The Dyno: Dynamic Rear Anti-Tip Device (D-RAD)

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RESNA Student Design Challenge

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Problem Statement

Ultralight rigid wheelchair users need a means to safely perform a functional and dynamic wheelie in order to navigate their environment.

Background

Acquisition of the wheelie skill is a critical component of independent, manual, wheeled mobility, allowing wheelchair users to navigate rough terrain, maneuver obstacles, perform weight shifts, and providing occasional moments of intra- and interpersonal ammusment.[1,2] Despite its importance, however, being able to successfully perform a wheelie is far from a universally shared skill across manual wheelchair users with only 59.9% of long term wheelchair users being able to hold a wheelie for 30-seconds.[3] Even those who can successfully perform a wheelie are at an inherent risk of injury from backwards falls.[1] The current approach to minimizing this risk is Conventional Rear Anti-tip Devices (C-RADs) as described by Kirby at el., these anti-tippers, however, inhibit skill acquisition by limiting caster to ground height, often leading to user abandonment.

Product Landscape & Development

Currently no product that supports a dynamic wheelie, prevents backwards tips, and is suitable for adult users available in the market. One pediatric model, the Dynamic 5th Wheel by Ki Mobility, is currently available, but is limited to brand specific and to pediatric use.[5,6] Pediatrics is also able to market Dynamic Rear Anti-tip Devices (D-RADs) for skill acquisition and neurodevelopment, a necessary part of childhood. The adult market has fewer funding options since RADs are traditionally no cost items.[7]

Past products have been designed, however none made it to market, most notably the ArcRAD.[8] The ArcRAD, patented in 2003, was the closest to meeting the user need, and consisted of a set of D-RADs with swivel casters for folding frame chairs.[8] This design did have some limitations that the Dyno addresses. Initially omnidirectional wheels, swivel casters, carbon fiber, and telescoping tubes were considered, but later abandoned due to cost, weight, and overcomplexity. The development process focused on creating a lightweight, aesthetically pleasing, single rather than dual design that worked for rigid frame wheelchairs. It also needed to have low effort user assembly and disassembly and could not add frame depth when the drive wheels are removed for transferring the frame over the lap in a vehicle.

Final Design

The final design consists of a single center mounted D-RAD consisting of 3 main component groups, the stabilizer bar, the camber clamp, and the anti-tip bar. Working from the ground up, the caster selected was a rigid, broad, but short caster. A small, but broad caster was selected to keep the weight low, while also minimizing the amount of sinking on soft surfaces. This caster is housed by a custom fork made via Multi-Jet Fusion (MJF) 3D printing with PA 12, a high strength nylon material. An aluminum 6061 tube inserts into this fork with a stainless steel clevis rod end bolted into the top end of this tube. This comprises the anti-tip bar. Another custom 3D printed clamp is attached to the center of the camber tube. The anti-tip bar connects to the camber clamp via a half inch diameter quick release T handle pin inserted through the clevis yoke and the clamp. An integrated safety stopper projects backwards at the top of the clamp to prevent tip back. To prolong the life of the caster and prevent additional rolling resistance when not in active use the caster is kept elevated a couple of inches off the ground by a non-weight bearing stopper via a small bolt or quick release pin. The height of the wheelie achieved when the user is fully supported by the anti-tipper can be set lower than the stopper height by drilling a hole through the posterior sagittal plane of the clamp to create an additional stopper through the insertion of a quarter inch diameter quick release pin. Finally, to prevent rotation around the camber tube without applying significant clamping forces that may damage the tube, a second clamp with a rearward projecting rod is attached to the seat stabilizer bar. The aluminum rod inserts into a channel through the camber clamp an extends to support the stopper. This changes the system from a singular axis for rotation to two fixed points without altering the frame of the chair.

Outcome

The final prototype underwent verification and validation testing following the criteria as shown in Table 1. Overall, the device passed verification and validation for a user weighing 120 lbs., however, when undergoing rearward stability testing for ISO 7176-1:2014(E) at the full 250lbs load the stabilizer tube bent and original camber clamp design broke. This prevented further rearward and lateral impact testing following ISO 7176-8:2014(E). The stabilizer tube was exchanged for a solid aluminum rod and the camber clamp material was significantly thickened. This new design however was unable to be tested with the 250 lbs test dummy for ISO standards due to time constraints. Further development is needed, but these outcomes

represent a functional concept and prototype that addresses the original need. Ideally the camber clamp would be made from aluminum to provide additional strength, and some cosmetic improvements could be made, but at the moment this is just an early functional prototype.

Table 1

Type	Criteria	Outcome
Verification	Supports the weight of a 120lbs user and prevents tip back?	Pass
	Supports the weight of a 250lbs user* and prevents tip back according to ISO 7176-1:2014 (E) standards.	Fail
Validation	User** can perform a D-RAD aided hands-free static wheelie.	Pass
	User** can perform a D-RAD aided forwards wheelie for 10ft.	Pass
	User** can perform a D-RAD aided backwards wheelie for 10ft.	Pass
	User** can perform a D-RAD aided wheelie down an ADA ramp.	Pass
	The device is lightweight and easy to remove and assemble.	1.5 lbs. Pass

*Formal ISO 7176-1:2014(E) testing was only performed on the 250lb dummy model.

**User weight 120lbs.

Cost

The Dyno prototype costs approximately $130 dollars to produce depending on fluctuations in material cost. Comparable products such as the Dynamic 5th Wheel cost $327.82, and a comparable to slightly lower cost could be expected for the Dyno. For a full price by component breakdown see Table 2.

Table 2

Item	Units needed	Cost per unit ($)	Total ($)
caster bolt	1	0.80	0.80

caster nut	1	0.21	0.21
camber clamp front half	1	27.27	27.27
camber clamp back half	1	39.74	39.74
general bolts	5	0.78	3.89
general nuts	5	0.36	1.78
stabilizer rod	1	4.00	4.00
stabilizer clamp	1	12.99	12.99
t-handle quick release pin	1	5.59	5.59
top stopper quick release pin	1	2.62	2.62
bottom stopper quick release pin	1	2.18	2.18
caster	1	12.50	12.50
clevis rod end	1	15.82	15.82
Total			129.39

Significance

When in place, C-RADs prevent tip back from occurring, but also prevented the user from doing a functional wheelie. For example, when navigating construction, this necessitated taking a much longer route to find an alternative curb cut. When the C-RADs are removed, the user may be able to get to the same destination in a quarter of the time by acceding and descending a 6-inch curb. While removing the C-RADs can enable the user to perform a wheelie and navigate the curb, it can also cause hesitation and fear from lack of protection, and of course actual injury from falls.

As dangerous as unprotected wheelies may seem, lacking the ability to perform a wheelie can also have a significant impact on quality of life. It was found that having the ability to perform a 180˚ wheelie was linked to higher social integration scores among users.[3] Having these skills also contributed to higher scores on the Wheelchair Skills Test (WST) which predicted higher reported life satisfaction, and community participation.[3] Another study found that having the capacity to perform advanced wheelchair skills such as descending steep inclines and high curbs in the wheelie position are significantly associated with increased fitness.[4] Having the ability to perform dynamic wheelies through the use of a D-RAD like the Dyno could a

significant positive impact on the quality lives and community involvement of many different wheelchair users.

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