

# CHAPTER 4

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# UPPER EXTREMITY PROSTHESIS

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## INTRODUCTION

The purpose of this project was to perform design and feasibility studies which may have applications for persons with upper extremity amputation living in a rural or Third World society. Many efficient, body powered and myoelectric upper extremity prosthetic designs are available in the US. However, these devices do not find broad application in rural or Third World environments because they are expensive, difficult to maintain, and require intricate methods of fabrication. The goal was to create a simple, cost-effective design for an arm prosthesis. Constructing all parts from inexpensive, readily available construction materials was essential. The design must also be fairly simple to fabricate with hand-held tools commonly available in an artisan's workshop.

Two upper extremity prostheses were designed for persons living in impoverished regions of Central America (Figure 4.1). The first design was made for an above elbow amputee and the second design was made for a below elbow amputee. The first design (Figure 4.2) consists of three major components, the socket attachment, the locking elbow, and the end effector. The socket attachment consists of a foam-lined, hinged plastic pipe that attaches to the user's residual limb and is supported by a nylon body harness. The locking elbow mechanism joins the upper and lower arm members, allowing rotation around the joint. The angular position at the joint is fixed with an adjustable length nylon strap. As the length of the strap increases, the angle at the elbow also increases. The final component of the prosthetic design is the hand-like end effector. This portion of the device is hook-shaped and consists of three pieces of plywood jointed with a small cabinet hinge. The opposable members can be opened about the hinged joint with a small wooden lever. The members are held closed with rubber bands. Thus, the end effector is used to grasp objects



Figure 4.1. Above Elbow Prosthesis (Right) and Below Elbow Prosthesis (Left).

between the two opposable members, or to carry objects with the hooked end.

The second prosthetic device consists of four major components: the terminal device, the socket, the harness, and the cable. The terminal device consists of two U-bolts, a toggle bolt, a PVC plug, an eyehook, nuts, washers, and rubber bands. The socket consists of ABS pipe and a flotation device. The harness consists of a packaging strap, metal buckles and a metal ring. The cable consists of a bicycle brake, U-clamps and a rope clip. The terminal device is body powered. It can be opened

by either shrugging the opposite shoulder or by extending the amputated limb. The floatation device in the socket can be inflated to provide a snug fit. The harness can be adjusted to provide a proper fit. The harness is also padded to ensure a comfortable fit.

### SUMMARY OF IMPACT

Only half of all new U.S. upper extremity amputees receive a prosthetic device each year. Only half of those who do receive one will continue to use it after one year. These numbers are even lower in Third World countries due to the lack of availability and the high cost of prostheses. The prosthetic designs developed for this project allow upper extremity amputees in third world countries to improve the functionality of their amputated limbs. Usually, amputees in Third World countries do not have the opportunity to own and use such a device and thus, are only able to use their one remaining hand to grasp and carry objects. Although the designs we developed are simple, they are helpful in performing easy tasks and making the remaining limb available to complete more difficult tasks. A good example would be using the prosthesis to hold a small pail of paint and using the other hand to apply the more sophisticated movements of the brush strokes.

### TECHNICAL DESCRIPTION

The design specifications of the first device (for an above elbow amputee) were generalized for the average sized individual. However, the component sizes used in the design can be easily adjusted to compensate for the size and length of the residual limb, and the size of the individual using the device. The second device (for a below elbow amputee) was designed for a right arm amputee, but can be easily modified for a left arm amputee.

In order for these upper extremity prostheses to have an impact on the Third World, the major design requirements kept in mind were: (1) the device must be made of inexpensive, readily available materials; (2) the components must be easy to fabricate and assemble with common hand and handheld power tools; (3) in the event of component failure, fixing and replacing parts of the prosthesis should be easy to perform in the local environment; and (4) using the device should provide the operator with a substantial improvement to functionality without sacrificing comfort.

#### *Above Elbow Prosthesis*

The three major components for the upper extremity prosthesis (Figure 4.2) were the socket attachment, the locking elbow, and the end effector. The socket attachment was made from 4" diameter ABS piping



Figure 4.2. Close-up of Prosthesis for an Above Elbow Amputee.

that is 8-7/8" long. A 6" segment of this pipe was cut in half through its axis and separated from the main portion of the pipe. Small cabinet hinges were used to attach these pieces to make a door that opens and closes. The inner lining of the ABS pipe was padded with convoluted packing foam. Velcro was glued to the outside of the ABS pipe. This will secure the door closed while the prosthesis is in use. To attach the prosthesis, the door on the ABS pipe would be opened, and then closed around the user's residual limb. This will provide a very tight but secure fit around the limb. A figure eight style nylon harness attached to the socket will allow the user's shoulders to provide additional support for the prosthesis. The socket was attached to the upper arm member with a 4" ABS pipe cap that slips over the 4" ABS pipe. A 1-7/8" hole was drilled into the top of this cap to allow a male and female ABS pipe adapter to be assembled through the hole. The male ABS pipe adapter on the outside of the cap was then affixed to the 1-1/2" diameter ABS pipe (3-1/2" long), acting as the upper arm member.

The upper arm member was attached to the 3/4" PVC pipe (12" long) acting as the lower arm member with a threaded pin going through the ends of each pipe. A hole was drilled at the end of each segment of pipe large enough for the threaded pins to be inserted. The smaller pipe was then inserted into the large pipe so the holes were lined up and the pin could be inserted. A cut 2-1/4" long was made into the larger pipe, allowing the smaller pipe room to rotate upward. An adjustable length nylon strap was riveted midway along the length of the PVC piping and just below the opening door on the outer socket. Adjusting the length of this strap allows the locked angle at the elbow to be changed to any position in the range of 60° to 180°. Using a non-ridged locking mechanism causes one major disadvantage. The elbow will only lock in tensile loads and not compressive loads. This weakness was determined acceptable since the primary use of this prosthesis is to hold and carry objects; applying a compressive force at the elbow would rarely be desired.

The end effector was the last major component of the upper extremity prosthesis. The end effector was made from two 1/2" pieces of plywood cut into a hook shape. The piece acting as the upper member of the hook shape was cut into two pieces 6-1/2" from the hooked end. Of these two pieces, the straight end was glued to the lower member of the

end effector at its corresponding position. A small cabinet hinge was then used to attach the two pieces of the upper member together, once again completing the hook shape. A 3/8" hole was drilled at an angle of 30° forward from normal into the hooked piece of the upper member. Glue was placed around the end of a 3" x 3/8" wooden dowel and inserted into this hole. Rubber from bicycle tires was cut to the shape of the hooked ends of the end effector and glued to the inner surfaces of each member. The two pieces of the end effector open and close about the hinged joint. Rubber bands were used to pull the opposing members closed and the wooden dowel lever was used to open the end effector for grasping small objects. The bicycle tire rubber on the inside surface of the end effector pieces give the grasping portion of the device a greater coefficient of friction to prevent objects from slipping out of the grasp. The straight end of the end effector was sanded into a round shape of 5/8" diameter so it can be slid into the 3/4" PVC lower arm and screwed into place.

### ***Below Elbow Prosthesis***

The second prosthetic device consisted of four major components: the terminal device, the socket, the harness, and the cable. The terminal device was made from two U-bolts, a toggle bolt, a PVC plug, an eyehook, nuts, washers, and rubber bands. To make the terminal device, one leg was cut off each of the two U-bolts, leaving enough room to form a strong hook. Next, a hole was drilled, centered in the top of the 2" PVC plug. The PVC plug was used because of its light weight. A toggle bolt provided a hinge for the hook. Next, one of the U-bolts was screwed through the toggle bolt far enough into the plug so a washer and nut could be attached to the U-bolt. An eyehook provided a point of attachment between the cable and the terminal device. To ensure that the device is easily removed for maintenance and repairs, the terminal device was attached to the ABS cap with two 2" nuts, one on the inside of the cap and one on the outside. The gripping strength for the hook was provided by rubber bands. Additional rubber bands can be added if greater gripping force is desired.

The socket consists of ABS pipe (6" length of 3" diameter) and a flotation device. The ABS pipe length may be altered depending on the length of the residual limb. After cutting the ABS pipe to size, the ends were sanded to ensure a level and smooth cut. Because ABS pipe is much lighter than PVC,

ABS pipe was used to minimize the total weight of the device. A hole was drilled in the ABS pipe through which to pass the inflation valve. The flotation was cut to 14" and resealed so it would line the ABS pipe inside in a single layer, with a little overlap at the ends. Vinyl glue was used to reseal the cut ends, and PVC glue was used to affix the top two inches of the flotation device to the inside of the ABS pipe. This allows the flotation device to be easily removed if it needs to be replaced.

The harness was made from a packaging strap, metal buckles and a metal ring. The harness was in the shape of a figure-8 with a metal ring to provide flexibility through a large range of movement. Quilted padding was used under the left arm to prevent the strap from cutting into the user's skin. A padded cuff was placed on the upper arm to provide a transition between the prosthetic device and harness. The cable was made from a bicycle brake, U-clamps, and a rope clip. The bicycle brake allows the cable to move freely while the housing is securely attached to the ABS pipe using U-clamps. The rope clip provides the attachment point to the harness. A fabric cover provides a finished and more aesthetically pleasing product.

Amputees were not available to test the prostheses. However, some tests were performed to evaluate the strength of each device. The first device was successfully loaded with a 25 Newton weight at the 90° elbow position and was able to grasp objects weighing up to 4.9 Newtons. The end effector was

most reliable for grasping objects with a thickness of less than 1" and weight less than 2.5 Newtons. Two tests were performed with the second device. The first test was to manually operate the cable to grasp and lift a 3-lb barbell. Two rubber bands easily provided the necessary gripping tension. The second test was to lift a 3-lb barbell using the closed hook position. The terminal device and connection performed well during these two tests.

An upper extremity amputee was able to comment on the usability of both devices. While neither device could compare with his custom made, body powered prosthesis, he was able to make positive suggestions. The primary need for future designs was to make a well fitting, rigid socket with minimal compliance between the residual limb and the prosthesis. The foam lined and pneumatic cushion designs made in this project were too compliant to allow the user much control. He also commented that the nylon strap used to lock the elbow of the above elbow prosthesis was not rigid enough, and any elbow lock needed to be able to resist flexion and extension simultaneously.

The total materials cost for the above elbow prosthesis was \$28.84. The total materials cost for the below elbow prosthesis was \$31.87.

# SLIDING TRANSFER BOARD

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*Client: Delia Rubio*

*Client Coordinator: James Whitehouse and Mary Andriano, RN, American Transitional Hospital, Nashville, TN*

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## INTRODUCTION

Individuals who use wheelchairs sometimes lack the physical strength to lift themselves out of the chair and onto another surface. In such situations, a transfer board provides a smooth surface that bridges the gap between two horizontal surfaces, and allows the person to simply slide from one to the other. For example, a person can slide from a wheelchair to a chair, bed, or bench using a transfer board. Nurses also use transfer boards to easily move patients from one surface to another. Because the movement is horizontal when the surfaces are at the same elevation, there is no need to lift and carry the patient from one surface to the other.

Typical transfer boards are long, rectangular boards made of maple, birch, or plywood. Lengths are available from 24" to 30", and widths are typically 8". Available boards range from 1/8" to 1/2" thick. The more expensive models are polished on top and tapered to 1/8" thickness at both ends to allow for easy placement beneath the patient's hips. Some models have slots to aid in gripping the board and/or hooks to attach the board to a wheelchair more securely.

According to several patients, current transfer boards have many unfavorable qualities. An improved design was completed.

## SUMMARY OF IMPACT

Current transfer boards have many unfavorable qualities. They are hard to hold, hard to slide across, hard to store for quick and easy access, and too long. When the ends are tapered, the ends were too sharp and cause pain. Also, the thinner boards tend to be too flimsy, and bend too much during use. Friction on the surface of the board makes it difficult for weaker individuals to pull themselves along the board. The new design will provide a light, but

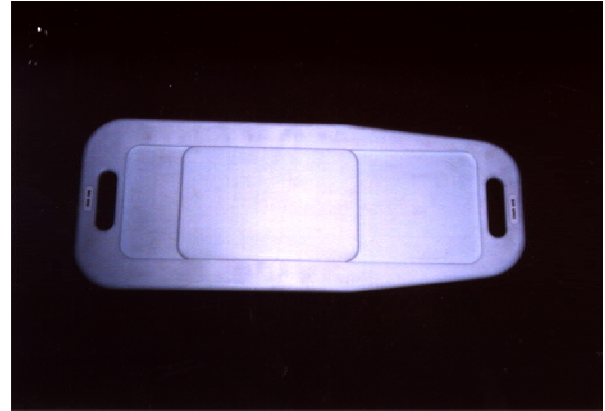


Figure 4.3. Improved Transfer Board Device.

strong transfer board. The board will be safe and inexpensive.

## TECHNICAL DESCRIPTION

The improved transfer board design (Figure 4.3 and Figure 4.4) provides an easier and more efficient way of sliding the patient along the board. The board itself is made of two pieces of ultra high molecular weight polyethylene (UHMW-PE), which is lightweight, strong, and self-lubricating. Two sheets of UHMW-PE were purchased, with dimensions 12"x36"x3/4" and 12"x12"x1/2". One sheet of the UHMW is inset inside a channel cut into the other sheet (Figure 4.5). The material has a low level of sliding resistance. Therefore, while a person is sitting on it, the inlaid sheet easily slides back and forth. The final design was built and tested. Different loads in different situations were tested. This included moving different weights to and from different heights. Finally, the board was tested by using it as intended.

The cost for materials was \$75.



Figure 4.4. New Transfer Board Device.

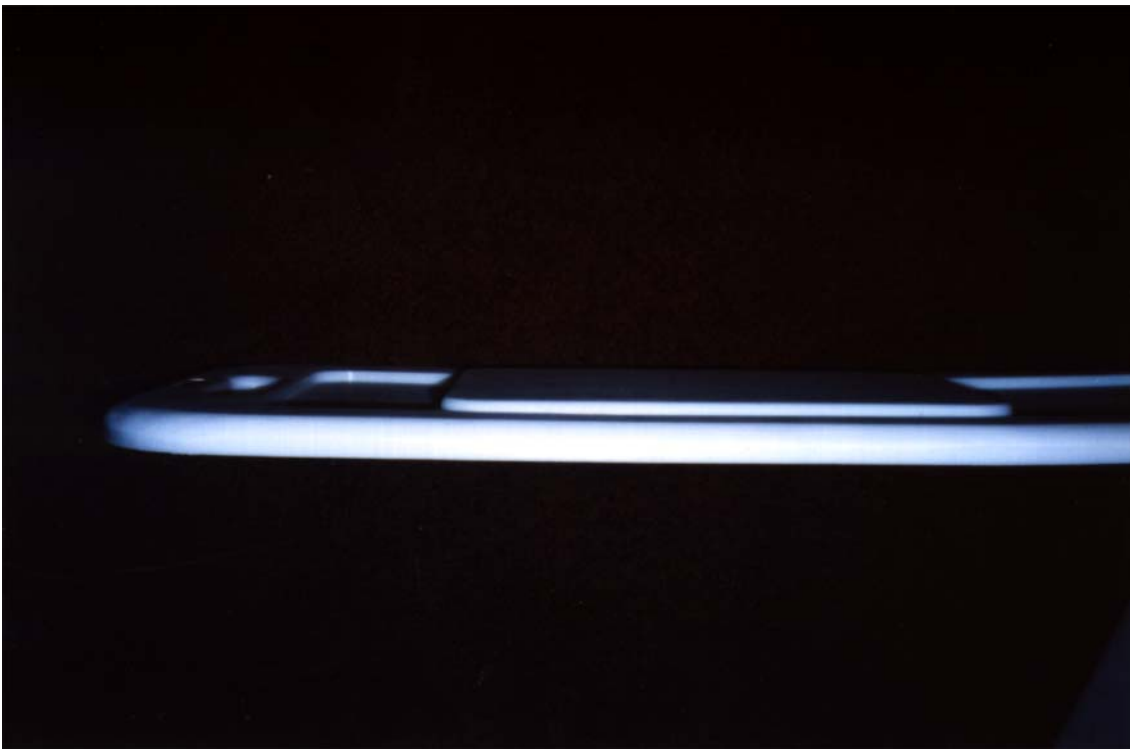


Figure 4.5. One UHMW-PE Sheet Set Inside a Channel Cut into the Other UHMW-PE Sheet.

# MAGIC GOLF BRACE

*Designer: Nan Huang*

*Client: Kevin Burke*

*Client Coordinator: Beckie Heffron, Prosthetic Orthotic Associates, Mesa, AZ*

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## INTRODUCTION

As a result of a childhood traumatic brain injury, an active, adventurous man who likes to participate in outdoor activities has difficulty holding a golf club with his wrists in a neutral position, making it hard to hold and swing the club with authority. The right side of his body exhibits neuromuscular impairments, including a contracture that holds his right wrist abducted at approximately 80 degrees and keeps his thumb and forefinger tightly closed together.

The Magic Golf Brace (Figure 4.6) is an orthosis designed to temporarily straighten his wrist without adversely affecting his ability to hold onto a golf club with his right hand. The brace includes a ratcheting mechanism that allows him to gradually straighten his wrist with his other hand. Because it is a ratchet, he can straighten it a little, or a lot, according to his needs at the time. A release mechanism allows the device to instantly release following each golf swing, which allows his hand to relax and enables blood to flow back into the areas temporarily pressured by the orthotic device.

## SUMMARY OF IMPACT

While using the device, the client is able to straighten his wrist and hold a golf club with better form. He is able to strike the golf ball with more control and power, and has increased his distance and reduced his score. It is not always best to position his wrist to emulate a normal golfer's wrist, but instead to enable him to perform at his best possible level. The client feels the brace will also allow him to participate more in other activities where a straight wrist is beneficial.

## TECHNICAL DESCRIPTION

The first step in the design process was to define the need by observing his golf swing movements, and to interpret his needs in terms of design specifications.



Figure 4.6. "Magic" Golf Brace

By observing him, it was determined that a moment of approximately 9.84 N-m was required to bring his wrist to a neutral position.

Researching patents and reviewing different types of commercially available gloves and braces indicated that it was unlikely for a "soft" type of glove to provide the necessary straightening moments about the wrist. Thus, a hybrid type of glove/brace was designed so that it minimally inhibits his swing and grip. The design is also reasonably lightweight, provides the necessary strength, is adjustable, rigid, and allows the wrist moment to be quickly applied and instantly relaxed.



Minimizing weight and intrusiveness resulted in minimizing the amount of contact area on the skin surface. Reducing the contact area increased normal and shear stresses applied to the skin. Because applying a large wrist moment was necessary, this meant leaving the brace in the active position for long periods of time would likely result in skin breakdown, blistering, and/or pressure sores. Fortunately, golf is a game that involves a lot walking and very little time swinging the club. For this reason, a different device with increased skin surface contact area would be needed for other activities such as kayaking, because the paddle would be gripped for long periods of time in a wet, skin-softening environment.

The materials for the brace included thermoplastic, foam padding, Velcro, and Aliplast. A Step Lock was used to provide the strong, ratcheting mechanism. Typically, Step Locks are used for ankle-foot orthoses, and include a steel bar (which resists both tensile and compressive loads) that passes through the ratchet and locks in one direction. The device was fabricated with the assistance of Prosthetic Orthotic Associates.

An 18-hole golf game served to field test the device. The prototype device accomplished many of the design goals. Improvements to the design were undertaken by the client and the orthotist. One improvement included rolling the edges of the plastic backward under the thumb to reduce irritation of the skin. Pressure points were identified immediately following a round of golf, and evaluated for the possibility of skin breakdown. While the pressure points were reddish in color, the skin appeared to be intact and healthy without blistering.

Cost for the device was approximately \$55.



Figure 4.7. Close-Up of Magic Golf Brace.

# TRANSFER DEVICE FOR AN ELDERLY PATIENT

*Designer: Alison Dreyer*

*Client: Frederick Schermer*

*Client Coordinator: Diane Foss and Bradley Heal, PT, Desert Cove Nursing Center*

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## INTRODUCTION

Although many elderly patients use wheelchairs, most patients can use their legs to some extent. However, many of these patients do not have sufficient strength to pull or push themselves up and out of their wheelchair to transfer to a different location. The new transfer device will allow the patient to pull himself up into an erect standing position. The patient will then be rotated 90 degrees by an attendant so the patient can sit on an adjacent bed or chair.

## SUMMARY OF IMPACT

The need for such a device was expressed by a professional working in the geriatric field. The device was designed for an elderly gentleman who was transferred from an assisted living home to a private home. The device was needed to assist the caregiver in transferring him to his bed. By the time the project was completed, his living situation had changed again, and he no longer needed the device. We believe the standing and turning frame will be useful for other individuals. The designers are currently seeking to improve the device and customize it for a new client

## TECHNICAL DESCRIPTION

The design (Figure 4.6) consists of two major elements, the turntable and the frame. The turntable consists of a 24" square, 1/2" mild steel base plate and a circular turntable made of 1/2" aluminum. Two circular disks are made of ultra-high molecular weight polyethylene (UHMW-PE) inset into the top of the base plate and bottom of the turntable. This provides a self-lubricating joint between the mating surfaces.

The frame is made of 2" welded aluminum tubing. Horizontal frame members, which extend from the vertical tube, were positioned for easy prehension by the client. From this position, it was expected



Figure 4.8. Transfer Device Including Turntable and Sturdy Frame.

that the client would be able to easily pull himself up, and hold himself in an erect stance. The arms of the device wrapped around to the sides to provide armrests, a railing against which the patient could lean, and two vertical handles for the care provider to grab. With the caregiver's hands positioned on the vertical handles, the client would be completely enclosed within the frame by the arms of the caregiver. This positioning provided the greatest margin of safety against the client collapsing and falling out of the frame. Centering his body within the frame, the large basal area of support dimensions, and low center of gravity of the device

also provided an adequate measure of security against the device tipping over and causing injury to the patient.

During prototype testing, the UHMW-PE bearings were adequate for a person weighing less than 150 pounds. However, for persons weighing more than 150 pounds, it became difficult to turn the device. The device must be positioned next to the client's

bed so the rotation (counterclockwise for this client) moves the client toward the bed. Therefore, if the patient prematurely lets go, the patient will fall onto the bed.

The total cost for materials was approximately \$815.

# PASSIVE STANDING FRAME

*Designer: Mathew Dixon*

*Client Coordinator: John Figy, ASU Physically Challenged Program*

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## INTRODUCTION

A passive standing device (Figure 4.9) was designed with the intent of offering standing assistance for a person seated in a wheelchair. The hand-cranked hydraulically powered standing device was designed for a university student recreational complex. The device is to be used to assist the many people who have wheelchairs and cannot stand on their own. The device is adjustable so it can accommodate people of various sizes. Adjustable vertical and horizontal knee and chest pads are coupled with an adjustable basket harness. The device can lift up to 400 pounds, yet is moved easily. Accessing and using the device is simple. The patient wheels up to the device, puts on the harness, and the device operator then pumps the hydraulic pump until the patient is in a standing position. While the patient is standing, he or she has access to a flat surface that can serve as a tray or a work area.

## SUMMARY OF IMPACT

This device will help those in wheelchairs to stand. The passive standing frame will lift the patient to a standing position, and hold them there for the desired amount of time.

## TECHNICAL DESCRIPTION

The device (Figure 4.9) was required to lift at least 400 pounds. Calculations were used to determine that the lever arm must be 1.5 feet long and the jack must be placed six inches from the initial connection. The height of the device is restricted by the height of the work tray. For the comfort of all

users, the tray is adjustable, with a minimum height of 36 inches. The lever arm tucks under the tray and was placed 18 inches from the bottom of the device. The jack used for lifting the patient is 9 inches tall, 5-5/8 inches in diameter, has an overall extension of 12-1/4 inches, and a platform base of 6x6 inches.

The jack moves the lever arm in a circular motion. Therefore, the jack rotates on a stand with a pin connection at the level arm. The device also has adjustable knee and chest support. On this standing frame, the knee support is 15 inches from the floor, and the chest support is 36 inches from the floor. The harness is a basket type structure designed to wrap around the patient's waist and extend down the bottom of the gluteus maximus. The harness connects to the end of the lever arm with carabineers and eyebolts. The harness length can be adjusted and there are several eyebolt positions to allow for additional adjustments. The work tray is made from 3/4" Lexan. There is a cutout in the tray for the chest pad. This allows the user to rest his or her arms on the tray. The tray is connected to the top of the frame using four inset bolts.

The materials for the device cost \$186.40 and the labor to construct the device cost \$80. The retail price would be \$450. This is less than current passive standing frames on the market (\$500-\$1000).



Figure 4.9. Passive Standing Device.

# WEIGHT ACTIVATED BRAKING ORTHOTIC KNEE BRACE

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## INTRODUCTION

Many patients who experience a loss of extensor muscle control use long-leg braces to assist them in weight bearing activities such as standing and walking. Additional benefits may be derived if the design of the typical orthotic knee joint is altered to provide dynamic resistance to flexion without limiting or inhibiting extension.

A new orthotic knee joint design (Figure 4.10), incorporating polymeric inserts, was developed. It provides a soft but increasing resistance to flexion. The new design is compatible with standard orthotic components and is readily incorporated with customized orthoses.

## SUMMARY OF IMPACT

A number of persons might benefit from such a device. The patient profile of possible candidates includes post polio patients, those with neuropathies (including diabetic neuropathies), persons with sciatic, spinal cord, and femoral nerve injuries, and stroke patients. In general, any patient who has limited control of extension and/or flexion in the knee could benefit from this device. The device could reduce the potential hazards associated with knee failure and current knee braces.

## TECHNICAL DESCRIPTION

The knee joint for the brace was made from 410 hardened stainless steel. The brace was made such that the members articulate throughout the range of motion in a manner consistent with the action of the knee joint. A pin and slot arrangement allowed flexion extension to occur without creating a fixed hinge location.

The uprights for the brace were made from  $\frac{3}{4}$ " x  $\frac{3}{16}$ " aluminum. The uprights are affixed to the distal and proximal ends of the joints by steel rivets to reduce the risk of fatigue failure associated with aluminum fasteners. The stop brake is made of elastomers supplied by Harkness Materials, Inc. The elastomers range in durometer values of 40A to 95A to suit the needs of the patient, and may be interchanged as needed in an existing joint. The elastomer material comes in sheets  $\frac{1}{2}$ " thick and can be cut on a band saw or a table saw to the desired dimensions.

Materials and labor to assemble the device were under \$1300.

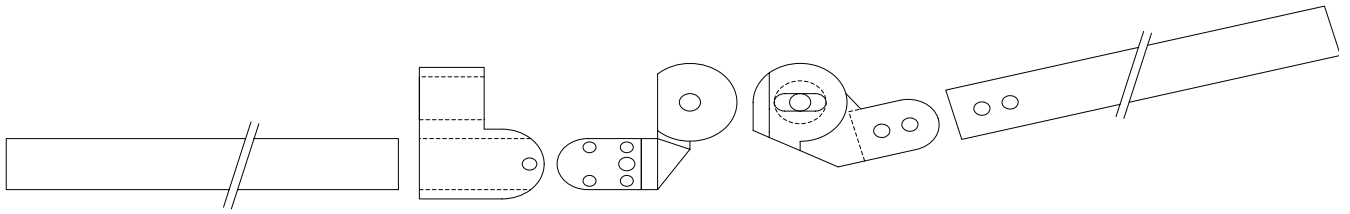


Figure 4.10. Exploded View of the Brace.

# DYNAMIC ANKLE SUPPORT DEVICE

*Designer: Andrew Kwarciak*

*Client Coordinator:*

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## INTRODUCTION

Because of the orientation and mobility of ankle components, the ankle is susceptible to instability during physical activity. Couple this with increasing forces from acceleration and collisions during activities and this instability can lead to injury. The most common mode of injury occurs when the leg rolls over the foot. To prevent these injuries, athletes wear tape or ankle braces to provide stability. While these methods prevent excessive inversion and eversion motions, they also restrict mobility and agility of the athlete. The objective of this project was to design an ankle support device that prevents injury and preserves agility.

## SUMMARY OF IMPACT

The ankle is a commonly injured part of the body, comprising nearly 15% of all sports injuries each year and frequent everyday use injuries. Each year, physicians see 1.2 million people with ankle sprains and 675,000 with ankle fractures.

Obviously, both on and off sport fields, ankle injuries are a problem that demands more attention. Current devices (sports tape and ankle braces) can limit inversion and eversion, thereby reducing injury. However, the devices inadvertently also limit agility. In many sports, agility is crucial. Therefore, there is a need for a device that can prevent injuries, but preserve agility.

## TECHNICAL DESCRIPTION

The new ankle support design (Figure 4.11) features a rigid plastic support, cut to resemble a stir-up. On the tapered portion of the plastic support, a Gillette joint, the most suitable for triplanar motion, connects the two sections. The plastic support is made from a sheet of 1/4" Copoly. The Copoly is heated until it reaches a liquid-like phase, and then pulled over a plaster leg mold. The Gillette joint is

fixed to the plaster leg prior to pulling the plastic. The plastic forms over the joint, creating a pocket in which the joint sits, thereby increasing the strength of the joint/plastic connection. The joint is removed, the plastic is cut into two pieces, two holes are drilled in the joint pocket, and the joint is re-attached to the support with special screws. The edges of the plastic are smoothed and the bottom of the heel cup is skived for a better fit inside of shoes. Elastic and nylon straps run parallel down the sides of the plastic brace. The straps are placed so they provide the maximum amount of support, but minimally inhibit agility. The elastic strap is pulled tight, while the nylon strap has some slack. The elastic provides a damping force on the foot/leg once rotation has exceeded the end of the predetermined range. This prevents any abrupt stops that would occur when the nylon is pulled taut. Holes were also drilled through the plastic and the straps were fixed to the rigid support with copper rivets at the top and bottom of the brace. On the heel cup, the straps were riveted directly into the plastic. On the upper cuff, the straps were attached via chafes, which were riveted just under the top edge of the brace. The same holes used to attach the straps were also used to attach the upper support strap. The upper support strap secures the brace to the ankle. Hooks and loops were sewn to the back of all of the straps to provide adjustable attachment points.

The inside of the brace was padded with a 1/8" foam pad. The pad was heated and allowed to cool inside of the brace. The brace molded foam was then cut, the edges were smoothed, and it was glued into place. From a 1/8" sheet of neoprene, a cuff was cut which was designed to fit snugly around the device. The neoprene was fitted with a zipper to ease attachment. The neoprene cuff serves to make the device aesthetically pleasing.

The estimated cost for the device is \$68.





Figure 4.11. New Ankle Support.



Figure 4.12. Ankle Support in Use.

