CHAPTER 9
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DESIGN OF A MOBILE ARM SUPPORT FOR PATIENTS WITH PROXIMAL UPPER EXTREMITY WEAKNESS

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INTRODUCTION

The mobile arm support (MAS) is designed to restore the independence of persons with proximal upper extremity weakness. The MAS is a spring-loaded linkage that assists users in elevating their arms from either the elbow or the shoulder. To ease accessibility, the device is able to be mounted on a wheelchair. The ultimate goal of the MAS is to give the user the ability to perform daily tasks such as eating and bathing without the aid of others.

SUMMARY OF IMPACT

The need for a MAS was described by occupational therapists (OT) in a clinic at the Ohio State Dodd Hall Rehabilitation Hospital. Persons with proximal upper extremity weakness are often capable of moving their arms when they do not need to overcome gravity, but range of motion is often limited when they must overcome their own weight. The OT desired a device that could be attached to a client's wheelchair and would allow the person to reach their head to perform the necessary tasks of daily living such as lifting their arm to eat or groom.. The device is designed to work for a wide range of sizes of people. This device reduces the effort necessary for the user to elevate their arm. The MAS enables the person to perform daily tasks on their own, therefore providing them with more independence.

TECHNICAL DESCRIPTION

The MAS is constructed mostly from aluminum with some steel components. The use of aluminum is critical to keep the weight of the device as low as possible as extra weight can leave the user feeling tired after extended use. Steel parts are used where added weight has a minimal impact on the user and higher strength was a necessity. The parts of the MAS are joined with aluminum pins that allows for both quick attachment and removal. The device is clamped to the wheelchair prior to use.

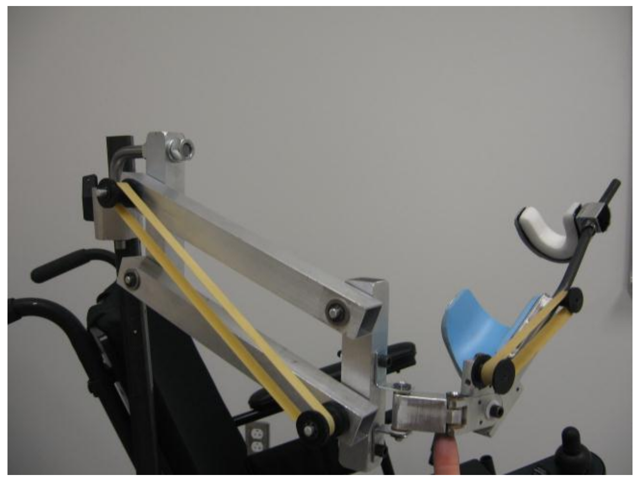

Fig. 9.1. The Mobile Arm Support.

The MAS mimics the motion of the arm through various linkages. A four-bar parallelogram linkage is next to the patient's upper arm. One of the links of the four-bar copies the natural motion of the humerus. The nature of motion of the distal link of the four-bar creates a stable platform that separates shoulder motion from elbow motion. Two links at the elbow rotate in the horizontal plane. These links increase the range of motion when reaching across the body by eliminating a pinch point that would occur without them. Another pin joint at the elbow allows the client to flex their arm at the elbow. Finally, a cuff located near the user's wrist rotates around its support on a bushing to allow the user to supinate or pronate the arm. Ball bearings or bronze bushings are used at every joint to minimize the effects of friction.

Passive assistance is provided at several positions in the MAS. Rubber bands connect diagonally across the four-bar to provide assistance when the user raises their arm from the shoulder. Rubber bands also provide assistance at the elbow for the user to flex their elbow. Rubber bands have several advantages over alternative materials in that they are cheap, and light weight. They also make adjusting the device to varying sizes easier. More rubber bands can be quickly added to support larger weight for heavier clients, and conversely removed for lighter clients. A torsion spring located at the cuff near the wrist assists the user in supinating their wrist from a mid-position.

The cost of parts and materials is $1200.

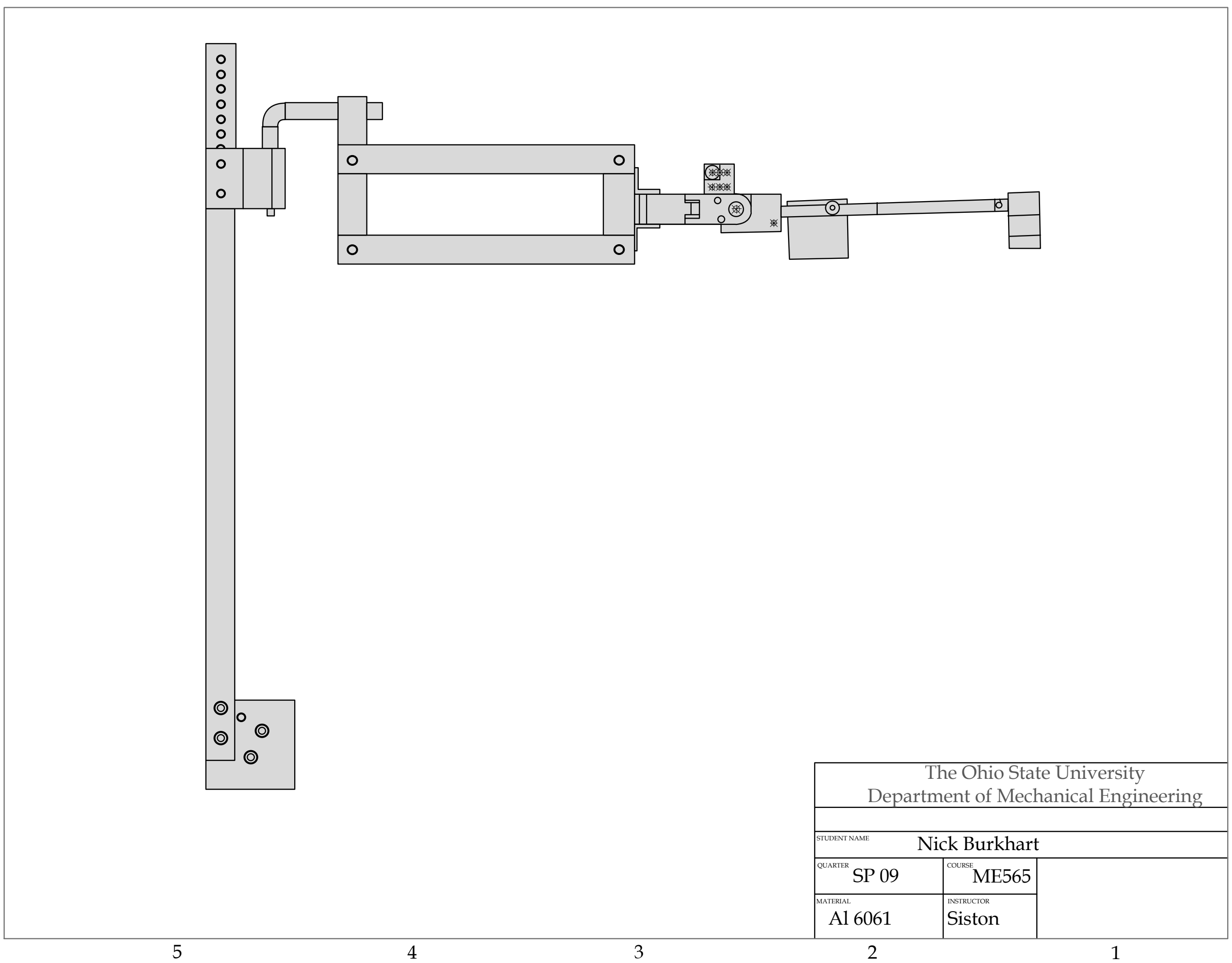

Fig. 9.2. Technical drawing of the Ohio State Mobile Arm Support.

DRESSING ASSISTANTS FOR WOMEN WITH THE USE OF ONE HAND

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INTRODUCTION

Our clients are women under the age of 65 with the use of only one hand due to stroke. Dressing can be difficult for this population, and many women will change clothing styles to save time and increase convenience. Changes of these types can sometimes result in lowered self-esteem and self-confidence, especially when striving to return to the workplace. Currently there are very few devices on the market specifically designed to help with one-handed dressing. Devices in this project are intended to help women put on a brassiere or a zip-up jacket with one hand.

SUMMARY OF IMPACT

Testing of the device involved the participation of neurologically unaffected subjects simulating one-sided paralysis, who attempted to don bras or zip up jackets with and without the devices. The devices did not always reduce the time it took for the unaffected subjects to dress, but many commented that it seemed much easier to dress using the devices. Most potential clients can take up to five minutes to fasten a bra unaided, and most often cannot zip a jacket unaided, so increased ease of dressing was an ideal outcome. An occupational therapist working post-stroke clients said, "These devices would be a very beneficial tool for a person with hemiplegia or hemiparesis to increase independence with dressing." Particularly about the bra device the therapist commented "This device is the best I've seen for help with fastening a bra one-handed."

TECHNICAL DESCRIPTION

Fig. 9.3 shows the two dressing aids designed in this project. The bra aid is shown on the left and the zipper aid on the right.

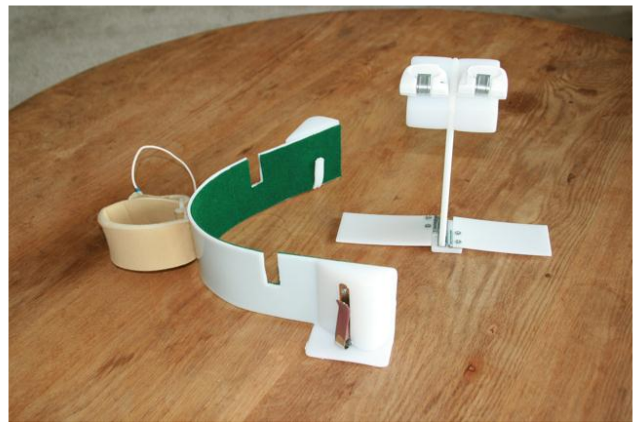

Fig. 9.3. Dressing aids (Left: bra device, right: zipper device).

The bra aid consists of a curved, wide polyethylene waist band, a cloth arm cuff, two polyethylene inner clips, and two aluminum outer clips fastened to two polyethylene curved surfaces. The waist band is meant to wrap around the user's torso just under the bust. Attached to this band at the apex of the curve is the cushioned arm belt meant to be secured around the user's affected arm. This holds the device in place during use. Prior to placing the device on the body, the user inserts either the hook or eye side of the bra band into one of the outer clips, then threads the bra through the notch in the waist band and around the inside of the device. The bra is then secured in the opposite side's inner clip to prevent the bra from slipping downward during use of the device. Once the bra is in the device in this manner (Fig. 9.4. left), the user puts her affected arm through the arm cuff with the outer-clipped side of the bra band facing out at the front of the body, reaches behind with the unaffected hand for the other side of the bra band, brings this side around, and fastens the two sides of the bra band in the front. This fastening is facilitated by the curved surface feature. When the eye side of the fasteners is threaded along this curved surface, the eyes stick out tangent to the curve, which makes engaging the hooks much easier. The inner surface of the bra aid is lined with felt to increase comfort of the device for the user.

The zipper aid consists of a vertical support, two leg flaps, two stoppers, and two clips attached to a clipping surface. It is constructed entirely out of polyethylene, with the exception of the clips, which are cut from a plastic hanger, and the zinc-coated hinges connecting the leg flaps to the vertical support. The leg flaps fold in and out for easy storage of the device, with the stoppers preventing the unfolded leg flaps from extending past 90º from the vertical support. When the leg flaps are unfolded, they are meant to be secured underneath the user's legs with the vertical support extending up between the user's legs. The user orients the clipping surface so that the opening side of the clips is facing toward the user's body. This causes the clipping surface to be angled down and out, allowing the user an unobstructed view of the clips while providing a somewhat vertical initial orientation for zipping. The clips attached to the clipping surface are hanger-style clips with a metal component which can be pushed in to hold the clip closed or pushed out to allow the clip to open freely. Once the jacket is on and the zipper device in between the legs, the user begins the zipping process by securing the "box" side of the zipper in one of the clips. She then slides the zipper's pin through the slider and into the box. The user then secures the pin side of the zipper in the other clip, and can then use the pull-tab to advance the slider (Fig. 9.4 right).

The cost of these devices is approximately $10 for the bra aid and $4 for the zipper aid, assuming that the parts are bought in bulk.

Fig. 9.4. The devices in use (Left: The bra correctly oriented for left-handed fastening. Inset: Fastening the bra. Right: The jacket fully secured in the device).

ADAPTED CRUTCH TECHNOLOGY FOR PERSONS WITH CHRONIC DISABILITIES

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INTRODUCTION

There are approximately 566,000 people who use crutches in The United States. This number represents 8.32% of the 6.8 million people in America who currently use mobility assistive devices. While current crutches can support the body and enable locomotion, most long term users of crutches experience pain and discomfort in the wrists and shoulders due to improper positioning and high loads during standard crutch use. Some long term crutch users also suffer from carpal tunnel syndrome, due to the extreme wrist angles that are experienced during ambulation with crutches. Therefore, the purpose of this project is to design a device that supports the body and enables locomotion while reducing the harmful forces that are observed at the wrists and shoulders during ambulation with traditional crutches. Through research about current crutch technology and associated injuries, our team determined that the target population for the adapted crutches is patients who use a wheelchair for their primary means of locomotion and crutches as a secondary mean of locomotion. These include patients with disabilities such as cerebral palsy, spinal cord injuries, and post-polio syndrome. These users typically have limited lower extremity function but some functional movement in their upper extremities.

Fig. 9.5. Adapted Crutch Prototype.

SUMMARY OF IMPACT

Motion analysis testing of healthy subjects and interviews with patients following spinal cord injuries suggests that the adapted crutch realizes its design goals. By using a force plate and Tekscan pressure sensors, our tests verify that our crutch does significantly reduce the time to peak loading reduction by a factor of approximately 13% of crutch-to-ground contact time. Through the use of motion capture, our tests verified that our crutch maintained the range of functional wrist angles of slight extension and slight ulnar deviation. Patients commented that the stability of our crutches was equal to that of standard crutches. Many patients felt that the crutches were aesthetically pleasing, that they would be happy using them once approved by a therapist, and mentioned that the “cool factor” of having a unique base for a crutch would add to the overall appeal of the device.

TECHNICAL DESCRIPTION

The body of the crutch is made from aluminum 2024-T3 tubing, and is adjustable from 28-36 inches from the ground to the handle. The forearm cuffs are made from ABS plastic, with nylon racks and pinions to allow for up to two inches of adjustability. The ground interface is made from type 2 titanium, for its high strength to weight ratio. The entire assembly is held together with standard sized nuts and bolts.

There are three different types of handles for the crutch. Each different type of handle has a different type of groove and contour to accommodate different user preferences and hand sizes. Each handle is made from ABS plastic with aluminum square tubing inserts to insure structural integrity. Some handles are coated in silicone rubber for added grip and comfort.

In order to reduce the impact loads seen during ambulation with standard crutches, the bottom of the adapted crutch compresses in a spring like fashion. The bottom of the device is bent into a "C" shape, with rubber padding attached to the bottom. This geometry creates both a spring like compression and a rolling action at the ground interface. The final "C" shape of the foot is based on extensive finite element analysis of different geometries and materials. These attributes of the foot of the crutch are what alleviate impact loading due to the rigid vault like action experienced during ambulation with standard crutches.

The cost of parts/material is about $2545.

Fig. 9.6. One of the prototype handles.

Fig. 9.7. The custom foot of the crutch.

ADAPTED TRICYCLE FOR CHILDREN WITH HEMIPLEGIC CEREBRAL PALSY

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INTRODUCTION

Children diagnosed with hemiplegic cerebral palsy have difficulty with motor skills and upper and lower extremity strength on one side of the body. The purpose of the adaptive tricycle project is to design, build, and test a fun and safe option that offers valuable therapeutic benefits for these children. The adapted tricycle is designed to adjust for multiple users varying in size, age, and in upper and lower extremity strength. The tricycle also secures the rider, allows for steering, provides easy-to-grip handles, and is easy to use. Other similar tricycles currently exist on the market, but none are able to adjust the gear ratio to accommodate children with differences in strength. The proposed tricycle uses a belt-and-pulley drive system, which can be easily adjusted to four different gear settings.

SUMMARY OF IMPACT

Riding the tricycle offers a great therapeutic benefit to the user while providing a fun experience. When the children first see the tricycle, they are excited about it and want to ride it, which motivates them to participate in a fun and therapeutic activity. While riding the tricycle, the moving parts and fun colors motivate them even more to continue to push themselves, and get valuable exercise.

The adaptive tricycle provides an opportunity for children with hemiplegic cerebral palsy to receive therapeutic benefit and make progress with their physical abilities. By making the gear ratio for the tricycle adjustable, the parents or occupational therapists can continue to adjust the tricycle as the child progresses. This adjustment will make the child extend their affected limbs farther and farther from their body as they become more mobile through the tricycle's use and ultimately result in substantial physical progress.

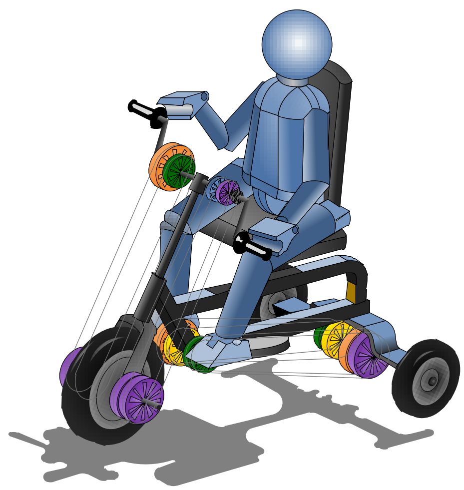

Fig. 9.8. Computer model of the adapted tricycle.

Fig. 9.9. Pulley and belt drive train.

TECHNICAL DESCRIPTION

The tricycle is driven by two independent sets of pulleys and belts. One connects the front hand cranks to the front wheel, and the other connects the foot pedals to the rear wheel. Each set has four pulleys at each end, which allows for four different strength settings: 1) very easy, 2) easy, 3) standard, and 4) difficult. The pulleys are machined from UHMW plastic, and are used to drive the orange urethane belts. The belts are tight enough so that they can carry torque from the cranks to the wheels, yet they are stretchable so the therapist can move the belts from one pulley set to the other easily.

The tricycle frame is made from welded steel tubing, and the seat, foot pedals, hand cranks and other common tricycle parts are purchased from AmTryke LLC. The cost of parts/material is about $2000.

Fig. 9.10. Photo of completed adapted tricycle.