25 Configuration Choices for Efficient Wheelchair Propulsion

Michael Babinec, OTR/L, ABDA, ATP

The first title for this article was, **"Why is this chair so hard to push when it weighs so little?"** The second title describes the text more accurately. What choices and recommendations can we as Clinicians or Rehabilitation Technology Suppliers make to allow manual wheelchair mobility to be as easy as possible for those who depend on it daily?

This is more than just a nice thing to do, but critical - if we are to avoid setting the stage for repetitive strain injuries (RSI's), shoulder injuries, pain syndromes, address endurance and sitting tolerance issues, or simply promote independent mobility. Remembering to look at a big picture is a huge part of this process, but one that is often overlooked. All of this is prior to teaching the propulsion techniques and wheelchair skills involved, another topic altogether.

How many times have you been asked, "How much does this chair weigh?" The weight of a manual chair is certainly a primary contributor to efficient manual wheelchair propulsion, but is by far not the only contributor. Lightest weight does not always translate to highest efficiency. There is a much bigger picture here. Placing an emphasis on "overall performance" can make much more of an impact than placing it on "overall weight". In some instances, the weight of the components (accessories, wheels, tires, casters, riggings and footplates, etc.), weigh more than the weight of the wheelchair itself. The propulsion efficiency can be further compromised with poor configuration choices.

Better questions to ask might be… "What components were (or were not) included in the weight of this chair?" "How much flex is there in the frame?" "Is the weight of the chair distributed well or is it very front loaded?" "What configuration was measured to come up with this weight?" "Do parts flex more than they should?" "Do parts easily remove when needed?" "Are these high quality bearings used for the wheels and casters?" "Are all 4 wheels in true alignment or only "just close enough?" "How easy is it to set up center of gravity for propulsion and stability requirements?" These are just to name a few.

There are certainly more than these 25 configuration & component choices to consider with manual wheelchair recommendations. Each of these 25 points can be a separate article unto themselves, and many already are. In Rehab, we need a place to start, and then we modify and adjust from there. Here is a place to start.

25. Lightweight Frame: Lets start with the most intuitive. The lighter the frame – the easier to propel – no argument here. Materials used to build a frame certainly make a difference. Steel frames weigh more than Aluminum, which weigh more than Titanium. Chairs built entirely of aluminum tend to weigh less than their counterparts made with some steel componentry & some aluminum.

Folding chairs with adjustability and growth certainly have many benefits. A liability for some however, may be the added weight required for the materials to allow these adjustments. This is the simple reason why rigid chairs often weigh significantly less than folders – less material overall.

24. Eliminate / Reduce Flex in the frame: The more a frame flexes during propulsion, the less efficient it is to propel. This flexing can be a benefit for some, but is more often a liability. Rigid chairs are much easier to propel than their folding counterparts as more of the users energy goes into propelling the chair rather than get absorbed (sapped) into the flexing frame. High quality folding frames include the elimination of excessive flex during propulsion activities.

23. Weight Distribution: When excessive weight is placed over the front casters, (front loading), there is significant rolling resistance the user has to overcome when attempting to propel the chair. Turning right or left can be quite a challenge in a front loaded chair. The greater the front loading – the greater the effort required to propel the chair. Consider where the user is positioned in the chair. Positioning of the large (drive) wheels, as well as choice of back type will impact weight distribution. Some aftermarket backs added to a wheelchair can position a user too far forward in front of the back canes – placing undue weight over the front of the chair if not chosen appropriately or installed to the user's advantage.

22. Wheel Positioning: Center of Gravity (C.O.G.), Fore and Aft positioning of the wheels, has a tremendous impact on ability to push a manual chair. It is critical to find the balance between stability and propulsion efficiency. Several principles apply here. First, the longer each propulsion stroke, the fewer it will take to go from point A to point B. Wheels placed toward the back for stability will inhibit the user's ability for a long propulsion stroke, requiring more frequent effort, (and stronger effort, as wheels placed further back will shift the C.O.G. closer to the front casters). Wheels placed more forward will make the chair easier to push - less front loading and a longer propulsion stroke- but may make the chair unsafe for the users skill level, as it can be too tippy for some. Rehab is often about finding a place to start, and then adjusting / modifying from there. A good place to start is to take a step back & look from the side, (big picture), and look for Head over Shoulders over Pelvis over Axle. Some clinicians like to look for the tip of the middle finger to be at or near the axle hub when a user's arms are relaxed over the side of the chair. Balance the need for stability with maneuverability & propulsion technique.

21. Component and Accessory weight: The more components added to a chair, the heavier it becomes, and the harder to propel. This can be as impactful choosing to add too many components as well as simply choosing the correct type. As an example, Single point arms like the tubular style (sometimes called a swing away half arm), weigh significantly less than two point adjustable height full length conventional arms, with many options in between these two.

There are clearly advantages to adding suspension to a manual wheelchair. Many very active users derive many benefits from suspension. One disadvantage however can be the added weight to the overall frame. This added weight could be a liability. When considering the many types available, remember not all suspension systems weigh the same.

20. Correct Seat Width (and Depth): The old Mantra used to be "Measure the hip width, then add an extra inch on either side to determine chair width". The new Mantra is "Make the Chair as narrow as possible – for accessibility reasons through doorways and such, AND to place the wheels as close to the user as possible for propulsion. It is much easier to push a manual chair with the wheels in close to the side than if they are positioned six inches outward. Seat depth too short simply leads to pain and discomfort (and sometimes worse). Seat depth too long will force the user to slide out of the chair, placing them in a mechanically disadvantaged position to propel.

19. Correct Back Height and Type: Back Support placed too high can interfere with scapular excursion, or the normal movement of the shoulder blade during active arm motion. Choices that limit upper extremity range of motion for those who depend on their upper extremities for function can have dire consequences. Heights set too low may not provide adequate support for the seated posture. Solid backs are great for providing a solid surface to push off from, but do add weight over an upholstered back. Back canes that have an 8^{o} to 10^{o} bend follow the upright posture of an active propeller much more closely than straight back canes, which unless opened up at the angle, can in some instances encourage a kyphotic sitting posture.

18. Correct Back Angle: Many wheelchair back angles are set at 90^{o}, but not everybody in a wheelchair has 90^{o} of hip flexion available – a requirement to sit in this chair. Individuals with less than 90^{o} of hip flexion will be forced either slide out of the chair, or sit with a rotated pelvis in the seat as they extend their hip on the side with limited flexion available. Both of these postures, sliding and sitting rotated, create a slew of problems for the user. In addition to limited hip flexion, reasons to open up or increase a seat to back angle include comfort, visual line of sight, posterior tilted pelvis, kyphotic trunk, respiratory needs, positioning for swallowing, and postural stability.

17. Correct Seat to Floor Tilt: Placing the front Seat to Floor higher than the rear positions the user in a slight degree of tilt. This can be extremely helpful to allow gravity to hold them against the contours of their seating system & thus both keep them in the chair and provide comfort and stability at the same time. Placing the chair in a slight degree of static tilt is especially helpful when opening or increasing the seat to back angle to prevent sliding out of the chair. Raising the rear axle, using smaller wheels, using larger casters, or lowering the front casters can accomplish static tilt.

16. Seat to Floor Height: Foot propellers need to have a seat to floor (StF) height that will allow their strong leg maximum pulling power with a long stroke. This often requires a StF such that when the strong leg is positioned at 90^{o} knee flexion, the foot is flat on the ground. Interesting to note is that StF heights set too low for foot propellers contribute to the same sliding forward out of the sea as heights set too high. For those who are not foot propellers, StF heights too high can cause accessibility problems and transfer problems.

15. Wheel Size: Size does matter - for propulsion. A larger wheel will allow a longer propulsion stroke, (thus fewer propulsion strokes to go from point A to point B) than a smaller one. Smaller wheels can be used to place a chair in static tilt, or turn it into a very low seat to floor height, but at the penalty of more frequent propulsion strokes.

14. Tire Type: Wider tires (most in contact with the ground) offer greater rolling resistance than narrow tires during propulsion, but offer great support for heavy loads and do better over soft surfaces. Narrow tires, (least in contact with the ground) are lighter & roll easy on firm surfaces, and require less work to propel over firm level surfaces. Pneumatic tires offer some shock dampening, low-pressure more than high-pressure, but add weight to the chair. Pneumatic tires that are below recommended air pressure are more of an exercise in body-building than an exercise in mobility. Flat Free Inserts offer protection against tire damage and air loss, but add weight to the overall chair.

13. Wheel Type: Spoke wheels are lighter than Composite wheels, but do require maintenance from time to time. Spinergy™ wheels are lighter than spoke wheels, and have a majority of the weight centered around the hub for easier propulsion, but are a cost issue for some. Although I cannot recall the source, adding one ounce of weight to the wheel is said to be the equivalent of adding one pound of weight to the chair for propulsion activities.

12. Hand Rim Type: Although the lightest hand rim seems to be aluminum, it may not be the easiest for the user to grasp for propulsion. There are several new types of hand rims available, many ergonomically designed for efficient propulsion or efficient hand position / grasp. One arm drive hand rims are still available, but not significantly easier to use than they were 5 years ago. Just because an individual is capable of using a one arm-drive chair, or hand rims that have projections to allow use with little to no hand grasp, doesn't necessarily mean they should. (The easiest one-arm drive wheelchairs to use often come manufactured with two batteries and a joystick).

11. Camber: Placing camber in the rear wheels makes a chair more responsive to propel, and brings the wheels closer to the body for an efficient push. The trick is finding the amount of camber that will bring efficiency to propulsion while still letting the user get through the doorways in their environment. Chairs with easily adjustable camber are often a good choice for very active users who can reduce the camber for a narrow footprint indoors, but increase the camber for more efficient propulsion over longer distances outdoors.

10. Wheel Lock Type: Push to lock or Pull to Lock… That is the question… It is not usually a good idea to change this configuration from the first chair when making recommendations for a second or third chair. Those are surprises the user can do without. On a first chair however, there is a strong argument for pull to lock. When these are unlocked, the lever arm is often pushed forward and out of the way. This keeps the wheel locks as far out of the way as possible when in the unlocked position to allow a long propulsion stroke without hitting the thumb on the wheel lock. Under-mount locks usually hide completely out of the way in the unlocked position.

9. Caster Size: Smaller caster sizes have a smaller caster swing or smaller caster trail under the chair when turning. A smaller caster trail is proportionally related to responsiveness of the chair. The smaller the caster swing is, the more responsive the chair is during propulsion. Although small casters can make a chair more responsive and easier to propel, they perform poorly over obstacles and many outdoor terrains. Finding the compromise for the terrain the user will travel in is one of the issues here.

8. Caster Type: Pneumatic casters certainly absorb shock, but sometimes even just checking the air pressure will deflate the caster sufficiently to make self-propulsion difficult at best. Semi pneumatic casters are a good compromise, but can add considerable weight to the front of the chair.

7. Caster Fork: This relates back to caster trail. The shorter the fork, the smaller the caster trail, and thus the more responsive the chair can be. Larger forks have the advantage of allowing adjustment of front seat to floor height, but at some small cost.

6. Caster Placement: Leading or Trailing position is a choice for many casters. One way to make a wheelchair more responsive – manual or power – is to tighten the distance between the casters and the drive wheels. Placing casters in their trailing position, or toward the rear of the chair, allows for a smaller more compact footprint, and a more responsive chair. Placing them in a leading position – or in front of the frame, make the chair less responsive, but can make it more stable for some, (especially those positioned in a seat placed out in front of the back canes).

5. Align the wheels and casters. The front caster housings of a wheelchair need to be positioned perpendicular to the ground to allow the casters to roll without interference in all directions. Chairs that are changed from a level seat to floor to a slight tilt need to have the casters "re-squared" to the ground, or placed back to perpendicular, or the chair will be hard to maneuver. Rear wheels need to be assured that they do not toe in or toe out, but remain true for easy rolling. This can easily come out of alignment when adding camber to the wheels, or lowering rear seat to floor height of a chair with camber already in place.

4. Quality Bearings: Bearings that come loose or become over tightened will affect the ability of the wheel to spin on it's axle without interference. Bearings that collect dirt can perform poorly very quickly.

3. Foot Plate Type: Composite footplates weigh less than many aluminum footplates. Often overlooked though is the position of the footplate. Many composite footplates pivot at the center of the lateral edge. This positions the footplate closer to the rear of the chair for a smaller, more compact footprint – improving maneuverability. Many aluminum footplates pivot on the rear corner of that edge, placing the footplate out away from the user for a longer footprint with a slightly larger turning radius.

2. Front Rigging Type: The closer in toward the user the footplate is, the smaller the footprint of the chair, and the smaller the overall turning radius. 60^{o} front riggings protrude farther out from the chair than do 70^{o} riggings - making the larger footprint, but are required for some. Choosing tapered front riggings over traditional non-taper riggings (if appropriate for the users posture) will also make the front of the wheelchair more compact for easier maneuverability – smaller turning radius.

1. The number One way to make a chair easier to propel… Install two batteries and a joystick… Remember, manual mobility is not for everybody, and sometimes can actually cause more harm than good.

Michael Babinec, OTR/L, ABDA, ATP
Manager: Rehab Training & Education
Invacare Corp.
One Invacare Way
Elyria, Ohio 44036
440-329-6025
mbabinec@invacare.com