Assistive Technology & Seating Service
Vancouver Coastal Health

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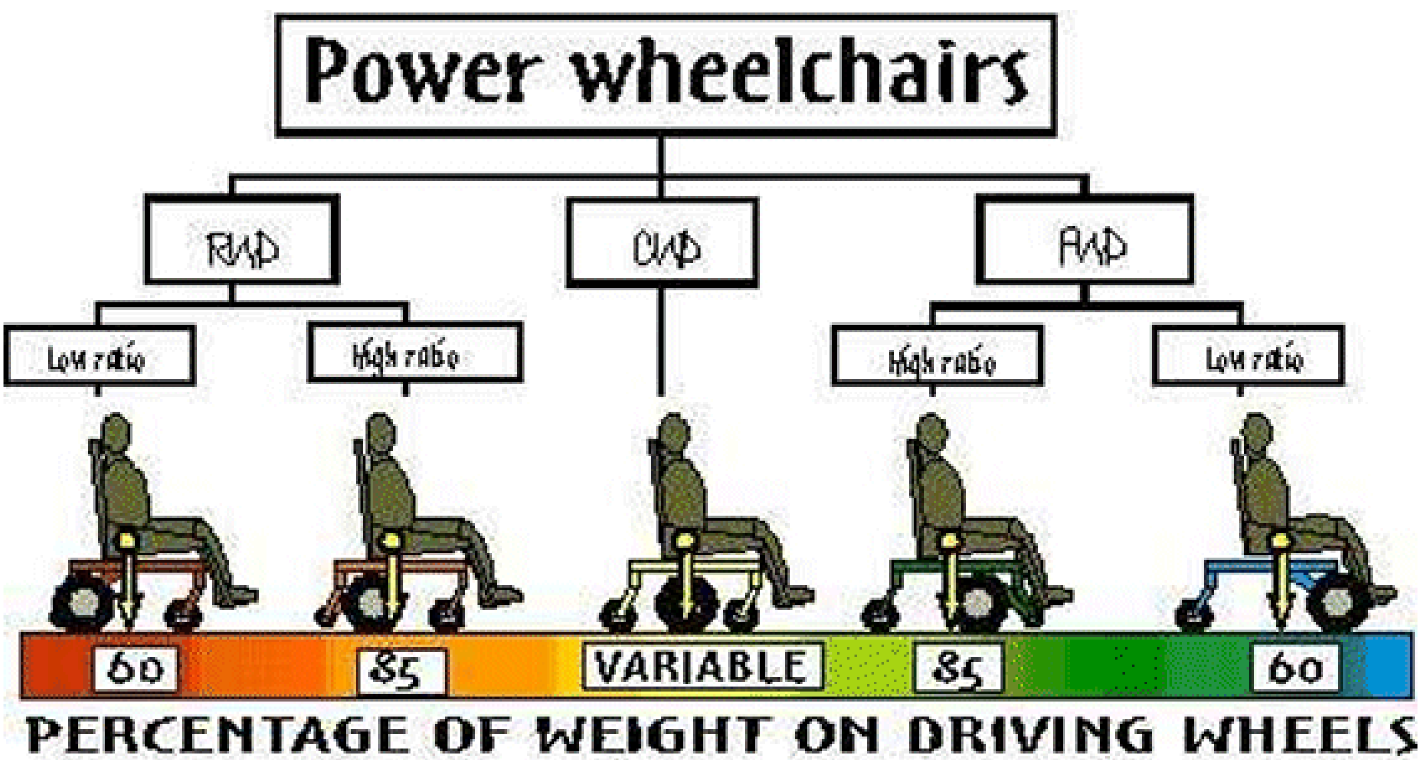
New Definition

Grouping or classifying any large collection of items is a critical tool that helps us predict how items within the same sub group will perform. It is important that the way the items are grouped is thought through carefully always keeping the objective in mind. Take pebbles on a beach for example, they can be grouped according to Colour, size, shape and texture etc. Each division is a valid one. However, if the objective is to collect good stones for skimming they should be sorted by shape, size and texture, colour would be irrelevant. If you wanted to collect rocks for decoration colour would be very relevant.

It is also important to decide when to stop sub dividing since it is possible to keep finding ways to divide the sub groups until every stone is in a group of it?s own.

So it is with power chairs. Traditionally power chairs were classified as Rear Wheel Drive (RWD) or Front Wheel Drive (FWD). The popularity of the Jazzy made a third category necessary and so the term Mid Wheel Drive (MWD) was coined. Then along came Vector with wheels touching the ground in front of and behind the drive wheels. Further confusion arose when Quickie and Invacare introduced models featuring wheels in the middle but some characteristics in common with their RWD stable mates.



Looking at the entire range of power chairs available to the consumer we found it necessary to redefine the classification system to understand and predict how power chairs perform. Our initial sub grouping is Rear Wheel Drive (RWD), Centre Wheel Drive (CWD) and Front Wheel Drive (FWD) this refers to the location of the drive wheels relative to the auxiliary wheels. Our second grouping classifies chairs according to the weight on the drive wheels. This classification makes it easier to understand and predict performance.

The wheels on a power chair can be located at the very back, the very front, or anywhere in between. For ease of understanding, this presentation considers the performance potential of chairs with 5 distinct wheel positions relative to the c of g.

The farther a wheel is from the c of g the less weight passes through it.

The ratio of weight on the driving wheels for centre wheel drive chairs varies depending on the caster location and whether the chair has suspension. I have tested CWD chairs with ratios ranging from 50% to 90% on flat surfaces.

A specific chair with weight somewhere between two of my examples will share characteristics from both.

New Definition

By this new definition, the chairs trialled in creating this report are categorized as follows:

Low Ratio RWD	High Ratio RWD	CWD	High Ratio FWD	Low Ratio FWD
The drive wheels are behind the centre of gravity (c of g). The front wheels are casters. The chair may have basic anti-tippers at the rear as a safety feature.	The drive wheels are behind the centre of gravity. The front wheels are casters. The anti-tippers at the rear are large and designed to be in contact with the ground in some normal driving situations.	The drive wheels are directly below the centre of gravity. The front and rear wheels are casters. They are designed to be in contact with the ground at all times.	The drive wheels are in front of the centre of gravity. The rear wheels are casters. The anti-tippers at the front are large and designed to be in contact with the ground in some normal driving situations.	The drive wheels are in front of the centre of gravity. The rear wheels are casters. The chair does not have anti tippers.
21st Cent. Bounder	Action Arrow RWD	Vector Velocity	Action Arrow MWD	Action Arrow FWD
Viva	Action Ranger X	Invacare Pronto		Permobil MPS

Quantum Blast	Ranger 904S	E & J Solaire		Permobil Corpus
Quickie S 525	Action Xterra*		Pride Jazzy*	Ω megaTrac® *
S?rider Spitfire 10	Quickie G 424*			Invacare Excel
Invacare Nutron	Quickie S 626*			
Quickie P200				
Quickie 222				
Quickie 121				
Invacare P7E				
Invacare P9000				
Invacare Ranger II				
Permobil Trax*				
Badger RWD				
Ranger 904				

Chairs spanning two categories exhibit some characteristics of each type.

* Indicates that the design incorporates a dynamic element allowing the chair to perform outside of the expected

performance envelope.

Factors Influencing Power Wheelchair Performance

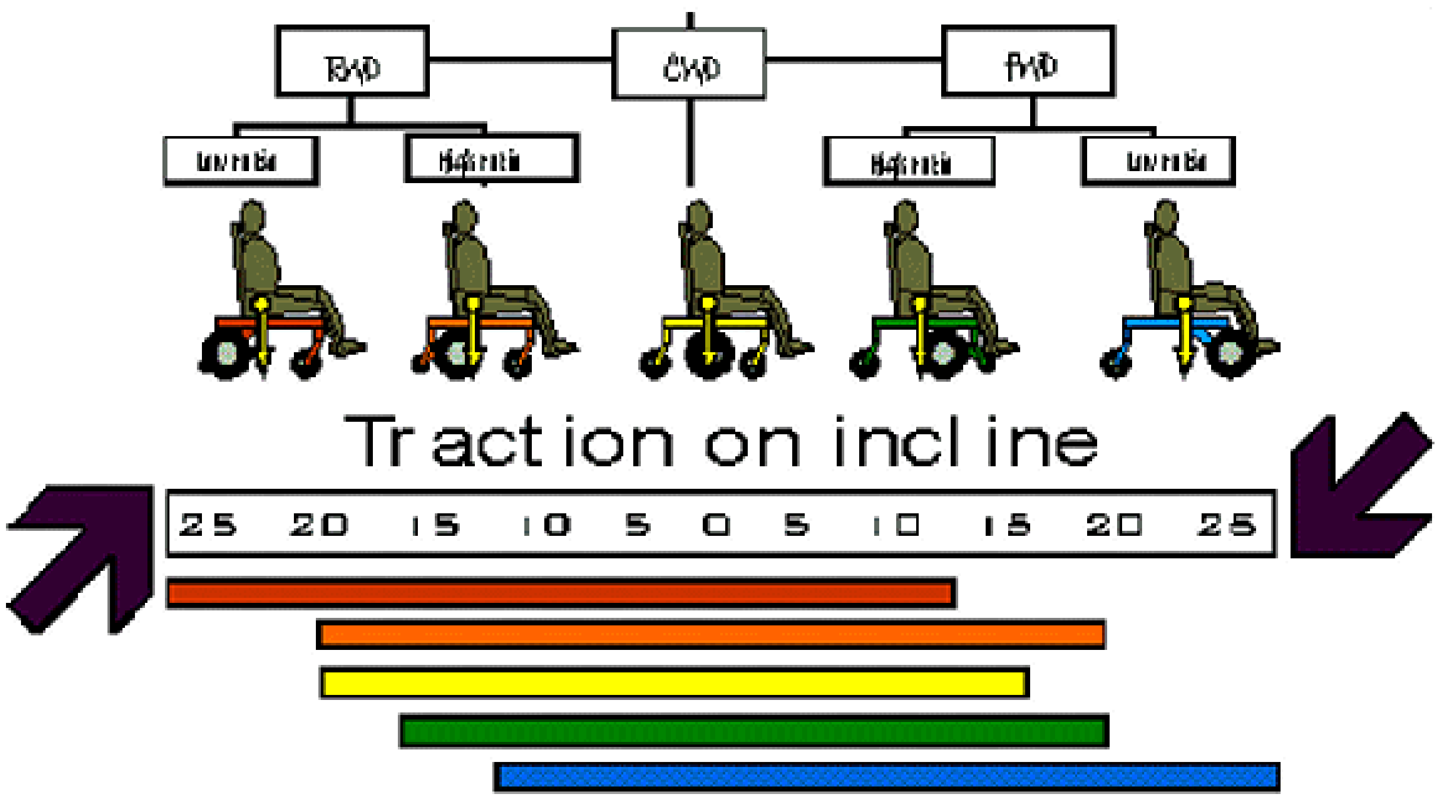
Our testing has given us an appreciation for the complexity of power wheelchair performance. To use an automotive analogy, if I tested a Ford Explorer and compared it to a BMW 318, it would not be fair for me to say that Ford vehicles have more cargo space and BMW?s are more responsive. It is also inappropriate to draw the conclusion that small cars are built by Germans and mid sized SUV?s are built in the US. Cause and effect must be analyzed and understood: some characteristics of a specific chair may be attributed to its base configuration while others are due to the programming. Many factors play an overlapping role in defining wheelchair performance.

Performance Potential

The main factors influencing performance are; Wheel location, power and power delivery

Wheel Location

The wheel location sets the envelope of the chairs maximum performance potential. It defines the upper and lower limits beyond which the chair cannot possibly function.



Using traction on a specific incline as an example, this diagram illustrates the potential of each configuration. For example the LR RWD chair cannot ascend a 26-degree hill. The chair would tip over backwards. It cannot descend a 13-degree slope without skidding out of control because all the weight is over the casters.

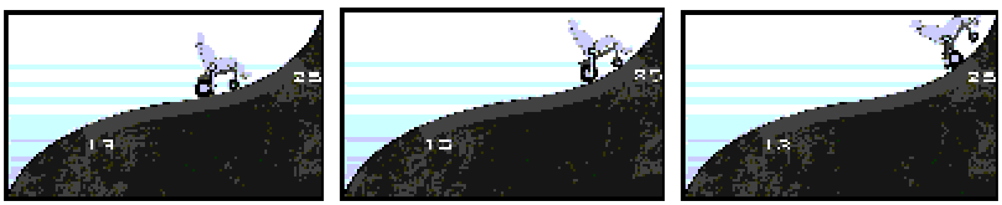
No amount of power or fiddling with the programmer will make the LR RWD chair safely descend a 13-degree slope. Or ascend a 26-degree hill

All five configurations have their own performance envelope that sets limits on the chairs potential.

Factors Influencing Power Wheelchair Performance

Power

Once wheel location is established the next defining factor to consider is power. The amount of power available determines how close the chair comes to achieving its potential.



If only moderate power is available the chair may only be able to climb a 13-degree incline. If moderate power is available the chair may be able to ascend an incline approaching its design potential. If "monster" power is available the chair will be able to reach but not exceed the limits pre-determined by the wheel location. Regardless of the available power the chairs performance when descending the hill will be unchanged.

Factors that contribute to putting power where it is needed i.e., the interface between tire and ground include:

- Wheel characteristics
- Battery capacity
- Controller rating
- Motors
- Drive mechanism (Direct drive or belt)

In the case of the LR RWD chair ascending an incline three things can stop the chair?s progress:-

1. Wheels stop turning - power is inadequate for the situation. Either the batteries are low or the controller and motors are not powerful enough for the task.
2. Wheels spin with casters on ground ? not enough traction to transmit power to ground. Putting more weight on the drive wheels or matching the tire design more appropriately to the terrain can resolve this.
3. Casters lift in the air ? the chair is approaching it?s performance limit and may be in danger ofg flipping backwards. Leaning forwards shifts the c of g forwards and restores traction.

Power Delivery

Once the basic configuration and available power have been established the power has to be delivered in a usable fashion. This is achieved by first choosing the appropriate driver control, be it joystick or switch or whatever.

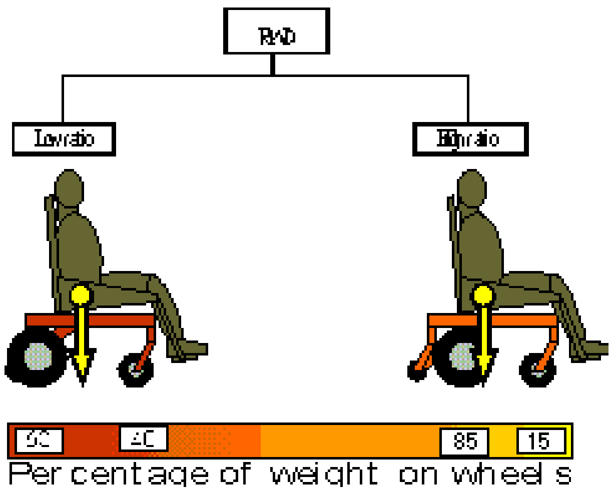
Programming then allows you to fine tune the power delivery. Different electronics manufacturers use different terminology and allow control over different functions. All, however only allow you to fine tune how the chair will perform within the performance envelope defined by the wheel location, wheel characteristics and available power.

Factors Influencing Power Wheelchair Performance

Drive wheel location relative to system centre of gravity

Horizontal location of C of G

The horizontal centre of gravity location determines how the weight is distributed between the driving wheels and the auxiliary wheels. Regardless of the tire type or the surface being negotiated, reducing weight on the auxiliary wheels produces less drag. Increasing weight on the driving wheels produces more traction.



Weight distribution is critical in determining how the chair will perform for a given user in a given environment. When a wheel has more weight passing through it, the performance characteristics of that wheel are more significant in determining the chair?s overall performance.

Whenever the chair is being driven, it is desirable to have as much weight on the driving wheels as possible.

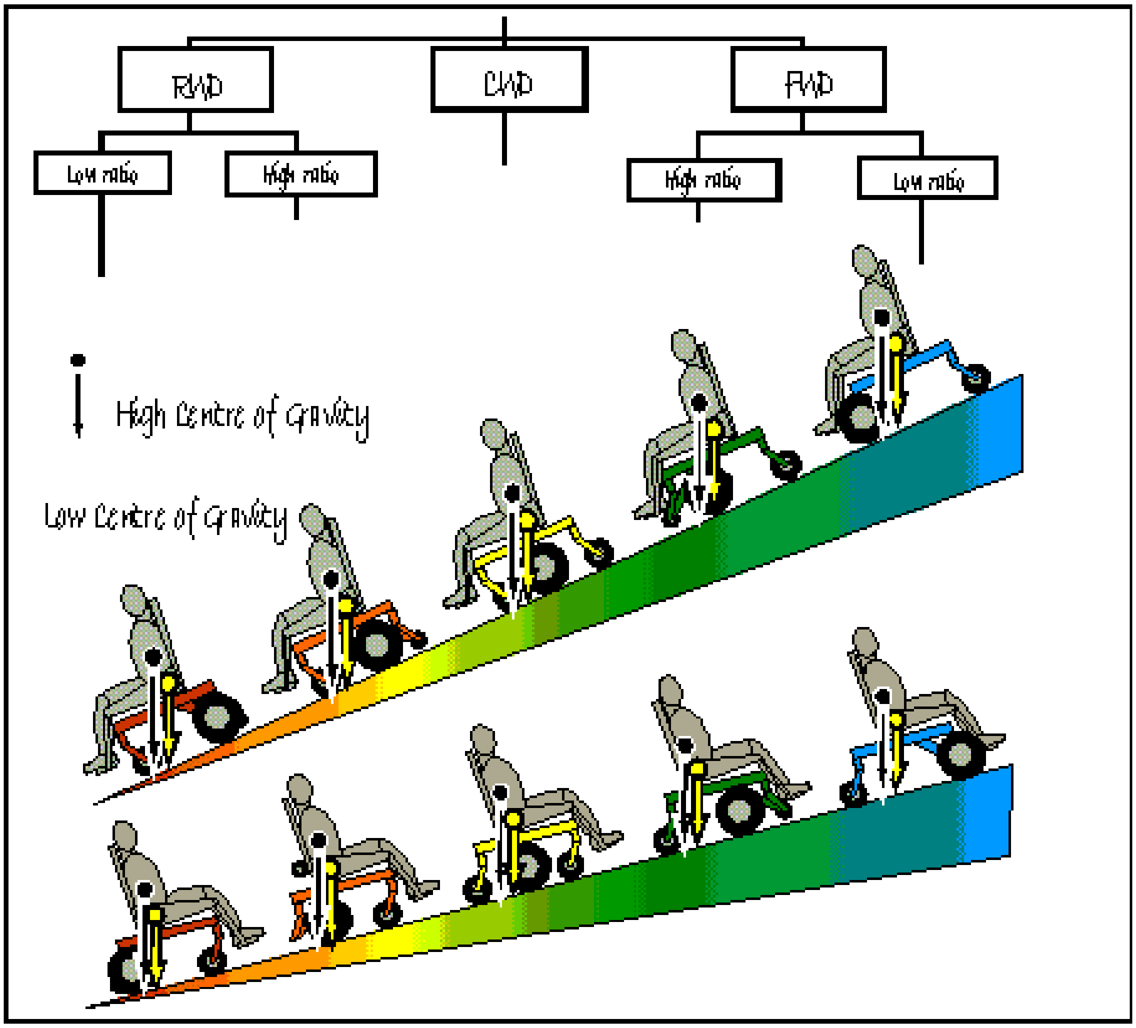
The effect of weight distribution is very evident when changing direction on slippery surfaces. Chairs with a significant amount of weight on their casters will spin their drive wheels and continue skidding in the same direction for a few feet. Those with nearly all the weight on their driving wheels will produce minimal wheel spin and a much quicker turning response. Wheelchair basketball players deal with the problem of skidded turns by popping wheelies prior to making a quick turn. This puts all of the weight through the driving wheels.

If the centre of gravity is in front of the drive wheels (as in all RWD chairs) the chair wants to continue in a straight line. If the centre of gravity is behind the drive wheels (as in all FWD chairs) the rear wheels want to overtake the drive wheels, requiring frequent steering corrections.

Factors Influencing Power Wheelchair Performance

Vertical location of C of G

The vertical location of the centre of gravity has an interesting effect on the performance of a power chair. A power wheelchair by design is intended to be dynamic; putting all the weight over the driving wheels is not the simple solution that it first appears. This is due to the height of the system centre of gravity affecting the weight distribution when the chair is being accelerated, decelerated, turned, or operated on an incline. A high centre of gravity amplifies these trends. A low centre of gravity causes these influences to have less of an effect on the chair?s responses.



In all aspects of power wheelchair performance a low centre of gravity is desirable. However, optimal performance may have to be compromised in order to meet the user?s desire or need for a higher seat height.

Factors Influencing Power Wheelchair Performance

Driving wheels

The driver of a power chair has direct control of only two wheels. The interface between these two driving wheels and the ground plays a crucial role in determining how a chair will perform. The ideal interface provides adequate traction to transmit all the chair?s power to the ground without creating wheel spin. At the same time the interface should not create excessive friction (drag), which wastes power.

The ideal balance of high traction and minimal drag is achieved by matching; tire diameter, width, tread design, air pressure and weight, to the surface being driven on.

Diameter

The optimal power wheelchair tire diameter is between 12" and 16". Large diameter tires roll over obstacles with less impact transmitted to the user. Tires larger than 20" are impractical since they require an energy consuming reduction gear between the motor and wheel.

Footprint

The footprint is the amount of tire in contact with the ground. It is affected by diameter, width, cross-section, air pressure and tread design. Generally speaking on level ground with good grip (e.g., dry concrete) a tire with a small footprint and smooth tread will provide the best balance of traction and drag. A tire producing a large footprint will perform better on soft terrain. An aggressive tread pattern will provide good grip and tend not to plug up if the surface is loose. On intermediate terrain a compromise tire will prove to be most suitable.

Type

Pneumatic tires offer the best traction and contribute significantly to ride smoothness.

The drawbacks are that they require pumping up every six weeks or so and may puncture. Thorn proof tubes or a "Tough strip" may offer a reasonably functional compromise. By adjusting the tire pressure pneumatic tires can be made to change their foot print to match the terrain e.g., releasing air will increase the footprint, improving traction on soft and uneven terrain. Semi pneumatic tires provide less traction and a rougher ride. The benefit is that they last for ages and will not puncture.

Suspension

Suspension aids in absorbing and dissipating shocks that occur when a wheel hits an obstacle. Suspension helps to reduce fatigue, pain, and spasms. In the case of some centre wheel drives the action of the suspension system can help to increase traction while torque is being applied to the wheels e.g., when ascending an incline. The suspension system can also reduce traction on the drive wheels particularly while descending a hill or negotiating a quick change of slope such as a curb cut.

Factors Influencing Power Wheelchair Performance

Auxiliary wheels (casters and / or anti tippers)

Weight on casters or anti tippers produces drag. Reducing the drag produced by these wheels is achieved by considering the same factors as for increasing traction on the driving wheels.

Diameter

Large diameter tires produce less drag and roll over obstacles with less impact transmitted to the user, contributing significantly to the total suspension effect of the chair. The larger diameter casters also require more space to make a complete revolution about the caster stem and this usually limits size.

Footprint

Generally speaking, on a smooth hard surface, a tire with a small foot print and smooth tread creates the least drag. A large wheel with a grooved tread pattern will provide a large footprint and minimize drag if the surface is soft and/or loose. On intermediate terrain a compromise tire will prove to be most suitable.

Type

Pneumatic tires at the front contribute significantly to the smoothness of the ride. Drawbacks are that they require pumping up every six weeks or so and may puncture. Thorn proof tubes or a "Tough strip" may offer a reasonably functional compromise. Pneumatic wheels at the rear have less of an impact on the overall performance of the chair. They should be considered if they carry more than 20% of the system weight.

Suspension

Suspension aids in absorbing shocks that occur when the wheel hits an obstacle. It may help to reduce fatigue, pain and spasticity particularly if there is a lot of weight on the auxiliary wheels.

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