FreeWheel™ Wheelchair Attachment – Evaluation
December 2010

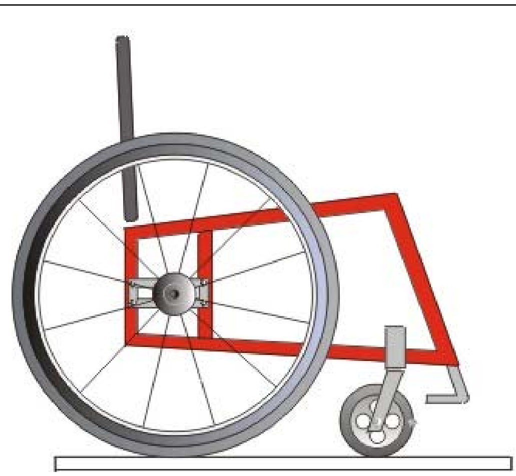
When I present lectures on wheelchair performance one of the things my audience seem to remember is a phrase I use; "Casters are parasites." I use this phrase to emphasize that a casters only contribution to wheelchair performance is to stop it from falling over. It is also important to understand the influence a caster has on the overall performance of a wheelchair is proportional to the percentage of weight it carries.

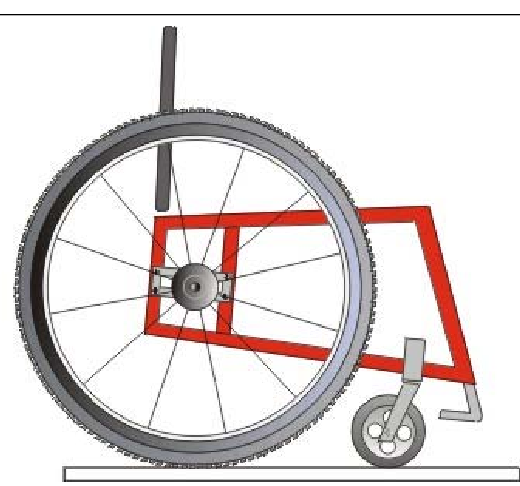
Caster characteristics should be chosen so the influence of the casters is minimized. If a chair is used indoors on hard surfaces, it is set up with lots of weight on the back wheels which are typically fitted with high pressure tires; the footrest is tucked in close so that the feet are under the knees. Small diameter casters are used because they do not require much space to swivel and roll reasonably well on hard surfaces. In fact, indoor performance has become so important that many high end wheelchairs can not be fitted with caster wheels larger than 5" in diameter.

The shortcomings in caster design have been addressed reasonably well with the evolution of the most recent version of the soft roll caster whose foot print changes rapidly; from small on hard surfaces, to large on soft surfaces providing a reasonable amount of "floatation". Also the use of suspension forks such as "Frog Legs" have, to some extent compensated for the lack of a pneumatic caster tire.

Despite these advances, the caster wheel, more than any other single component, limits wheelchairs versatility. Wheelchair users with an interest in wheeling on anything other than smooth hard surfaces such as beaches, parks, farms, etc. where the terrain is rugged and sometimes soft, often buy a spare set of wheels fitted with mountain bike tires. This helps reduce rolling resistance and provides improved grip to some extent, but those parasitic casters cause even more problems.

When wheels are exchanged for ones with different outer diameter, chair geometry is compromised, the caster stems are no longer vertical and the chair will be reluctant to turn. The seat has less 'dump' and the back is tilted forward putting more weight on the casters making them even more prone to digging in. This also puts the wheeler in a bit of a precarious position if trunk balance is compromised.





Chair with 24" conventional tires　　　　Chair with 26" MTB tires

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In order to avoid this change in geometry a wheeler has three choices:-

1. By far and away the most popular choice is to buy a 25” wheel with a high pressure 25” x 1” (559mm x 25mm) wheelchair tire on it. They also buy a set of 24” wheelchair rims and fit a 24” (540mm x ’personal preference) knobby treaded wheelchair tires to them. These wheel tire combinations have the same outside diameter and don’t change caster geometry. There are a limited number of tire treads available in this size and of course you are still stuck with the same parasitic casters in both terrains;

2. Another alternative is to use 26” wheelchair wheels with 26” x 1” (590mm x 25mm) high pressure tires for indoor use, and then buy a set of 25” wheelchair wheels to which you can fit any 26” mountain bike tire up to about 2.5” wide. This also has little effect on the caster stem geometry, but makes the chair almost unusable indoors; Or

3. Occasionally someone will switch both casters and wheels, allowing them to select and match casters and wheels more suited to each type of terrain. This option involves a lot of work to change from one configuration to the other.

Only the latter solution addresses the fact that the biggest hindrance to decent off road performance is the caster wheels.

The FreeWheel takes the existing casters out of the equation, and replaces the casters that were selected to perform in a certain setting with a wheel designed to perform in soft and/or uneven terrain. Conceptually it is very clever. I was given a free wheel and over the course of two weeks put it through it’s paces and analyzed the effect it would have on the wheelers ability to perform numerous everyday tasks.

The Chair
I used a Tilite Cross Sport rigid chair configured as follows:

	Cross Sport	Cross Sport with FreeWheel
		
Seat width	16.5”	16.5”
Seat sling	17”	17”
Back height	19”	19”
Back Angle	3 degrees	8 degrees
Front seat to floor	19.5”	21”
Rear seat to floor	17”	17”
Footrest clearance	1.75”	4”
Caster clearance	0”	2.25”
Overall width	24.75”	24.75”
Overall length	33”	49.5” or 64” if reversing
Turning Circle	42”	88”
Camber	3 degrees	3 degrees
Toeing error	0 degrees	0.5 degrees
Weight	28 lbs	32.5 lbs
Transport weight	11.5 lbs (16 lbs with Jay2 back)	11.6 lbs (16 lbs with Jay2 back)
Tire pressure	100 psi	100 psi rear / 40 psi front
Wt. Dist. % on rear	79% (84% with FW clamped to back)	92%
Tires	Pr1mo V trak - 24” x 1” (540 x 25)	Pr1mo V trak - 24” x 1” (540 x 25)
Casters	4” x 3/4” hard urethane	Horng Fortune 12.5” x 2.25” (54 - 203)
Wheels	Spinergy 18 spoke	Spinergy 18 spoke

Set up
My footrest is a “two tube with ABS plate”. Setting up the unit for the first time took me 15 minutes. The instructions were clear and concise and feature clear drawings and photographs. I also fitted the FreeWheel to a chair with a clamp plate; this was just as simple and took less than ten minutes thanks to familiarity with the process.

Setting up the perch for the free wheel which clamps to the rear rigidizer bar when not in use is simple enough but I suggest taking time to experiment with the angle the “U” shaped post is fixed at. It took me 15 to 20 seconds of fiddling each time I wanted to clamp the free wheel to the post. After I adjusted it so that the clamping shim was parallel to the straight surface when the free wheel hung from my finger it took less than 5 seconds and no fiddling.

Adjustments

Chair

In addition to setting up the FreeWheel you have to consider the effect carrying the wheel on the back of your chair will have on weight distribution (tippiness) I had to move my rear axle back by ½”to keep the weight distribution similar to the original value. Some chairs may also need wheel locks and caster stems to be adjusted. *Manufacturer’s note: Out of just over 1,000 users of the FreeWheel, none have expressed any need to change the COG.* Analysis of the situation led us to the conclusion that many people have their wheelchairs set up with a little too much bias towards the casters (70 – 75% weight on rear wheels). If the FreeWheel is mounted on the perch this shifts the bias more towards the rear wheels which improves wheeling efficiency. If, as in our case the chair is set up with strong rear bias (85% weight on the rear wheels) adding the FreeWheel to the perch makes the chair too tippy, particularly on inclines.

Free Wheel

The Owner’s Manual suggests adjusting the FreeWheel so that in the tail dragger position both the FreeWheel and casters are on the floor. I suggest that adjusting the FreeWheel so that the casters are slightly off the floor when you are sitting up is better. This keeps the casters off the floor whenever you are wheeling, even when going backward. As you lean forward to remove the FreeWheel; the weight shift causes the casters to contact the floor and make removing the unit simple. The instructions are clear and easy to follow to complete this step.

Bearings

Out of the box our wheel didn’t want to spin very freely, so we took the time to adjust the cone bearings to optimal tension.

Steering

Setting the wheel to track straight is simple enough and clearly covered in the instructions. I would add that you should make sure the footplate is level. I spent a frustrating couple of hours trying to get things going straight until I realized the problem. The set screw doesn’t hold as well as it should, maybe Loctite© will help, but we had to keep adjusting the steering to keep it tracking straight. When the tracking goes off, it is not catastrophic; just a bit annoying that you have to make more frequent course corrections.

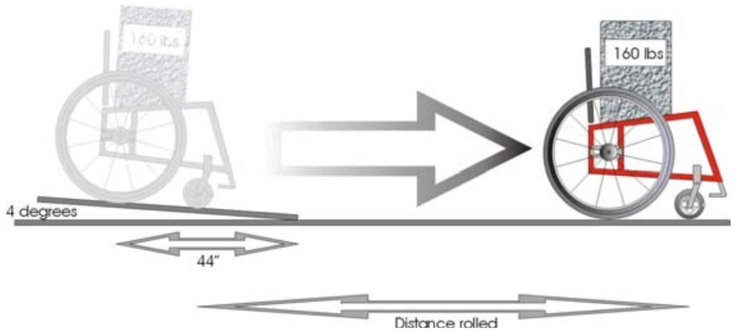
Installing and removing

With good hand dexterity and trunk control it takes about 5 seconds to complete each task. The clamping system is deceptively simple and effective. The FreeWheel clamped very securely to our footplate with minimal effort from the wheeler.

Geometry changes

- Front seat height is increased by about 2”.
- Backrest angle recline was increased by 5 degrees. The angle change was measured without an occupant, we expect the actual change would be 2-4 degrees, depending on the % of weight on the rear wheels, more weight would result in more of a change in back angle.
- With the free wheel installed overall length was increased by 16.5”or 31”depending if the wheel is in the trailing or leading position. No change with the free wheel locked on the perch.
- Centre of gravity was shifted back by both the addition of the FreeWheel’s weight to the rigidizer bar or the change in angulation caused by the FreeWheel. Either way, users should consider compensating for this by changing the rear axle position or if the back angle is readily adjustable, e.g., Elevation chair, tilting the back forward can accomplish the same thing. *Manufacturer’s note: Out of just over 1,000 users of the FreeWheel, none have expressed any need to change the COG.*
- Toeing is affected if the wheels have camber; ours had 3 degrees and the FreeWheel raised the front by about 2” and induced half a degree of toeing error (toed out). Another chair with 6 degrees of camber had a 1” toeing error induced by the FreeWheel.

Performance - All tests were performed by a 160lb able bodied, experienced wheelchair user. Or in the case of roll down tests with a 160lb weight distributed over the wheels the same as a person.



The distance rolled in this type of test is inversely proportional to the effort required to wheel the chair.

Distance rolled on hard surface	**Distance**	Comments 4 degree ramp rear wheels 44" from start of gym floor.
Regular chair	45'7"	Chairs rolled same distance on hard surface
FreeWheel	45'3"	

On hard smooth surfaces the standard chair and FreeWheel require the wheeler to expend the same amount of energy to roll a given distance.

Distance rolled on soft surface	**Distance**	**Comments** 4 degree ramp rear wheels 44" from start of 1" Resilite mats.
Regular chair	6'3"	
FreeWheel	8'8"	The Free Wheel equipped chair rolled 25% further

We used therapy mats for this test and clearly the standard chair would require significantly more energy to propel in a straight line on soft surfaces like carpet, grass, mulch etc.

Slalom	**Time**	**m/s**	**km/h**	**mph**	**Comments** 10 cones placed 1m apart, there and back.
Regular chair	27.2s	0.7	2.7	1.7	
FreeWheel	35.8s	0.6	2	1.2	Surprisingly easy to maneuver accurately but overall length necessitated wide turns.

As expected the standard chair was 25% quicker through this tight maneuverability testing course, what surprised us was how easy it was to negotiate the course with the FreeWheel.

Outdoor asphalt path	**Time**	**m/s**	**km/h**	**mph**	**Comments** Rolling smooth surface 103m long with max incline of 1:13 (5 deg or 8%) Figure of 8 shape.
Regular chair	76s	1.3	4.8	3.0	The chair made sharp turns easier while travelling quickly.
FreeWheel	67s	1.5	5.6	3.4	The chair was easier to steer around gradual curves while descending.

The FreeWheel gave the chair a sense of stability and significantly smoothed out any irregularity in the pavement. I felt a little bit of trepidation making fairly sharp turns at speed because slowing down the inner push rim adequately to make the turn took more pressure than with the standard chair and I had to be careful not to burn my hands.

Lap of GF Strong	**Time**	**m/s**	**km/h**	**mph**	**Comments:** 500m Mixed hard surfaces including concrete, asphalt, metal grates, speed bumps and various curb cuts. 1:9 descent and 1:8 ascent.
Regular chair	240s	2.1	7.5	4.6	Rough ride over grates, a little nervous making curb cut and turn at the same time. Had to slow down approaching speed bumps.
FreeWheel	220s	2.3	8.2	5.0	Able to negotiate speed bumps at full speed, metal grate transition markedly smoother than without FreeWheel. Ascending hill took less balancing of power and weight distribution i.e. I could lean forward a long way to keep the front wheel on the ground without significantly increasing the drag.

I was surprised at how much the free wheel improved the overall feel of the chair and I wonder whether a significant number of people might find this environment the one they use the FreeWheel in most often. A lap of our facility exposed me to black top, concrete, leaf covered pavement, metal grates, speed bumps, inclines, side slopes and compound slopes. In all cases the FreeWheel enhanced the performance of the chair and improved the quality of the ride. In terms of time the FreeWheel was 9% faster, subjectively the ride was much much better.

Wet Grass	**Time**	**m/s**	**km/h**	**mph**	**Comments:** Flat wet, boggy grass 27 m in length
Regular chair	69s	0.4	1.4	0.9	The chair was in a wheelie almost the entire course.
FreeWheel	40s	0.7	2.4	1.5	The chair was in a wheelie part of the time.

Wheeling on this surface is a bit of a paradox, rookie wheelers want to put as much force as they can into the push stroke and achieve this by leaning forward. This weights the casters - increasing drag and reduces traction to the rear wheels. Experienced wheelers lean back or pop a wheelie to reduce drag and maintain traction at the expense of the power they are able to put into their stroke. The FreeWheel allows you to put more power into your stroke without digging the front end into the ground. Having said that I still lifted my front wheel for a good part of the course. The FreeWheel makes popping a wheelie less of a twitchy experience since the long lever arm of the unit means that the chair has to go through a bigger angulation change to affect the overall centre of gravity.

Threshold	**Height**	**Comments:** Wheeler rolls directly at threshold and does not shift weight to lighten front end.
Regular chair	<1”	Casters dig in at anything close to an inch.
FreeWheel	4”	Smooth transition even at 3” little rough at 4”.

To test this I rolled my chair towards a threshold so that I would hit it perpendicularly. I closed my eyes before impact to make sure I wasn’t using body English to help the chair. The FreeWheel provided a smooth ride over a 3” threshold and was able to comfortably and consistently climb 4” though it was a bit rough.

Max Curb Up	**Height**	**Comments:** The highest curb wheeler is able to ascend.
Regular chair	10”	Good technique and timing make this possible.
FreeWheel	7”	Timing is difficult; to negotiate high curbs with the FreeWheel it is necessary to pop the FreeWheel over the curb and land it on the upper surface after the casters cross the curb and before the rear wheels hit.

If the wheeler has good technique and trunk control they will be able to climb a much higher curb in the standard chair. Perversely it is the casters that compromise the FreeWheel’s ability to climb high curbs. The wheeler’s timing has to be so precise in popping and landing the front end on the curb that it is unrealistic to expect most people to get consistently good at it.

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Max Curb Down	**Height**	**Comments:** Highest curb we were able to roll off without popping a wheelie and landing on rear wheels.
Regular chair	4”	Beyond this the wheeler pitched out.
FreeWheel	12”	In addition we were actually able to descend stairs with an 11” tread and 7” riser in the forward direction by grasping the hand rails on either side.

The FreeWheel increases the wheelbase of the wheelchair sufficiently that it is possible to descend average stairs, (with a hand rail on each side) in the forward direction without pitching out of the chair. The wheeler has to have good arm strength and trunk control since the entire weight of the chair and wheeler is on them.

Concerns
We used the FreeWheel extensively during our two week test period. During that time the unit was mounted on three different chairs. It proved to be remarkably problem-free for a clamp on accessory when mounted on the initial chair which had a two tube with plate design.

Two tube with plate

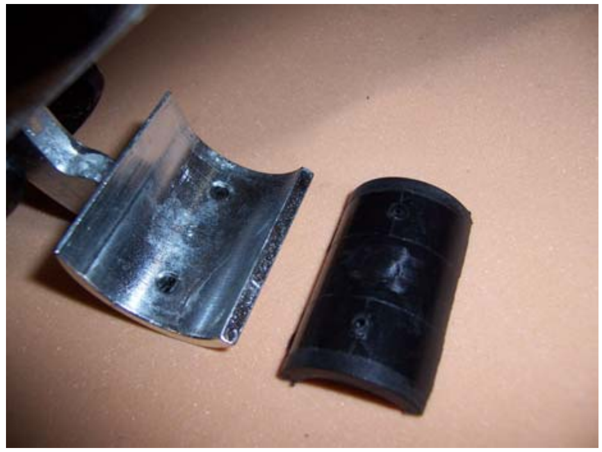
Clamp plate

Problems were as follows:-

- The unit fell off twice probably due to improper securement on our part, regardless of the cause it is reassuring the consequences were minimal since the chair casters only had 2” to drop.
- The clamp loosened, with the result that the FreeWheel leaned over sideways a little during maneuvering, tightening an Allen bolt fixed the problem in no time.
- Our unit showed no signs of damage other than a little wear on the “rear end” which can be replaced for a modest fee should that become necessary.
- The FreeWheel mounting system focuses any impacts experienced by the large wheel into the footplate assembly, a significant degree of flex was noticed by all testers most of whom liked that the shock was being absorbed. However, I am concerned that this may prove to be problematic for the FreeWheel since the flex appears to occur at the footplate. Ours was made of titanium, a metal which tolerates repeated flexing. Aluminum on the other hand does not tolerate being repeatedly flexed very well and is more likely to break if subject to this kind of force. *Manufacturer’s note: In over 4 years of reliability testing on aluminum chairs there have been ZERO breakages.*

After I completed my testing the FreeWheel was mounted to a chair belonging to a client with considerable rural wheeling experience. He had a Ti Lite clamp plate footplate and this particular mounting is described on the last page of the Set Up Guide provided with the FreeWheel. I failed to follow instructions with the result that I bent the cup securing the FreeWheel to the footplate. To it’s credit the clamp held the footplate securely for three days. It was only after we tried to fit the unit to a third chair with a two tube footrest that we discovered the damage.


Bent Cup


Broken extrusions

The other damage I will take responsibility for are the broken extrusions on the cup shim, care should be taken when removing the shim to push it out of the holes in the cup from the bottom (as it sits on the chair), it would probably be a good idea to leave the screws partially in the holes and press them out to get you started. Most users are unlikely to have this problem since this is only a concern when fitting the unit to different foot plates.


Bent rear end

We bent the rear end when using it on the second chair. This was entirely our fault, the rear end doesn't need to be really tight. (As the instructions clearly state.) The front clamp does nearly all the work of securing the unit, the rear end just holds the FreeWheel on the footrest when you pop a wheelie or impose side forces. *Manufacturer's note*: *Of the one thousand units sold we have replaced free of charge four rear ends.* So once again make sure you follow the instructions.

Summary

Be careful setting up the FreeWheel to your chair, it isn't difficult just important that you do it right. The instructions are very clear, follow them diligently.

The FreeWheel showed no inclination to flutter and isolated the wheeler from the many irregularities encountered when wheeling along sidewalks. Ninety two percent of the weight on the rear wheels in a conventional chair is too much for most people and would result in inadvertent wheelies when wheeling up hill or even wheeling with gusto on level surfaces. However, 92% with the long lever of the FreeWheel sticking out at the front works fine and it is nice to be able to lean into your push stroke when climbing hills or pushing across soft terrain without having the casters rob your push of it's oomph.

When you do venture inside or need to put your chair in a vehicle, the FreeWheel detaches from the footplate and can be stowed securely on the back of the chair in less than 10 seconds. It bears mentioning that using the FreeWheel indoors is not terribly difficult but the chair does handle better without it.

If the free wheel is used extensively I suggest the chair be set up so toeing of the wheels is set so energy expenditure is minimized e.g. it might be better to have $+^1/_4$" toe when using casters and $-^1/_2$" toe with the FreeWheel than 0 and -¾" respectively. Bear in mind that there is inherently less resistance to rolling with the FreeWheel fitted when the chair is used on practically any surface, hard or soft.

If larger knobby tires are used whenever the FreeWheel is used in off road settings two benefits will be realized. The 25" wheelchair rims can be fitted with a vast selection of mountain bike tires. And the toeing error induced by use of the FreeWheel will be offset somewhat by the use of a larger diameter rear wheel.

The FreeWheel is brilliant. It addresses the problems associated with casters by replacing them with a purpose built alternative. In fact the FreeWheel was so good at all outdoor activities I would suggest that most people would use it in any situation where manoeuverability isn't the most important characteristic. A wheeler does not need to choose a compromise when selecting casters for their chair, casters can be selected for indoor use and the FreeWheel attached for outdoor use.

Ian Denison

Full time Wheelchair Users Perspective

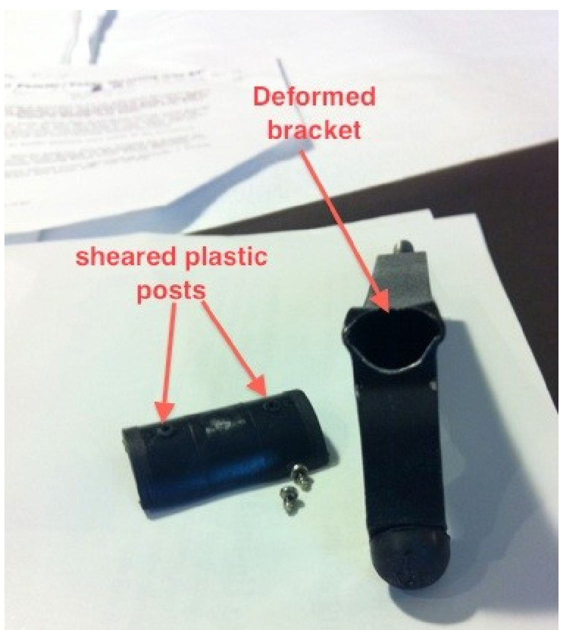
I really enjoyed you letting me demo the freewheel, I can see that this sort of attachment to my chair would provide much greater mobility and enjoyment of a number activities. Unfortunately I never got to try this out in the advanced terrain that I had wanted to due to scheduling at GF during the few days I had it.

That said, within the urban environment and the basic rugby pitches and grassy areas I tried it in it performed greater than my expectations. I love the turning radius of this unit. I was able to turn comfortably in tight areas, not feeling too out of place even going into the Safeway food store and getting a few groceries and not feeling stuck in the display cases.

Turning on small hills felt stable despite my initial fear of tipping sideways. I did not feel like I could get enough weight over the front wheel (freewheel) when going up some grassy inclines and slopes, but this is not the fault of the freewheel, more just the reality of having so much weight over the rear wheels. Sidewalks and other urban bumps, drops and grooves were a breeze to navigate, both dropping off and jumping up. I know this would work out very well in my backyard as it is grassy and hilly with lots of divots in the ground.

Although I was anticipating using this more in a rural like setting, the area that I most enjoyed using it was actually in the urban environment. The freewheel gave me confidence to go belting down sidewalks at speeds that I would normally reserve for a hand cycle.

I was disappointed that while it was easy to attach to my chair, when we tried to adapt it to another chair we found that it would not attach to his tubular footrest as the gap between the tubes was too short. Thank you for letting me have a go with it.



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