CHAPTER 12
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A Motorized Therapeutic Cycle for Quadriplegics

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INTRODUCTION

Stiffening of the joints, and shrinking of tendons and muscles is a typical problem encountered by those confined to a wheelchair. It is generally costly, and a major inconvenience to attend the necessary physical therapy sessions to alleviate such a problem. Bill is a 41 year old quadriplegic who has limited control of his arms, and no control of his legs. Bill wanted a device that would exercise his lower extremities, and knows many other disabled individuals who could use the Leg-Exerciser, a motorized therapeutic cycle.

The Leg-Exerciser is designed to cyclically move Bill's legs as a solution to the stiffening problems he has experienced. To construct the Leg-Exerciser, an Air Strider Aerobic Exerciser was retro-fitted with an electric motor and specialized leg guides. The motor generates cycling motion of legs strapped into the leg guides. This motion enables the knee and ankle joints to be safely stretched through their natural range of motion. A speed control on the motor allows the operator to adjust the speed of rotation to a comfortable level. The machine is designed to be used in his home, and is quite compact as shown in Figure 12.1.

SUMMARY OF IMPACT

Having lost the use of his legs in 1972, Bill has since been dependent on someone to help him exercise on a regular basis. The Leg-Exerciser was specifically designed for Bill by taking his physical dimensions into consideration, and will help to alleviate his dependence on others for exercise. The machine is designed so that one can be strapped into the leg guides and begin exercising with minimal assistance. Bill is able to exercise his legs for any duration without being limited by the schedule constraints of a therapist. He and his attendant find that ease of getting in and out of the exerciser make it simple to use. As Bill's joints stretch through the cyclic motion, they loosen and remain elastic. At the time of this writing Bill has had three weeks use of the Leg-Exerciser. He is completely satisfied with the performance and has made the observation that, in addition to the legs, it also works muscles in the back that have not been used for a long time. He notices already that he is improving his flexibility, and he believes that he notices improved kidney and bladder function, although that may just be a subjective feeling.

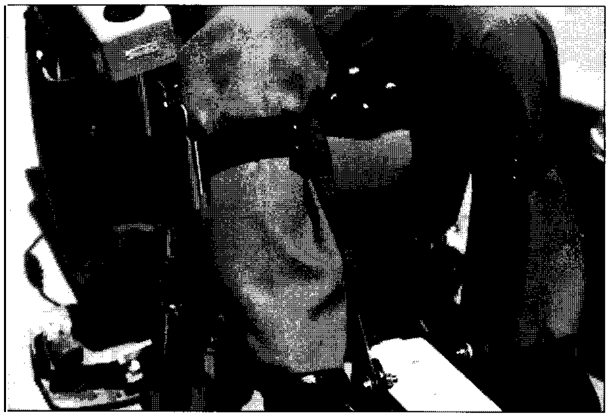

Figure 12.1. A Motorized Therapeutic Cycle for Quadriplegics.

TECHNICAL DESCRIPTION

The objective of this project is to design a motorized exercise apparatus for the lower extremities. Constraints included the following: accessibility from a wheelchair, ease of entry and exit, and variable speed.

Quadriplegics typically encounter stiffening of the joints and bone density loss. This can sometimes result in a brittle fracture. The standard remedy consists of a physical therapist manually stretching tendons and joints. This can be a monotonous and costly activity. A motorized cycling motion was identified as an appropriate method of accomplishing similar stretching. At first, a single crank design, similar to a bicycle, was considered. This however offered no support for the ankle, as the foot would simply follow the pedal through its path. A dual crank (four-bar mechanism) was found to stabilize an appropriate knee and ankle motion. Two cranks were connected to two parallel spring connected foot platforms. The spring connection was used to permit ankle flex and extension at the limits of the cycle, while limiting the excursion-limit loads on tendons in the leg.

We located an Air Strider Aerobic which uses a similar dual-crank mechanism. It was originally intended for the operator to be situated in a standing position. It was necessary to retro-fit the exerciser with a motor and leg guides. These modifications are shown in Figure 12.2.

The electric motor powers the cycle through a travel path 13” in diameter. The guides kept the legs in an upright position. A variable speed motor (50 - 5000 rpm) is coupled to a right-angle gear-reducer with a customized adapter plate that was machined from aluminum. Power is transmitted through a series of chains and gears, sized so that the desired one revolution per second speed is obtainable. It is also necessary to design and build an adjustable motor mount, allowing for tensioning of the chains.

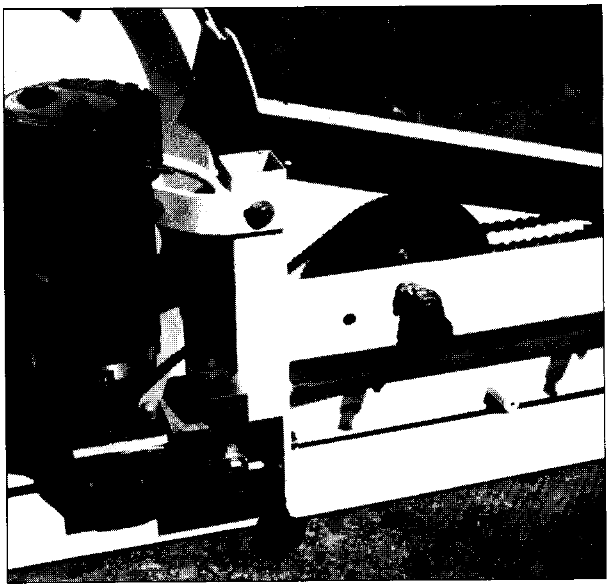

Figure 12.2. Motor and Chain Drive Assembly.

Leg supports are designed and manufactured specifically to the dimensions of Bill’s legs and are fitted with Velcro straps at the calf, ankle, and foot. The leg supports are pivoted at the ankle and are designed to follow the motion of his legs. In addition, it is necessary to fit the original pedals with inclined foot plates. These foot plates maintained an appropriate neutral-starting angle between the foot and lower leg, as shown in Figure 12.3.

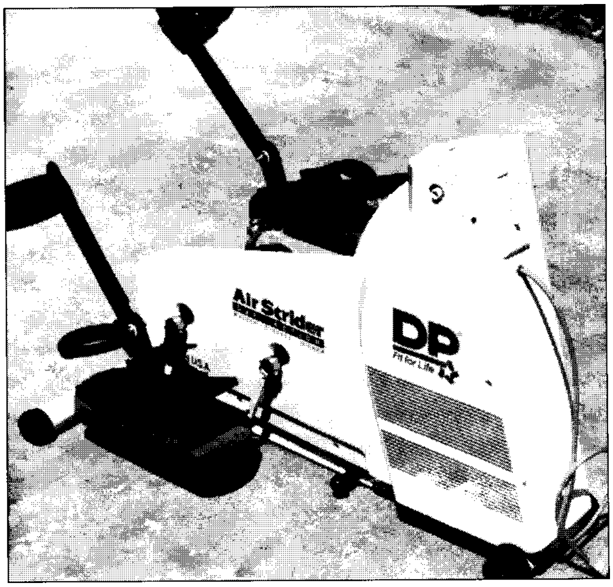

Figure 12.3. Full View Showing Leg-Support Assembly and Spring-Supported Foot Pads.

An analysis was carried out to determine the range of motion created by the predicted path. These predictions were compared to Bill’s actual range of motion as determined with the help of a physical therapist. The exerciser produced 35” of deflection, while Bill only had a range of 18”. To adapt the device appropriate to Bill’s ability, a spring system was installed to compensate for the discrepancy. These springs can be seen in Figure 12.2 and also in Figure 12.3.

The final stage of design involved the installation of a remote power switch and housing additions. The original switch was difficult to access. Thus a new switch was placed in an easy-to-reach location. There were also open areas left in the original housing due to the removal of unneeded parts. These areas were covered with panels, not only for aesthetic value, but also for safety reasons.

Retractable Handle Addition for a Racing Wheelchair

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INTRODUCTION

Deborah, a professor at the University of Florida, is diagnosed with muscular dystrophy, and often requires the use of a wheelchair. Her use of the wheelchair occurs when she tires. It is for this reason that she uses a "racing wheelchair." It is light, compact, and easy for her to use. A disadvantage, however, is its lack of a handle. There are times when she requires someone to push her wheelchair, and, since the wheelchair is approximately $2\frac{1}{2}$ feet tall, it is inconvenient for someone to have to bend over to reach the chair while pushing it up a slope. It is for this reason that a handle addition is necessary. The handle is shown in Figure 12.4 in the deployed position, and in Figure 12.5 stored under the seat.

Figure 12.4. Wheelchair Handle in Operating Position.

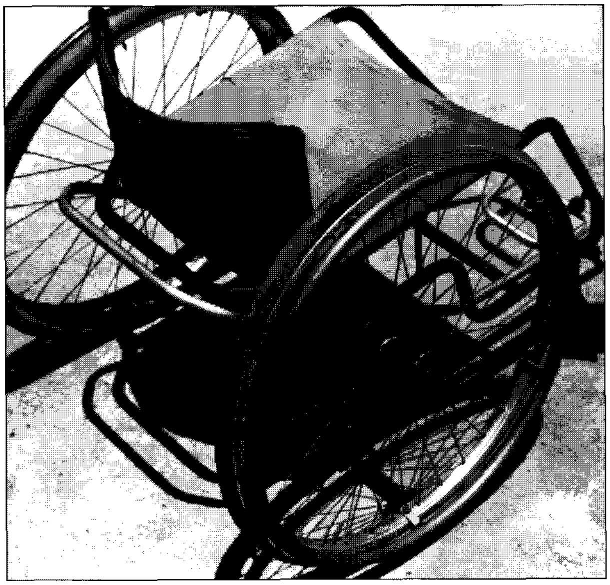

Figure 12.5. Wheelchair Handle in Under Seat Storage.

SUMMARY OF IMPACT

To be effective, the wheelchair handle addition ultimately needed to be convenient. This goal of convenience is satisfactorily met with the following criteria:

- compact design
- minimal weight addition
- ease of transition between storage and utilization
- positions

This design permits Deborah to store the wheelchair in the trunk of her car in the same manner as before the handle addition since no extra space is necessary. The wheelchair and handle also remain light enough so that she is still able to lift the chair out of storage with ease. When in need of assistance, the handle is easily transferred from its storage position on the chair to its upright position, allowing an attendant to pull, as well as push, the chair in any direction.

TECHNICAL DESCRIPTION

The primary goal in the design of the wheelchair handle is simplicity. It is necessary to have a handle that, when stored, conformed to the space already occupied by the chair. The design resulting from this particular criterion consisted of a handle made of tubing bent at angles imposed by the existing geometry of the chair. Stainless steel tubing with an outer diameter of 0.625 in and a thickness of 0.035 in is chosen because of its combination of strength, weight, and ductility. A prototype of the handle, made from ductile aluminum tubing, established appropriate angles. The subsequent angles in the stainless steel tubing are fashioned after those in the aluminum tubing model. The complete handle is shown in Figure 12.6.

Once the stainless steel tubing was bent, a guide was installed in the underside of the chair. It attached to the existing brackets on the chair, and simply serves to guide the handle into and out of its storage position.

A final design detail is the method of securing the handle in its upright position. It is necessary, due to the angles of the tubing and the existing frame, to provide movable hooks. These hooks slide up and down on the handle, allowing the handle to be withdrawn from beneath the seat and positioned for use before attachment to the wheelchair frame. They are made of aluminum, with welded gussets providing the necessary strength, and can be seen on the handle in Figure 12.6.

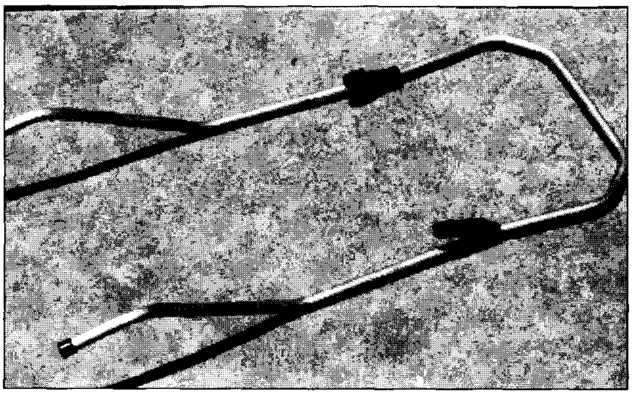

Figure 12.6. Handle Removed.

Nurse-Call Wrist Switch

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INTRODUCTION

An individual suffering from cerebral palsy suffers a loss of fine motor control resulting from damage to motor areas of the brain early in life. A characteristic of this disease is a spastic or "jerking" movement of the body's appendages. Further, the harder the individual tries to control their motion, the more spastically the muscle contracts. Additionally, the patient is generally unable to speak or hear well. Consequently, it is difficult for the individual to get the attention of a caretaker, especially if they are not in close proximity to each other.

We identified a lo-year-old boy, Vance, who lives at home in a multiple-sibling household, and who could benefit from a personal call switch that could get the attention of his caretaker. The purpose of this project is to adapt currently available electronics into a transmitter/receiver device that can be used by a cerebral palsy client to signal a caretaker of the need for immediate assistance. The device built is a wrist switch for Vance which signals his caretaker when she is not in close proximity. The device is shown in Figure 12.7, along with its wall mounted receiving unit.

SUMMARY OF IMPACT

Vance is wheelchair bound because of the affects of cerebral palsy. Although he can speak with a variety of one-word responses, his speech is very limited. He occasionally needs prompt attention, but has difficulty gaining the attention of his caretaker due to the client load in his home. The Nurse-Call Wrist Switch designed for Vance gave him a means of immediately gaining the attention of the caretaker, without disturbing the rest of the class with a loud buzzer or bell sounds. This minimizes undesired attention from other clients or students when in class. Vance is pleased with the wrist switch because it does not attract undue attention as would other methods such as a bell on a neck chain. He exhibited no hesitation to use the new device.

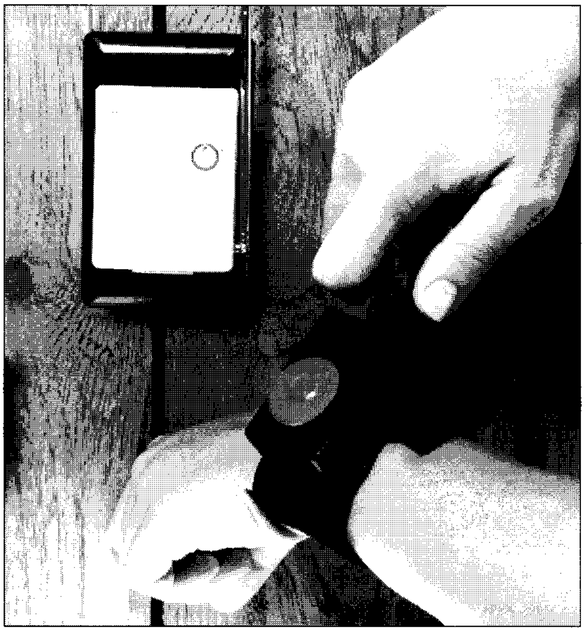

Figure 12.7. Wrist-Call Unit and Wall Mounted Receiver.

TECHNICAL DESCRIPTION

Some essential considerations of the design included size, durability, accessibility and range. First, the device needed to be small enough to be comfortable and relatively lightweight to avoid fatigue. Next the device had to withstand knocks against the surroundings, such as a wheelchair or a table. Also the device is to be operated with minimal effort. Finally, the range needed to be far enough for the caretaker to receive the signal from anywhere in the house.

As shown in Figure 12.7, the device consists of a transmitter switch worn on the patient's wrist, and a corresponding receiver plugged into an electrical outlet. The switch is adapted from an X-10 Powerhouse key chain remote control, which operates from two AAA batteries. The original outer switch interface was removed and replaced with a more accessible circular disk switch activator.

Figure 12.8 shows the inside view of the wrist unit; components include: battery holder, circuit board, and front panel switch holder. A Velcro strap holds the switch onto his wrist. The corresponding transceiver receives the signal from the transmitter, and then re-transmits the signal over the electrical lines of the house. In this way, lamp modules can be added throughout the house so that when Vance triggers the switch, any lamps plugged into these modules will turn on. Hence, the main receiver can be plugged into the same room with Vance, and the caretaker is able to move from room to room. She can either take a lamp module with her to plug in or have several lamp modules in rooms where she is more likely to be. When the caretaker responds, she resets the wrist-switch to the off position.

The size of the switch is approximately $1\frac{1}{2}"\times2\frac{1}{2}"$, which is twice as large as some watches. It is relatively durable, and the wrist strap is removable for cleaning. The diameter of the switch interface is approximately 1" so that Vance can turn it on with relative ease. The corresponding off switch is harder to access to avoid unintentional triggering.

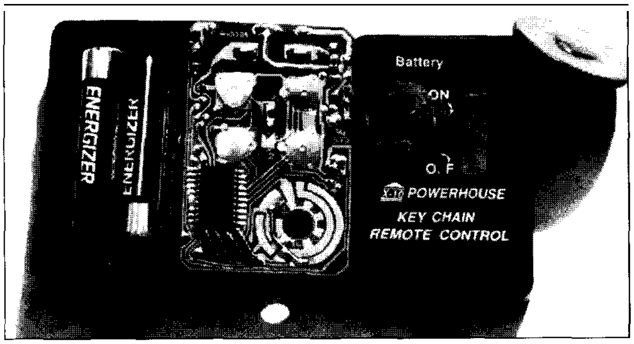

Figure 12.8. Inside View of Transmitter Unit.