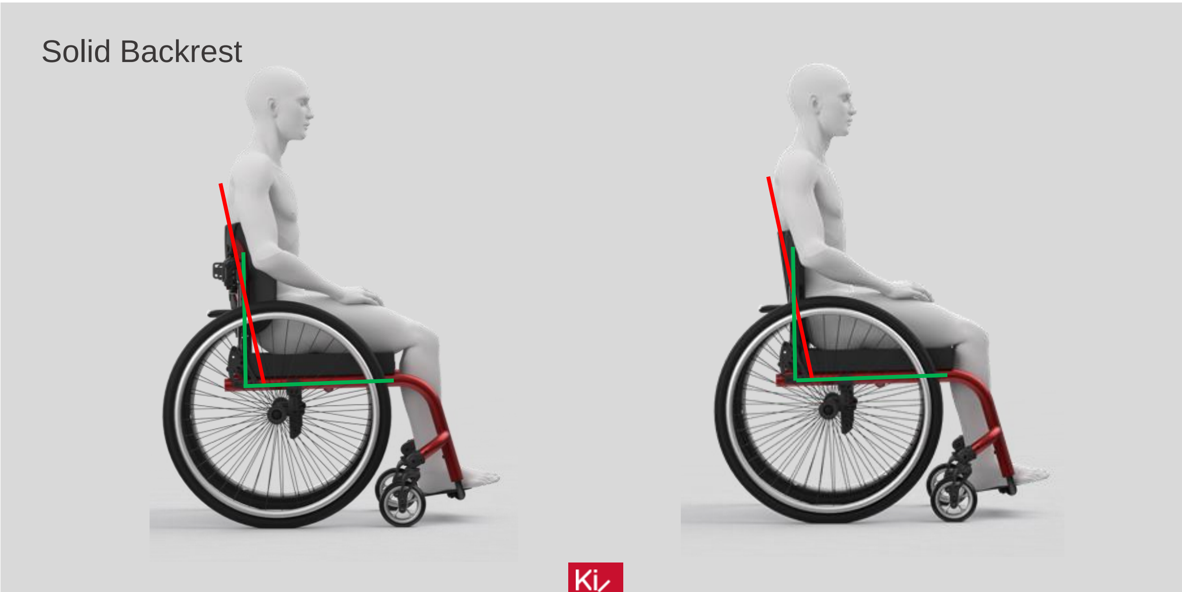
- Back Angle vs. Support Angle



Back angle becomes relative angle of support surfaces

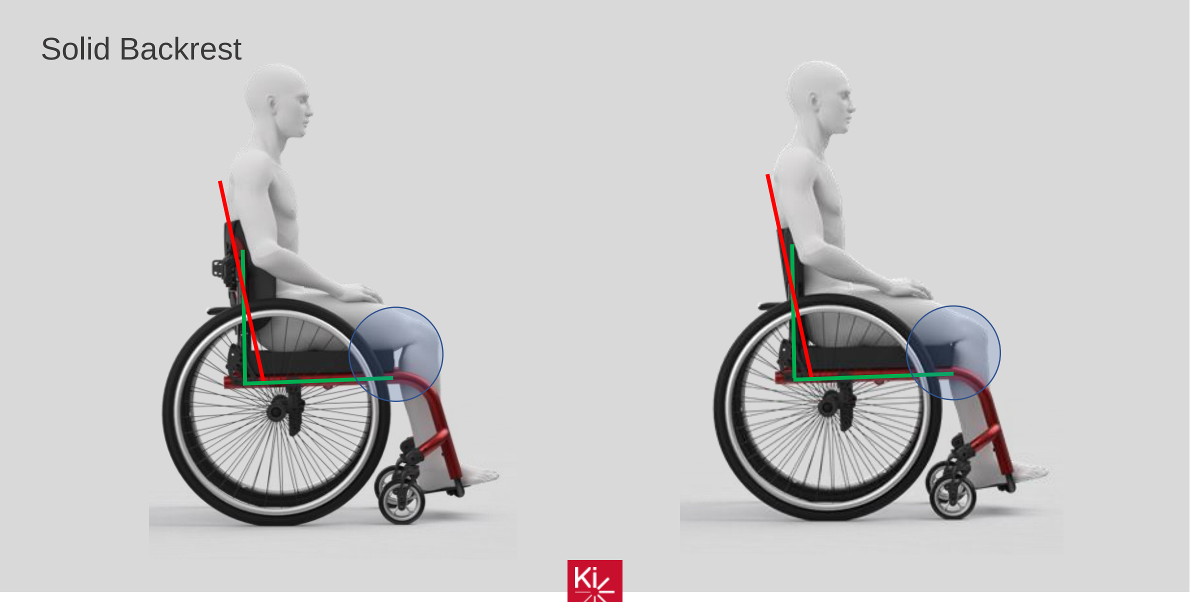
In the case of back upholstery, it can wear-change of back angle, seat depth, positioning, orientation to the drive wheel, CG location, and mass distribution

Back Angle



A solid backrest, through adjustment, can achieve a similar support surface angle

Back Angle

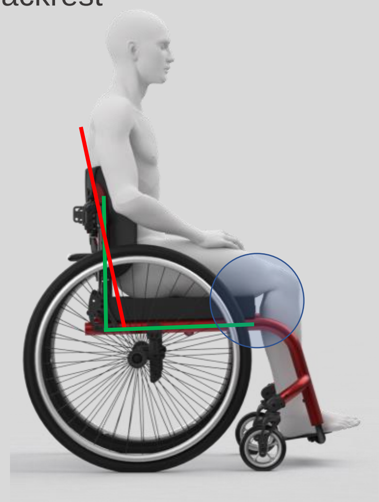


However, support surface shape and backrest mounting and adjustment can reduce available seat depth

(impacting all that goes with it- drive wheel access, CG and mass distribution)

Back Angle

Solid Backrest

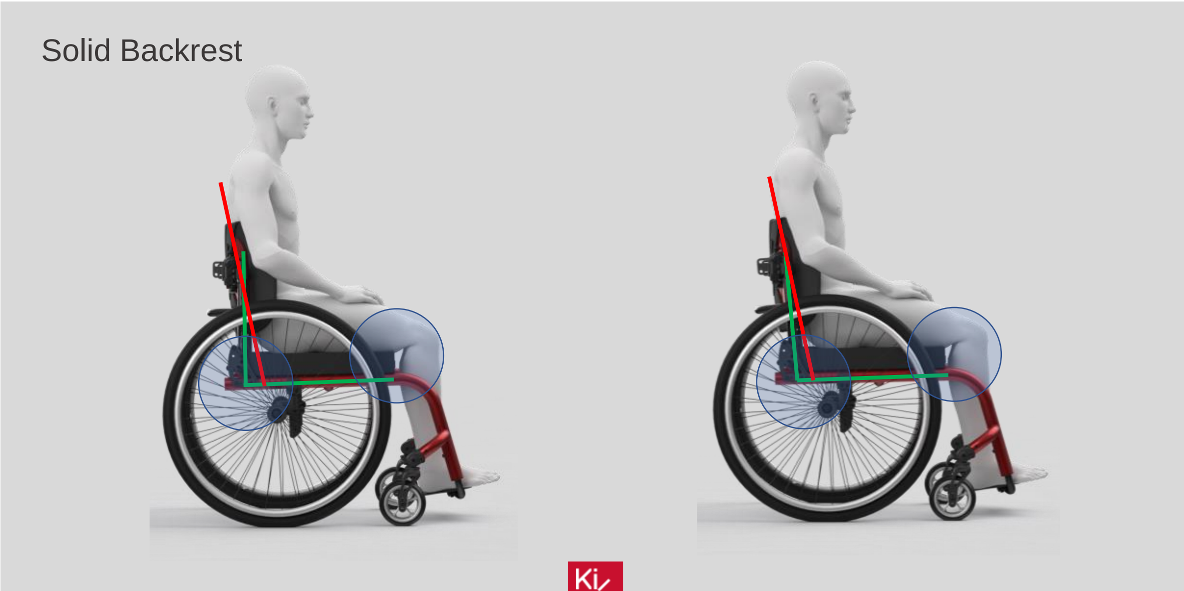


Sometimes that loss of seat depth with a solid backrest may be reconciled to some degree. . .

Back Angle

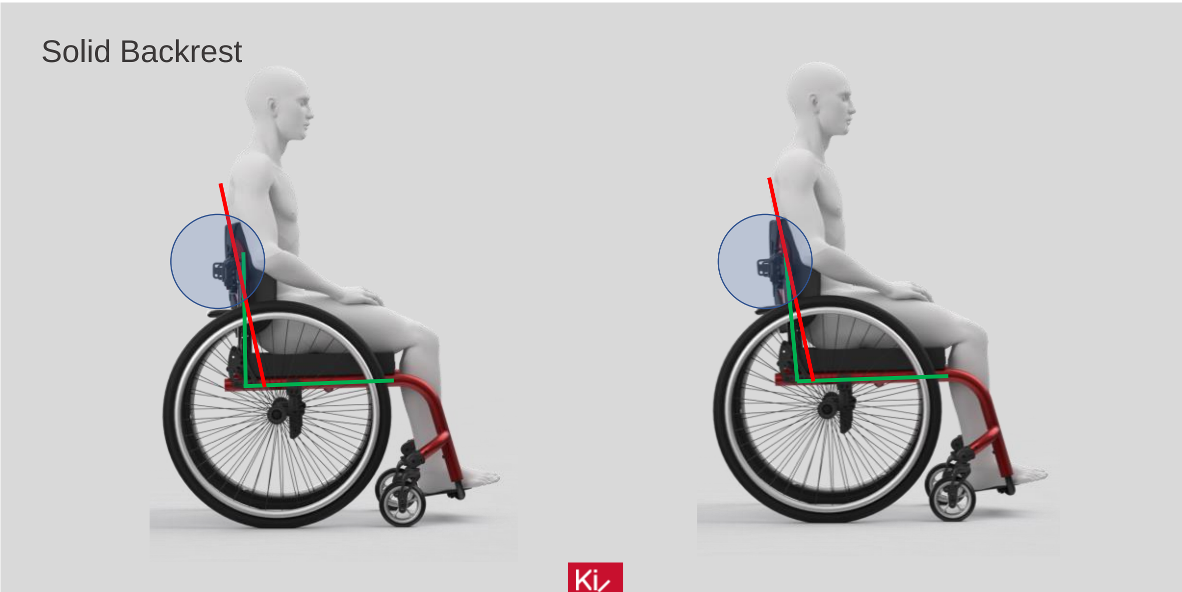
Depending on the depth adjustment of back (need to be careful not to drop the support surface between the back canes, impairing UE movement)

Back Angle



adjustment of the back angle through the back cane hardware can sometimes achieve similar results, and allow the canes to more closely match the desired angle, rather that just orienting the angle of the backrest.

Back Angle



In the image on the right, we see that the canes are more closely aligned with the angle of the back support.

Back Height

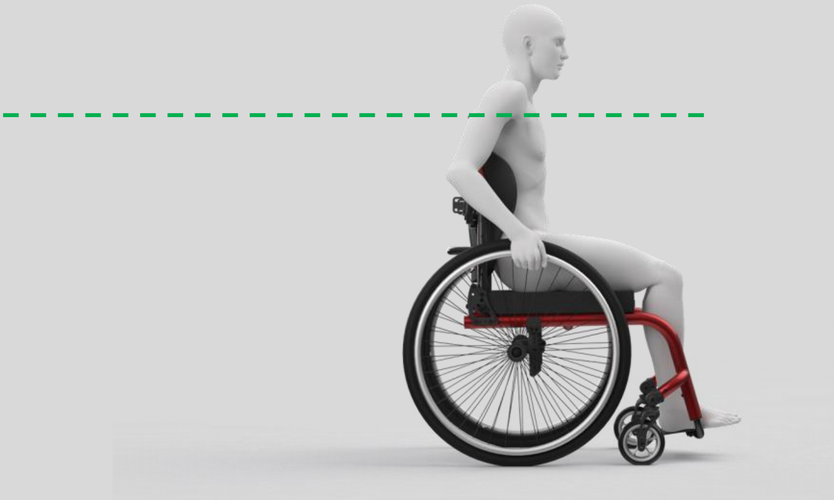
- Can impact postural stability
- Can impact upper extremity range of motion for function

Let’s move on from back angle to discuss back height.

Back Height

Higher support

- Provides more posterior trunk stability
- May decrease shoulder extension range of motion



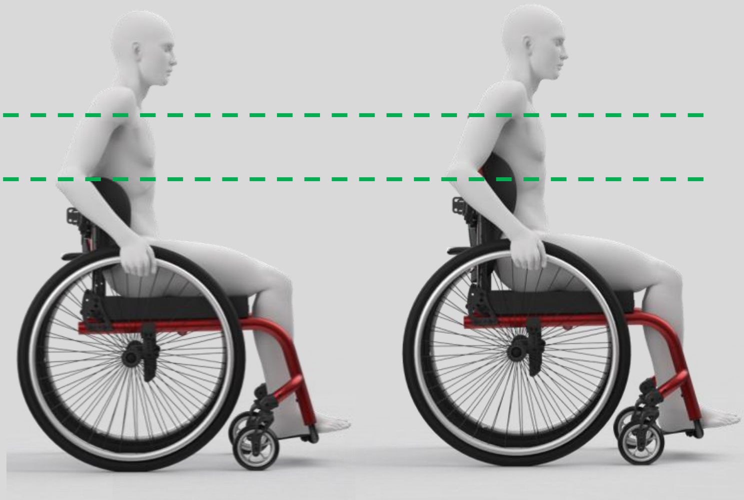
A higher back support provide greater posterior trunk support,

can assist with stability, but sometimes at the cost of shoulder extension ROM

Back Height

Lower support

- Provides less posterior trunk stability
- May increase shoulder extension range of motion



lower back support decreases posterior trunk support,

improved shoulder extension range of motion

can assist with achieving a longer push stroke and therefore more efficient propulsion

Back Height

A pilot study on the impact of solid back support

- Higher vertical reach
- Longer one stroke push
- Faster 23 meter push
- Faster ramp ascent


Research Article

Wheelchair backs that support the spinal curves: Assessing postural and functional changes

(Pedersen, et al., 2019)

When we consider the research, a pilot study on the comparison of solid back support versus back upholstery did show data trended toward higher vertical forward reach, further one stroke push, faster timed 23 m push, and ramp ascent with a solid backrest

statistical significance was not reached, likely due to it being a pilot study with a relatively low number of participants.

Back Height

Lower backrest

- Greater shoulder range of motion
- Longer push stroke
- Greater push time
- Reduced push frequency
- No significant impact on handrim forces

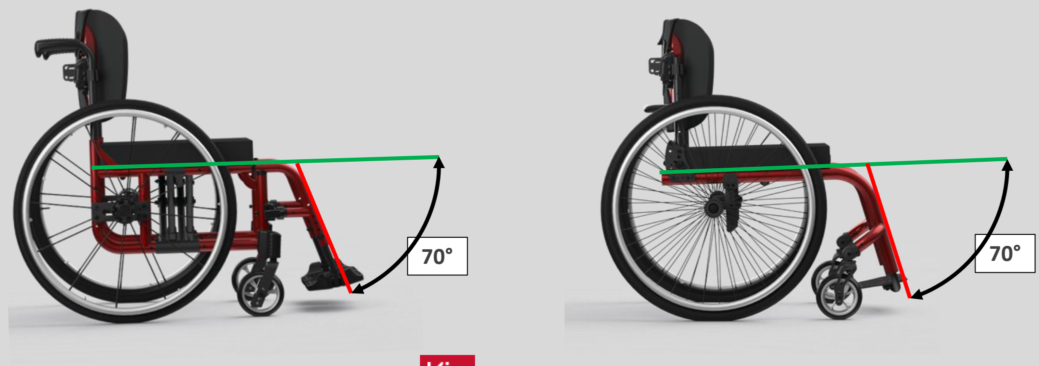
Yang et al., (2012)

A second study by Yang et al showed that with a lower backrest subjects demonstrated…

clinically, there is a need to strike a balance between needed stability and UE mobility

Front Frame Angle

Measurement of lower leg support angle



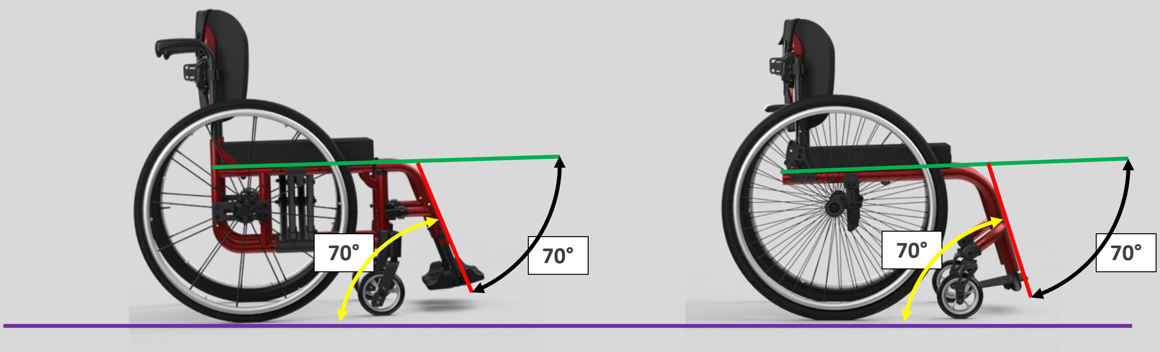
The last setup factor we're going to discuss is front frame angle. . .

For a chair with a removeable footrest, the footrest angle is measured in relation to seat rail, assuming a level seat/horizontal with the ground

For a rigid chair, the paradigm is more complicated

Front Frame Angle

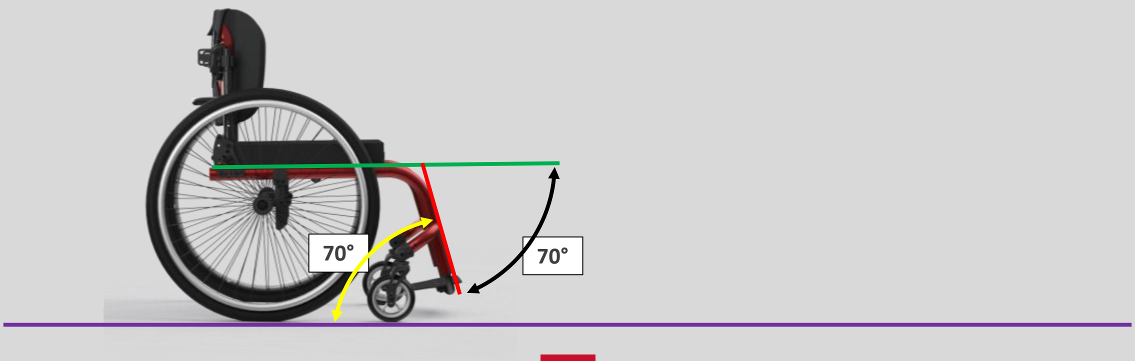
Measurement of lower leg support angle



When you look at an order form, most manufacturers relate the angle of the frame to the ground, like the yellow arrows,
Some manufacturers will always give you that angle in relation to a level seat, regardless of 'dump' or seat inclination at time of order,
others make it true – matched to the seat inclination at the time of order

Front Frame Angle

Measurement of lower leg support angle

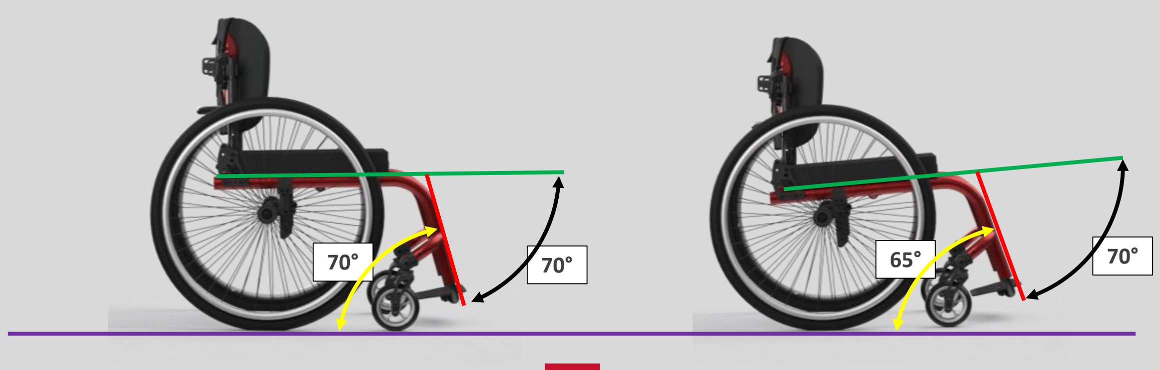


BUT, if you add in seat slope later, ALL BETS ARE OFF.

Left image: Rogue 4 – unoccupied
Right image: Rogue 5 - unoccupied

Front Frame Angle

Measurement of lower leg support angle



You may start out with a true 70 degree frame angle, but when you add seat inclination you will end up with less

Left image: Rogue 4 – unoccupied
Right image: Rogue 5 - unoccupied

Front Frame Angle

Considerations

- Hamstring length
- Range of motion (hip/knee/ankle)
- Spasticity/Tone
- Seated stability
- Maneuverability

important to consider what factors may impact the choice of front frame angle at initial prescription and in the future:

Putting It All Together

Now that we have looked at the specific aspects of chair setup, recap the important take-aways

Putting It All Together

A wheelchair needs to be set up for all the activities that a user performs from the device

First, if we focus only on propulsion, we potentially exclude setting the wc for how it may be used up to 90% of the time. Remeber the Bouts of Mobility study where users were only moving about 10% of the time

Putting It All Together

A wheelchair needs to be set up for all the activities that a user performs from the device

It requires adjustability to optimize the setup for changes in functional ability and need

Requires adjustability to optimize the setup for changes in functional ability and need – over the life of the chair

Putting It All Together

A wheelchair needs to be set up for all the activities that a user performs from the device

It requires adjustability to accommodate changes in functional ability and need

Adjustments to a single set up factor do not happen in isolation

We didn't look at all possibilities, but consider the impact of many of the changes we discussed on things like CG and weight distribution, which impact stability and propulsion efficiency of the chair.

Putting It All Together

A wheelchair needs to be set up for all the activities that a user performs from the device

It requires adjustability to accommodate changes in functional ability and need

Adjustments to a single set up factor do not happen in isolation

Using Evidence Based Practice provides a framework to plan for potential changes in wheelchair setup

Evidence Based Practice can help us effectively plan for potential changes in wheelchair setup, both at the time of prescription, and in the future, so that we don't wind up with a chair that we are unable to modify to meet the user's needs

Putting It All Together

Optimize the Wheelchair to Take Advantage of the Technology to Get Best Outcomes, Now and In the Future!

Instead, what we want to be able to do is. . . .

Questions

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