Abstract

Exercise and outdoor activities are a fun and healthy way to socialize and create community, and people with disabilities often need adaptive devices to be able to participate. Due to the nature of disability and it's uniqueness to the individual, adaptive devices are generally quite expensive and thus fairly inaccessible. This paper will explore the landscape of assistive sports equipment, specifically hand grips designed for hand cycles and propose a design that is affordable to manufacture while maintaining the crucial elements of assistive technology; namely independence, usability and pain alleviation. The proposed design incorporates an off the shelf wrist guard with a universal bike pedal attachment using custom designed 3D-printed and off the shelf parts to maximize both comfort and affordability. The attachment mechanism takes advantage of the steel shaft of the pedal attachment and a small magnet to allow for a secure connection with a quick release.

1 Introduction

Hand cycles are completely powered and operated by the users hands meaning people who would ordinarily be unable to use a standard bike like quadriplegic and paraplegic people would be able to bike around like anyone else. The problem is that hand cycle equipment is often quite expensive, making it inaccessible to many who may benefit from the technology. The goal is to design inexpensive hand cycle grips for those with wrist pain or limited hand strength.

1.1 Background

Hand cycles are a great form of exercise for people afflicted by spinal chord injuries that impact lower limb mobility. They are fairly modular and customizable, which makes them very compatible with the individualized nature of disability. In particular, there are many different options for grips (the pedals of a hand cycle).

A particular style grip called a "quad-grip" is designed for use by quadriplegic people. Quad-grips allow the user to pedal without the need for an grip strength by attaching the users hands firmly to the bike. This means the user can pedal with their arms and upper body instead of their hands and wrists. This is kind of grip is of special interest because of how it requires no motion or strength from the users wrists or hands: exactly the parts of the body afflicted by carpal tunnel. They are also self-donning meaning the user requires no assistance put them on and use them, allowing the user to maintain independence. According to the Disability Action Center, independence for people with disabilities has many positive effects on their well-being, including improved confidence and sense of self worth as well as better mental health outcomes [1].

Figure 1: Quad-grip made by Bike-On

A study from the University of Sydney and Tufts University found that exercise can be therapeutic for those living with things like neurodegenerative diseases and mobility impairment [2]. The study finds that not only can exercise improve physical health outcomes for disabled people but psychological and social outcomes as well.

There are many adaptive hand cycle grips currently on the market and one thing that unites all of them is cost. The main seller for hand cycle equipment, Bike-On, is selling different style grips that range from $135 - $499, never mind the cost of the hand cycle itself. While there are organizations like BORP (Bay Area Outreach and Recreation Program) that provide affordable hand cycle rentals, affordable add-ons like grips are harder to come by.

According to the National Disability Institute, the poverty rate among people with disabilities is 27% and that gets as high as 37% among Black/African American people with disabilities. When compared with the 12% national average, it becomes clear that there is a clear relationship between disability and poverty [3,4]. Partnered with high expense of adaptive exercise equipment and the positive impact exercise has on disabled peoples health outcomes [2], the elevated poverty rate for disabled people demonstrates a clear need for affordable adaptive exercise equipment.

1.2 Overview

Section 2 will analyse and discuss an interview conducted with someone intimately knowledgeable about hand-cycling. Section 3 will then breakdown the design of the device. Section 4 will explain why the proposed design builds upon already existing technology and addresses a need in the community. Section 5 goes into the why an affordable, adaptive hand-cycle grip can expand access to hand-cycle oriented exercise for people with lower-limb impairments.

2 Interview Case Study

An interview with an avid hand-cyclist gave insight into their needs for an adaptive hand-cycle grip. They were paralyzed from the waist down due to a spinal chord injury and in addition to their paraplegia, the need-knower has carpal tunnel which can affect their ability to cycle for long periods of time.

Interview statement	**Interpreted need**
" **... it does agitate my wrists sometimes.**"	Pain alleviation
"Honestly, this is the first thing I've done that's **made me feel able-bodied again.**" "... every other sport that I've done... **you really feel handicapped**"	Maintaining independence
"... **it's not cheap.** Which Yeah, that's just name of the game whenever you come to ability, or any kind of medical equipment" "... the least expensive bike you could buy today is **around $9,000.** And it takes six months to get. "	Keep cost low
"... hand-cycling is, is a **key component of my physical therapy**" "The benefit of biking is I tend to focus on the pull motion... **it's a really good exercise for my back.**"	Usable and maintains bike function

Table 1: Interview Quotes

There were four main needs that the need-knower expressed during the interview: pain alleviation, independence, affordability, and usability.

2.1 Pain Alleviation

The need-knower has carpal tunnel, a condition that causes pain and paresthesias in the wrist and radial fingers due to compression of median peripheral nerve [5]. This condition can be caused and exacerbated by repetitive movements of the hands a wrists such as hand-cycling [6]. In order to alleviate the pain of the repetitive motion of hand-cycling, the design must serve to shift the bulk of the movement and force of pedaling to the users arms instead of his wrists and hands. This will help to prevent exacerbating the need-knower's carpal tunnel.

2.2 Independence

The need-knower expressed very clearly that independence is very import to him and a key reason why hand-cycling has been so appealing to him. He has been able to fully participate in the sport without the need for assistance which has been an issue for him in the past with other sports. The design must be self-donning, meaning he can put it on, take it off, get in and out of it, without assistance. Leaving out this feature would in effect, strip hand-cycling of one of it's core appeals to him.

2.3 Affordability

The need-knower takes pride in running an adaptive sports organization aimed specifically at making hand cycles more accessible for people in his community. As he mentioned in a quote above, hand cycles can be quite expensive on their own, even before buying any extra equipment one may need, such as quad grips. To the need-knower, this isn't just a personal need but a need for his community. He hopes that the design can be affordability replicated for other hand cyclist in order to make the sport as accessible as possible.

2.4 Usability

The need-knower relies on hand cycling for more than just exercise. It is also an aspect of his physical therapy and apart of his social life. The social component of hand cycling for the need-knower comes from his ability to keep up with his friends and family while they cycle with him. The design must maintain the usability of his bike. In other words, the functionality of the bike cannot be changed in any fundamental sense so as to not impact the need-knowers physical therapy or social life.

3 Proposed Device Design

3.1 Device Design

The proposed device design aims to take advantage of parts that can largely be purchased off the shelf or 3D-printed. This approach allows us to keep the cost of the device low and relatively easy to manufacture.

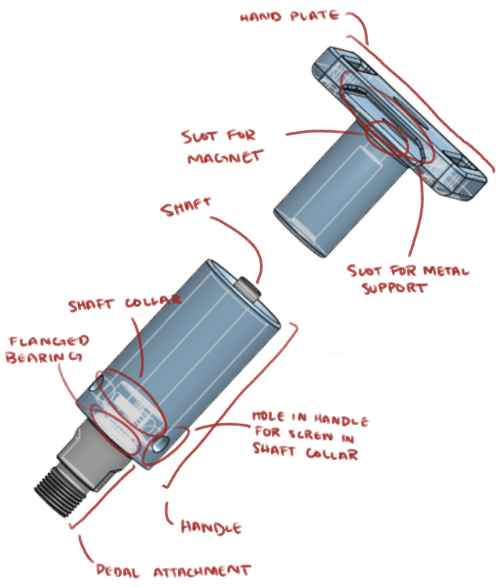

Figure 2: Model of device with notes

First a standard off-the-shelf bike pedal was taken apart for the pedal attachment and shaft. Bike pedal attachments are universal and this includes hand-cycles. The pedal attachments were apart of a larger shaft that ran through the bike pedal. The shaft of the pedal attachment was then machined to an 8mm and polished so it could be attached to a 3D-printed handle using a flanged bearing and shaft collar. For extra security, a heat gun was used to slightly melt the beveled surface of the 3D-printed handle and to press the bearing into the PLA. The handle is hollow so that a 3D-printed hand-plate sewed to an off-the-shelf wrist guard with a strap can slide into it. To make manufacturing possible, one end of the strap is sewed directly to the wrist guard while the other end is sewn to a piece of Velcro that can attach directly to the wrist guard. The hand-plate is doubly secured by a metal plate that runs through the wrist guard. It hand-plate houses a small magnet that takes advantage of the magnetic, steel shaft and allows the two parts to click together and remain secured while pedaling. This design draws inspiration from the quad-grips sold by Bike-On.

4 Intellectual Merit

Although there are other designs for adaptive hand-cycle grips with the same goal of affordability, the proposed design is unique in that it is also designed for comfort which is an essential part of adaptive technology. By incorporating an off-the-shelf wrist guard into the design, it is made more accessible while maintaining a level of comfort in the design. Other similar products on the market use complex spring and bearing mechanisms or pins to secure the users hand to the cycle. These products are well made but they require a huge amount of effort to manufacture. The design proposed in this report only incorporates parts that can presumably be found by the average consumer and can be adapted to manufacturing methods available at say your local public library.

5 Broader Impact

As access to technologies like hand-cycles expand, so too will the need for more adaptable and customizable accessories. Given that many disabled people struggle with poverty, it is essential that adaptive accessories, like the proposed handcycle grip design, become available. Although the particular design might not be widely used, it proves that inexpensive adaptive devices can exist in the space and makes the technology more available for people.

References

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Appendix

Product: Pedal for hand-cycle

Question/Prompt	Customer Statement	Interpreted Need
Typical uses	*Cycles a lot	*Can slip his hand slip his hand in and be secure
	*Feels able bodied and self sufficient when cycling	*Need to be comfortable
	*Current pedals are uncomfortable and exacerbating carpal tunnel	
Likes-Current tool	*Allows him to exercise his back and balance out chest muscles with pulling motion	*Maintain Pulling motion
Dislikes-Current tool	*Puts a lot of stress on his wrists	*Move stress from wrists
	*Current options are $ 500	*Inexpensive
Suggested Improvements	*Add straps	*Incorporate wrist guard deign into pedals
	*Make something like a ”quad pedal”	*Incorporate wrist guard deign into pedals

Table 2: User needs chart

Usability	Pain Management/Comfort	Scalability
Usable for the elderly	Alleviate pain	Inexpensive
Elastic assist	Bike for longer periods of time	Simple design
Light weight	Replicable	Open source
Durable	Comfortable	Durable
Easy to use	Distribute load more evenly	Adaptable (Specifically to quadriplegic users)
Comfortable	Move stresses up the wrists	
For sensitive skin	Allow for pulling motion (Maintain therapeutic aspect)	
Avoids excessive fatigue		
Longevity (Bike for long periods of time)		
Maintain (independence/-self sufficiency		

Table 3: Hierarchical list of customer needs

	Arm brace/ Support bar	Disconnected Wrist Brace	Push Latch Wrist Brace	Counter-weight	Finger Holes
Independence (x2)	+2	+2	+1	+1	+1
Moves stresses (x2)	+2	+1	+2	0	-1
Simplicity (x1)	+1	+2	-1	-1	+2
Comfort (x2)	-1	+2	+2	+1	-1
Longevity (x1)	+1	+1	+1	+2	+2
Makability (x2)	+2	-2	+1	0	+2
Total	+12	+9	+12	+5	+6

Table 4: Weighted Matrix

Figure 3: Idea selection

Figure 4: Disassembled pedal with notes

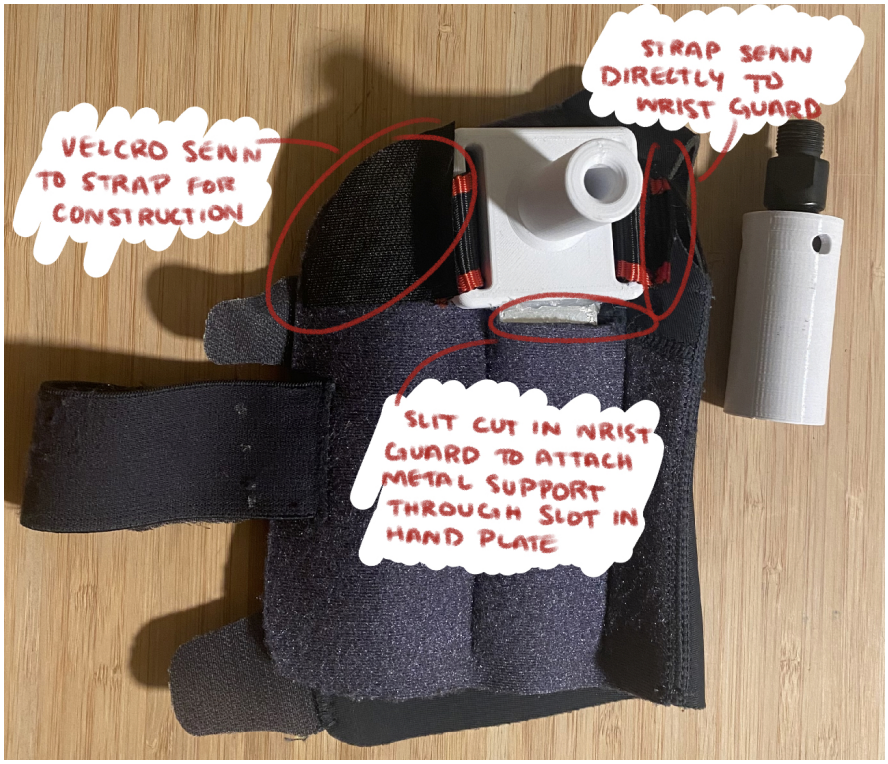

Figure 5: Assembled prototype with notes