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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. In this paper, we 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.

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. Our 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

In section 2, we will analyse and discuss an interview we conducted with someone intimately knowledgeable about hand-cycling. We will then breakdown the design of our device and how we aim to test it in section 3. In the section 4 we will explain why our 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

We conducted an interview with an avid hand-cyclist in order to get insight into their needs for an adaptive hand-cycle grip. They were paralyzed from the waist down due to a spinal chord injury. In addition to paraplegia, our 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 our need-knower expressed during our interview: pain alleviation, independence, affordability, and usability.

2.1 Pain Alleviation

Our 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 our need-knower's carpal tunnel.

2.2 Independence

Our 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. Our 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

Our 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 our need-knower, this isn't just a personal need but a need for his community. He hopes that our design can be affordability replicated for other hand cyclist in order to make the sport as accessible as possible.

2.4 Usability

Our need-know 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 our need-knower comes from his ability to keep up with his friends and family while they cycle with him. Our design must maintain the usability of his bike. In other words, we cannot change the functionality of the bike in any fundamental sense so as not to impact our need-knowers physical therapy or social life.

3 Proposed Device & Test Methods

3.1 Device Design

The device we have designed 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.

We first took apart a standard off-the-shelf bike pedal so we could use the pedal attachment in our design. 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. We decided to machine the shaft of the pedal attachment to an 8mm and polish it so we could attach 3D-printed handle using a flanged bearing and shaft collar. For extra security, we used a heat gun to slightly melt the beveled surface of the 3D-printed handle and pressed the bearing into the plastic. 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.

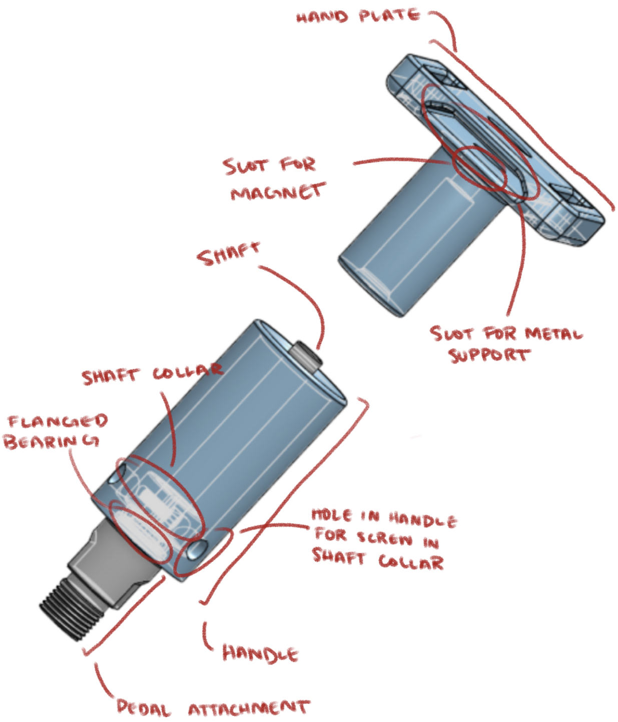

Figure 2: Model of device with notes

3.2 Test Methods

We are using an accelerometer sensor (Sparkfun Triple Axes LIS3DH) [7] to measure the acceleration of the user's hand while cycling. These accelerometers can been widely used to monitor acceleration signals in biomedical applications [8]. The accelerometer is attached to a breadboard which is connected to an Arduino board. There is a button that allows the user to report when they feel discomfort.The circuit, the schematic of the connections as well as a simple test of operation are shown in Figure 3.

The device was taped to the hand of a user while he was cycling. The preliminary data of the acceleration as a function of time for a 5 second period is shown in Figure 4. It should be noted that the accelerometer sensor reports the absolute acceleration meaning that the gravitational force is also taken into account and g=9.8 m/s^2 is reported while the hand is stationary. Here we have two threshold as low threshold and high threshold. Once the vertical acceleration (i.e. vertical force) reaches the high threshold the LED turns on. The red portion of the curve which is above the high threshold corresponds to the LED turning on. In this study, we just presented the preliminary data and possibility of the design. In future work, we will use this data to provide feedback to the user to avoid injury. However, in the short term, it will be used only to examine the efficiency of the hypothesis. The Arduino code is provided in Appendix C.

4 Intellectual Merit

Although there are other designs for adaptive hand-cycle grips with the same goal of affordability, ours is unique in that it is also designed for comfort. An essential part of any wearable or adaptive technology is comfort. By incorporating an off-the-shelf wrist guard into the design, we can ensure both comfort and affordability. The measurement unit allows us to continuously collect and analyze the kinetic factors based on the user's comfort/discomfort. This can be utilized for predicting the possibility of carpal tunnel. The data also provides useful information towards categorizing different degrees of the carpal tunnel from mild to severe and this can be beneficial in tracking the progression or treatment of the carpal tunnel [9]. As a future study based on the present data, a model can also be developed with machine learning technique to accurately identify the hand activity from raw EMG and accelerometer data [10].This helps to predict the progression of the symptom based on the inputs such as positioning angle of the hand, the angle of the cycling handle, etc.

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 our hand-cycle grip design, become available. Our device is capable of preventing the progression of carpal tunnel syndrome as it allows the users to continuously track and report the forces imposed on their wrists. Although our 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. A possible clinical use of this research can be proved by recording EMG signals and combining the muscle activity data with the kinetic data of the wrist (obtained from the accelerometer sensor).

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