INITIAL EVALUATION OF THE FREEWHEEL™ WHEELCHAIR ATTACHMENT

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INTRODUCTION

The FreeWheel™ wheelchair attachment was developed to overcome the burden that front casters pose to manual wheelchairs[1]. The phrase "casters are parasites" was coined to emphasize that casters only contribution to wheelchair performance is to stop it from falling over[2]. It is also important to understand the influence that casters have on the overall performance of a wheelchair is proportional to the percentage of weight they carry[3]. The different methods of wheelchair setup further underscore the issue. If a chair is used indoors on hard surfaces (e.g. wheelchair basketball), it is set up with lots of weight on the rear wheels, which are fitted with high pressure tires, and with hard small diameter casters. In fact even when considering daily use wheelchairs, indoor performance has become so important that many ultra-light wheelchairs cannot be fitted with caster wheels larger than 5” in diameter.

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

Despite these advances, the caster wheel, perhaps more than any other single component, limits a wheelchair's versatility. This lack of versatility is more pronounced on surfaces such as grass, sand, or snow; that is anywhere the terrain is rugged and sometimes soft[4]. One simple component change a person can make to their wheelchair for improved use on soft surfaces is installing "mountain bike" tires. This helps reduce rolling resistance and provides improved traction to some extent. But those parasitic casters are still there to cause problems. Fortunately, the FreeWheel takes the casters out of the equation.

FREEWHEEL DESIGN

The FreeWheel is a lightweight (~ 5 lbs.) caster wheel attachment for manual rigid wheelchairs (Fig. 1). It attaches to the footplate of most typical rigid wheelchairs with a simple over-center cam clamp that operates similarly to conventional wheelchair "scissor" wheel locks. A single large caster wheel 12” x 2.25” (54 - 203) with tire inflated to 40 psi is thus secured to the front of a wheelchair in the centre line of the chair.

Figure 1: The FreeWheel™ attached

An innovative design feature of the FreeWheel is its non-perpendicular caster stem. To install the FreeWheel, it is positioned in the "tail dragger" position. Due to the non-perpendicular stem, both the FreeWheel and wheelchair casters are on the floor. Thus, a user can install the FreeWheel independently while sitting in their chair (Fig. 2). By rolling forward, the FreeWheel snaps into its rolling position, with the non-perpendicular stem causing the front casters to be lifted up out of contact with the ground. This causes the front seat height of the chair to be raised approximately two inches, with associated changes in seat and backrest angle. A detent mechanism keeps the front wheel straight to improve stability and handling, although with slight pressure, it will release to allow easy turning in any direction. When not in use, the FreeWheel can be stored on its perch which attaches to the rear backrest stabilizer bar.

Figure 2: FreeWheel™ installation

FREEWHEEL SETUP

A Tilite Cross Sport rigid chair, sporting 4” x 3/4” hard urethane casters and Spinergy 18 spoke rear wheels with Pr1mo V-trak tires (24” x 1”; 540 x 25) inflated to 100 psi, was setup with and without the FreeWheel attached according to Table 1.

The footrest used here was a "two tube with ABS plate" design. Installing the FreeWheel for the first time took approximately 15 minutes. The instructions were clear and concise and feature clear drawings and photographs. The FreeWheel was also setup for use on a chair with a clamp-style footrest to gauge ease of installation; this was just as simple and took less than ten minutes thanks to familiarity with the process.

The Owner’s Manual suggests adjusting the initial FreeWheel setup so that in the "tail dragger" position both the FreeWheel and casters are on the floor. The relative height of the FreeWheel with respect to the footplate is adjustable with simple hex keys. We suggest a setup such that the casters are slightly off the floor when you are sitting up. This keeps the casters off the floor during wheeling, even when going backwards. By leaning forward, the weight shift causes the casters to contact the floor to aid in installing or removing the FreeWheel. The instructions are clear and easy to follow for completing this initial setup. Once setup, and with good hand dexterity, it takes about 5 seconds to install or remove. The clamping system is deceptively simple, effective, and secure.

Installing the perch (onto the rear backrest rigidizer bar), for storage when the FreeWheel was not in wheeling use, was also quite simple. We suggest taking time to experiment with the angle the perch is fixed at. Initial attempts at storage to the perch took about 15 to 20 seconds of fiddling each time. After it was adjusted so the clamping shim was parallel to the straight surface when the FreeWheel hung from a finger, it took less than 5 seconds with no fiddling.

Table 1: Wheelchair evaluation setups

	Cross Sport	Cross Sport + FreeWheel
Seat width (in)	16.5	16.5
Seat sling (in)	17	17
Back height (in)	19	19
Back Angle (degrees)	3	8
Front seat to floor (in)	19.5	21
Rear seat to floor (in)	17	17
Footrest to gnd clearance (in)	1.75	4
Caster clearance (in)	0	2.25
Overall width (in)	24.75	24.75
Overall length (in)	33	49.5
Overall length, reverse FreeWheel position (in)	n/a	64
Turning Circle (in)	42	88
Camber (degrees)	3	3
Toeing error (degrees)	0	0.5
Weight (lbs)	28	32.5
Transport weight (lbs)	11.5	11.6
Transport weight (lbs), with Jay2 back	16	16
Wt. Distribution F% / R%	21 / 79	8 / 92
Wt. Distribution F% / R%, with FreeWheel stored	n/a	16 / 84

If storing the FreeWheel on its rear perch, the effect of the added weight to the rear of the chair may need to be considered. The change in weight distribution may increase the chair "tippiness". In this evaluation, the rear axle was moved back by ½” to keep the weight distribution (centre of gravity; COG) similar to the original value. The manufacturer responded to this observation that just over 1,000 FreeWheels have been sold to date; not a single user expressed any need to change the COG. Our anecdotal conclusion was that a wheelchair setup up with a strong rear bias to COG (e.g. 85% weight on the rear wheels), storing the FreeWheel on the perch makes the chair too tippy, particularly on inclines. In our experience the typical setup of rigid wheelchair is with a 70 – 75% weight bias towards the rear wheels. Adding the FreeWheel in these situations may actually improve wheeling efficiency by moving the COG closer to 15 / 85% weight distribution.

FREEWHEEL EVALUATION

Geometry changes

The addition of the FreeWheel to the front of the chair creates some significant changes in the geometry of the chair. The following measurements were conducted without an occupant in the chair. It is expected that these geometry changes will differ slightly with a seated occupant depending on their weight and flexibility of their specific wheelchair frame.

Front seat height was increased by two inches. Backrest angle recline was increased by 5 degrees. Overall length was increased by 16.5 inches (or 31 inches if the wheel is in the trailing position). Toeing is affected if the wheels have camber. The test chair had 3 degrees, which resulted in 0.5 degrees of toeing error (toed out) with the FreeWheel installed. Another chair with 6 degrees of camber had a 1 degree toeing error induced by the FreeWheel. Centre of gravity was shifted rearwards by both storing the FreeWheel on its perch, and due to the change in seating geometry caused by the FreeWheel when installed. Either way, users should consider compensating for this by changing the rear axle position, or if the back angle is adjustable in real-time, e.g. the Elevation wheelchair[5], tilting the back forward can also compensate the COG changes.

Wheeling Performance

The test chairs were first equipped with 160 lbs. weight distributed over the seat. A simple roll down test (down a 4 degree declined ramp) with a hard surface yielded rolling distances of 45.3 and 45.6 inches with and without the FreeWheel installed, respectively. The same test with a 1 inch Resilite therapy mat surface yielded rolling distances of 8.8 and 6.3 inches with and without the FreeWheel installed, respectively. Clearly the standard chair would require significantly more energy to propel over soft surfaces like carpet or grass.

Single trial wheeling tests were performed for an initial evaluation of the FreeWheel. All tests were performed by a 160 lbs. able bodied physical therapist with over 20 years of experienced wheelchair use.

Table 2: Wheeling tests

Wheeling test	**Cross Sport** ***Time (secs)***	**Cross Sport + FreeWheel**
Slalom – 10 cones, 1 m apart	27	36
100 m asphalt path	76	67
500 m course of hard surfaces including concrete, asphalt, metal grates, speed bumps and curb cuts.	240	220
Wet Grass – 27 m	69	40

As expected the standard chair was 25% quicker through a slalom course (Table 2), although it was surprisingly easy to negotiate with the FreeWheel.

The FreeWheel also performed surprising well on hard surfaces, slightly bettering the times of the standard chair on 2 different courses (Table 2). The FreeWheel gave the chair a sense of stability and significantly smoothed out any irregularity in the pavement. Subjectively, the ride was much better than the standard chair and allowed the wheeler to proceed with less attention given to irregularities in terrain. Wheeling on grass really emphasized the benefits of the FreeWheel, allowing for more wheeling power without digging the front casters into the ground.

We also tested the ability of the FreeWheel to climb curbs or thresholds (Table 3). First, the chair was wheeled perpendicularly towards a threshold and impacted without any changes in body position (ensured by keeping eyes closed). The FreeWheel provided a smooth ride over a 3 inch threshold and could consistently climb 4 inches, although it was a bit jarring. The standard chair was quickly stopped at any threshold close to 1 inch in height.

With good technique and trunk control, a much higher curb was ascended in the standard chair compared to the FreeWheel. Descending without a wheelie was much easier in the FreeWheel. The increased wheelbase also allowed for the descent of average stairs in the forward direction (with hand rails on each side).

Table 3: Curb tests

Wheeling test	**Cross Sport *Height (inches)***	**Cross Sport + FreeWheel**
Threshold – no weight shift	< 1	4
Max Curb Up	10	7
Max Curb Down	4	12

USER PERSPECTIVE

The perspective of a full time wheelchair user is summarized here.

"I can see that this sort of attachment to my chair would provide much greater mobility and enjoyment of a number activities. Within urban environments and grassy areas it performed greater than my expectations. I loved the turning radius of this unit – being able to turn comfortably in relatively tight areas, even in a grocery store.

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 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.

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." Other user's experiences are being surveyed.

CONCLUSIONS

Instructions for setting up the FreeWheel should be followed diligently, although they are clear and easy to perform. The FreeWheel attaches and detaches from the footplate quickly and easily. It can be stowed securely on the back of the chair in less than 10 seconds. Although not optimized for indoor wheeling, it is possible to use the FreeWheel indoors if necessary.

The FreeWheel showed no inclination to flutter during wheeling on various surfaces. It also isolated the wheeler from the many irregularities encountered when wheeling along sidewalks. There is inherently less resistance to rolling with the FreeWheel 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 larger diameter rear wheels will compensate for the toeing error induced by the FreeWheel, and provide increased traction at the rear wheels.

In short, 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 that most people may find it beneficial in any situation where maneuverability isn't the most important characteristic. The FreeWheel is also a great example of a user-driven small company innovation that makes a significant impact to people with disabilities[6].

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