# CHAPTER 14
# UNIVERSITY OF FLORIDA


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# The Power Cycle A Hand Powered Vehicle for Paraplegics

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## INTRODUCTION

Wheelchairs are fine for short distance travel in and around buildings, but they are slow for use in traveling longer distances. Even the racing chairs do not offer an efficient means of transportation over longer distances. The Power Cycle has been engineered to provide a faster and more efficient means of human powered transportation for people unable to use their legs. This tricycle type device incorporates a cam to take full advantage of the human power available through the rowing motion. The operator's hands are able to propel, steer, and stop the cycle without moving from the control bar (T-bar). Mechanical advantage in the drive system is adjustable by using a three-speed gear hub on an intermediate shaft. Finally, the passenger can load and unload from this cart easily. The Power Cycle is shown being used in Figure 14.1.

## SUMMARY OF IMPACT

A patient (Pat S.) in the Special Physical Education Laboratory at the University of Florida is an amputee with coronary and peripheral vascular disease. His options for exercise are rather limited as he is dependent on a wheelchair. The power cycle was designed for Pat. It is operated chiefly by the muscles of torso and upper extremities. The cycle design is excellent for him to use to significantly work on muscular strength, range of motion, and endurance. This device will also allow him to be far more mobile than he is in his wheelchair. Pat will be free to transport himself much faster and much farther than he is presently able to do. In so doing he not only will improve the quality of his life through this new freedom of movement and enhanced social integration, but he will enlighten hundreds of others as they observe, or rather experience, the sight of Pat fleeting by on his power cycle.

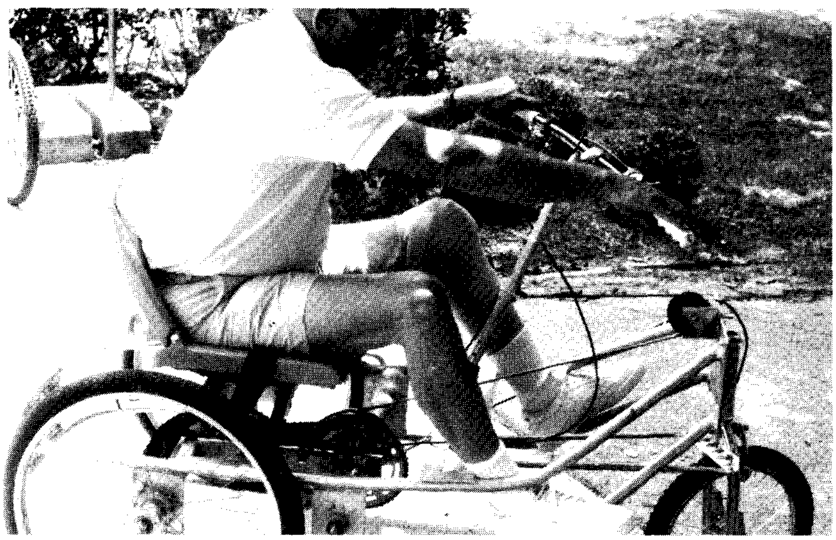

Fig. 14.1. Power Cycle in use.

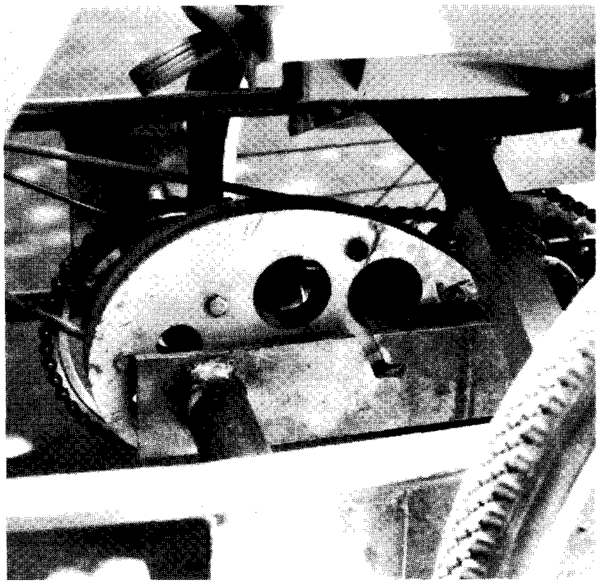

Fig. 14.2. Close-up of Hyperbolic Cam in the Drive-Train.

A further benefit will come of the Power Cycle by encouraging other patients in the Special Physical Education Laboratory to expand their exercise and coordination experiences through the cycle's use. Since Pat attends this laboratory regularly, he has become somewhat of an assistant to Dr. Stopka in helping handicapped students sent in from the local school system. Pat plans to use his Power Cycle to help their therapy.

## TECHNICAL DESCRIPTION

The purpose of our design was to provide a means of human powered transportation that took greater advantage of the human power available and could be operated without the use of the legs.

It has been shown in numerous human performance studies that, of those human motions possible for paraplegics, the rowing motion can deliver the most power. This motion uses strong muscle groups and involves a large number of muscle groups. The force the body can exert through the rowing motion decreases as the body position moves from a full forward reach to an upright posture with the fists pulled up to the chest. The velocity at which this motion is performed is assumed to be constant. What we call the T-bar is the hand-held lever arm that transmits this human power input (force * velocity = power) to the drive train. The reaction force of the drive train on the pavement must be as large, at least, as the cycle's resistance to motion. Since this force will be maximum starting from rest on a ramp or hill, we designed for effort in this case to be within easy human capability. In addition this resistance to motion was assumed constant at steady speed operation. Using the ideal assumption that the input velocity (at the T-bar) and the output force (reaction at the wheels) are constant, the power transmitted through the drive train will be maximized if the drive train can be made to vary the output velocity directly with respect to the input force.

A nearly direct variation between the input force and the output velocity is achieved by incorporating a cam into the drive train. Several geometric shapes were considered to provide the desired velocity variation. A circular shape produced a constant output velocity variation with respect to the input force. This represents no cam. An elliptical shape produced a favorable output velocity variation only over a small angle of rotation. The same is true for a cardioid shape. Since these two cams have desirable operation over less than 90 degrees, they were deemed not satisfactory for our application. The hyperbolic spiral shape gives a nearly linear relation between input force and output velocity over a larger angle of rotation than any of the other shapes considered. Our hyperbolic cam (Figures 14.2 and 14.3) operates over a full 180 degrees. The equation in polar coordinates describing the hyperbolic spiral shape is radius * angle = constant. The value for the constant was determined by the constraints on the arc length of the cam to be used, the physical size of the cam, and the beginning and ending cam radii. The best section of the curve for use as the cam surface was selected to satisfy size constraints and maximize the angle of rotation.

The remainder of the drive train design was a matter of selecting the best combination of sprockets to handle the maximum output force required (i.e. rolling up a wheelchair ramp). Also, a three-speed hub was incorporated as a means of varying the gear ratio. This method of varying the mechanical advantage was chosen because it requires a negligible amount of rotation to change the gear ratio.

In operation, power input to the T-bar was transmitted to the cam with each pulling stroke using a nylon strap. One end of the strap was secured to the T-bar. The other end wrapped onto the surface of the cam and bolted to that surface. As the operator pulls the T-bar to his chest, the nylon strap unwraps as it turns the cam. Power is transmitted from the cam through the series of 4 sprockets to the rear wheels. The drive assembly fits under the seat of the driver and extends forward in the frame remaining under his legs.

The length and position of the hand-held T-bar were selected to accommodate Pat's full range of motion. Thus, optimizing his power input. A universal joint at the base of the T-bar allows the operator to steer the cart by rotating the T-bar in the direction he wishes to turn. Steering is accomplished by rotational motion of the T-bar. This rotation is translated to the front wheels via metal straps tying the steering arms together. The brake is mounted on the front fork. The brake and gear shift controls are the same hardware found on many 3-speed bicycles. The hand-brake and gear shift levers are mounted on the cross-member of the T-bar in the same orientation they are found on most bicycles. This orientation makes their use comfortable and practical.

Many existing vehicles designed for the physically impaired do not do enough to make their vehicles easy to get into. The Power Cycle features a seat that swivels and stands at a height just about even with the back of the knee. This puts the seat just about even with the top of the rear wheels. The seat also slides front and back. This allows the operator to drop down into the seat more gently and unhindered by the rear wheels. Then, with his hands the operator can turn himself forward and lock the seat slide when a comfortable position is found. The cycle is equipped with a seat belt to allow the user to put all the power he can into pulling the T-bar.

Finally, footrests to strap the feet into and rear wheel locks to hold the cycle stationary during transfer were added. (Pictures were taken before they were installed.) For a user of the Power Cycle who wants to carry his wheelchair with him, we have included ample room for a carrier of some sort to be installed behind the seat. This can be seen in Figure 14.4. Our cycle did not have need of the carrier although one may be installed in the future should Pat want one.

Total cost of the Power Cycle was under $300. This included utilizing some parts from used bicycles.

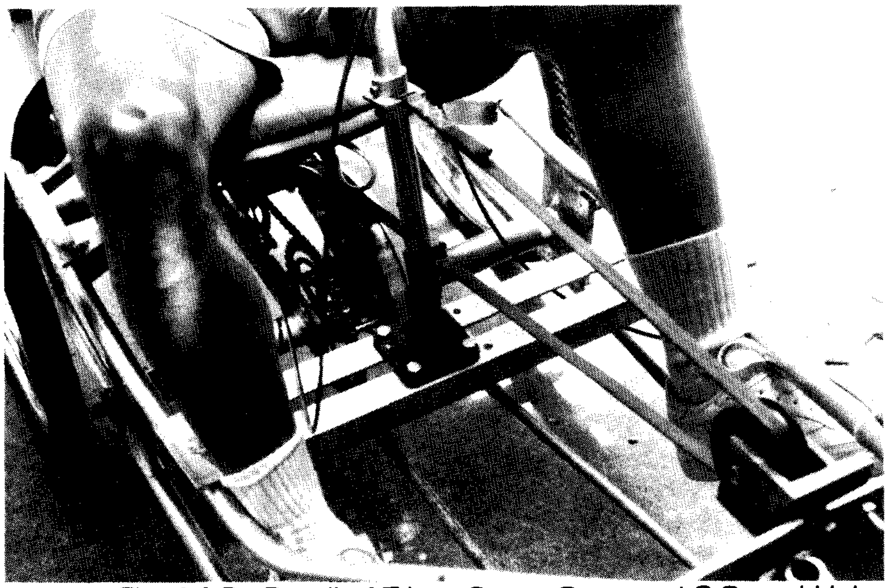

Fig. 14.3. Detail of T-bar, Strap, Cam, and 3-Speed Hub.

Fig. 14.4. Rear View Showing Possible Carrier Area.

# Keyboard Adaptation for a Quadriplegic Student

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## INTRODUCTION

The goal of this project was to develop a customized keyboard for an Apple IIe computer to aid a quadriplegic boy, Greg. Greg not only enjoys working on a computer as a means of entertainment and communication, but also completes some of his classwork assignments with the aid of the computer. It was considered desirable to make his interaction with the computer self-accessible, more accurate, and faster than the current technique which he uses. His existing method involved striking the keyboard with a long mouthstick to which a weight, such as a marker pen, is attached at the end.

Fig. 14.5. Greg With New Mouth Probe and Keyboard. Note Probe Holder Attached to Keyboard for Easy Accessibility.

By positioning the stick with his mouth above the desired key and dropping it down, Greg was able to type with good accuracy. However, the weight of the stick considerably shortened Greg's work time due to the time manipulations of the stick required and due to fatigue.

In order to increase Greg's accuracy and manageability over time, a "mouth probe" was designed and its length and weight were decreased. A special curved keyboard compatible with the mouthpiece was also adapted. The complete apparatus is shown in Figure 14.5. The circular keyboard has a curvature consistent with the turning of Greg's head, allowing for easy striking of the keys. Key striking is achieved by use of the mouth probe which allows Greg to use protraction and retraction of his tongue to push the probe onto the desired key. A rubber band attached to the tip of the moving probe acts as a spring to pull the probe back once it has struck a key.

## SUMMARY OF IMPACT

The recipient of this device is a twelve year-old boy named Greg who is a victim of Cerebral palsy, one of several neuromuscular disorders resulting in muscular incoordination and loss of muscle control. Greg is a quadriplegic with excellent attitude and intellectual capabilities. Upon trying the new device for the first time, Greg did not take long to decide that the circular keyboard and mouth striker would make his working on the computer easier. The bottom bite plate was initially too wide for Greg's mouth, so we removed it for modification. Greg then held the mouth probe in position with just the top plate for supporting the torque generated by the device, and, to our surprise, began typing on the keyboard. When asked about comfort and ease of key striking, Greg indicated that everything was fine. The device was well suited for his disability, and was even more comfortable and easier to use once the bottom bite plate was modified and in place.

## TECHNICAL DESCRIPTION

The keyboard was adapted from an Apple IIe keyboard. Keys are spaced on a circular arc at a radius of 38 cm. This value was obtained by realizing that the minimum focusing distance for the human eye is 24.5 cm, adding an extra 14 cm for the distance between the eye and the center of rotation of the head. The keyboard rests at an arbitrarily chosen angle of 9.5 degrees from the horizontal table top for increased key visibility and ease of key striking.

Fig. 14.6. Designer with Greg Typing Away.

The keyboard is accessible for repairs by removal of six screws holding the sheet aluminum containing the keys. The wiring from the keys to the board, as well as the board itself, are protected from external elements by an Acrylite acrylic housing of 1/4" thickness.

The spacer support for the mouth probe used to strike the keys is made out of 1/16" thin acrylic sheet with dimensions of 10.0” in length by 1.215” in width by 0.250” in thickness. The spacer slides into a modified snorkel mouthpiece with no further attachment. The range of movement of the striker using one’s tongue is 1.0”. An upper and lower bite plate were incorporated to support the weight of the extending mouth probe by holding the device in a horizontal position. The length of the mouth striker with the probe stick and bite plates in place is 12.375”. The vertical distance between the two bite plates is 0.440” and the depth of the portion retained in the mouth is 1.610”. The bite plates are 1.780” wide. The total mass of the mouth striker is 68.8g, which is less excessive than the previous device Greg used. The cost of the keyboard was $45, that of the acrylic used in both the keyboard housing and the mouth device was about $30. The snorkel piece was purchased from a local dive shop for $10, making the total cost of supplies less than $100.

Fig. 14.7. Detail of Mouth Probe.