

# CHAPTER 10

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# THE BIONIC VEST

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## INTRODUCTION

The purpose of this project is to develop a vest that improves the motion control of a person with cervical and upper thoracic spine injuries. These particular injuries often cause patients to lose the ability to control balance because of loss in functionality of abdominal and lower back muscles. The vest is designed to be used daily and provides the necessary support without sacrificing comfort. Creating a device that increases independent movement of the upper body and better the client's quality of life are key foci incorporated in the design. The prototype vest is designed specifically for use by our client, Keith Parsons. The effects of his injury do not allow him to move his torso from the bent position to the upright position. The purpose of the vest is to replace the muscle functions that he lacks and restore movement to enable him to sit up straight after bending forward and to the sides of his wheelchair see (Fig. 10.1).

## SUMMARY OF IMPACT

The final design for the bionic vest enables our client to achieve stability. This device is designed to let the user bend down in a wheelchair, pick an item up off of the ground, and then return to the upright sitting position without the use of the upper extremities. A second function of the vest allows the user to bend to the side as well as the front. The system is portable and convenient, and is functional even in the absence of a wheelchair. The materials chosen to construct the prototype ensure that it is also comfortable and lightweight.

## TECHNICAL DESCRIPTION

The air bladder is attached to the abdominal region as shown in Fig. 10.2. The bladder also wraps



Fig. 10.1. Completed Bionic Vest Prototype.

around the sides of the vest to aid in side-to-side motion. The lower back and abdominal portions of the vest are a customized back/abdominal support brace comprised of Delrin slats as ribbing. The inner fabric of the vest is neoprene to provide support and breathability for the patient. The back portion of the vest does not contain air bladders, but contains the Delrin ribbing for support. The vest itself is less than 0.5" thick. The pump used is relatively inexpensive, rechargeable, and provides air at an adequate rate to inflate the vest. The bladder is shaped into a triangular wedge as shown in Fig. 10.4. The red portions in Fig. 10.4 represent the Delrin ribbing. The bladder and air pump are connected using 3/8" clear vinyl tubing. The air pump switch was extended three feet in order to allow the user easy access.

The cost of parts and materials is roughly \$170.



Fig. 10.2. Vest Deflated.



Fig. 10.3. Vest Inflated.

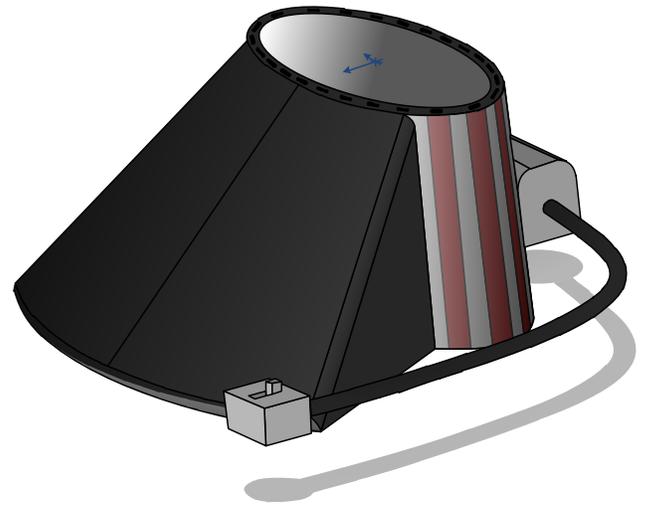


Fig. 10.4. CAD drawing of final prototype design.

# BIONIC GLOVE: DESIGN OF A GRASPING GLOVE FOR A PERSON WITH QUADRIPLÉGIA

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## INTRODUCTION

The bionic glove is designed to allow people with quadriplegia to use their fingers to pick up objects that they would not otherwise be able to grasp. This device consists mainly of two plates fastened to the hand by Velcro straps and rotated via actuators. The user slides their hand into the finger portion of the glove and uses the straps to then secure the glove to their hand (Fig. 10.5). Once secured, the user can then activate the glove to allow it to open and close as desired. The glove is designed for our client, Keith Pearsons and has also been reviewed by a board of doctors at Hershey Medical Center.

## SUMMARY OF IMPACT

A person with partial quadriplegia suffers from different levels of mobility based on their particular spinal cord injury. Some people with partial quadriplegia, such as our client, have some mobility in their arms down to their wrist, but no movement or strength in their fingers and hands. This lack of mobility makes certain tasks very difficult if not impossible without assistance. This project focuses on designing a product that allows people with quadriplegia such as our client, to grasp and gain back independence in activities like weight lifting, fishing, and playing pool.

## TECHNICAL DESCRIPTION

The project objective is to design and build a glove that allows the user to have partial control over the movement of their fingers. This design allows the user to grasp while maintaining wrist mobility. The design is based around a four bar mechanism on the back of the hand and fingers that uses two electric linear actuators to allow the fingers to sweep through 50 degrees of motion in a grasping manner. Airprene is used as the glove material because it is both comfortable and breathable. Rigid straps are sewn into the airprene glove to secure the



Fig. 10.5. The Bionic Glove.

mechanism firmly to the hand. The mitten design allows the client to easily slide their hand into the glove and secure it without assistance. Once the user put on the glove, a cylindrical object can be placed in the palm and the actuator activated to close on the object. The user then activates the actuators again to open the glove once the user is done using the grasped object (Fig. 10.6).

The device is capable of a holding strength of 70 pounds. At loads higher than this the actuators begin to back drive. Neither the actuators or any of the electrical components are damaged by the back drive. The glove gives a solid grip while transferring much of the load to the wrist. Due to its size, this glove is not suitable for objects that are less than one inch in diameter. Some recommendations are to create varying sizes of gloves to accommodate more individuals. It would also be beneficial to include customized actuators that have a longer stroke to allow for a larger sweep angle for the fingers to allow the user to grasp smaller objects. It

would also be useful to make the plates out of a lighter but strong material like titanium.

The cost of parts and material is about \$800.



Fig. 10.6. Battery and Electronics Box.

# LEG STRETCHING DEVICE FOR PERSONS WITH SPINAL CORD INJURIES

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## INTRODUCTION

Spinal cord injuries can cause many physical problems such as chronic pain and muscle spasms that can severely affect the quality of life. Stretching the affected muscles has been proven to reduce or eliminate the patient's spasticity but requires the assistance of a care provider. The goal of this project is to increase the level of independence of individuals affected by spinal cord injuries. This was accomplished through the development of a simple and lightweight mechanical apparatus that allows the patient to stretch the quadriceps independently. The final prototype is shown in Fig. 10.7.

## SUMMARY OF IMPACT

Safety is of the utmost importance due to the fact that the user may not realize if the stretch is causing any harm to them if they lack feeling below their waist. For this reason, the device is constructed of materials that will not cut, scratch, or irritate the user's legs. Stainless steels, aluminum, and plastics are the most viable options for fabrication. None of these materials rust nor cause any kind of allergic reaction, and keep the user's leg from digging into the surface which prevents skin or knee damage. The device increases independence by containing design qualities that allow the user to put it on by themselves. It is also designed to be able to be worn through the night.



Fig.10.7. The leg stretcher consists of a brace and a ratchet mechanism.

## TECHNICAL DESCRIPTION

The two main components of the manually powered quadriceps stretching device are the leg brace and the ratchet mechanism. These two devices are joined together by a sheathed steel cable. The leg braces consist of memory foam pads and fabric straps attached to an aluminum frame. The memory foam pads provide enhanced comfort by forming to fit each leg, while the lightweight aluminum frame provides the structural integrity and light weight requirements needed for an easily transportable device. The fabric straps keep the users leg in position and secure while the device is being used. These leg braces stretch the quadriceps approximately 120 degrees when sufficient tension in the cable provides a moment about the knee. Below is an image of the device in use.

The component that actually creates the tension in the cable is the ratchet mechanism. It is essentially a

wooden box containing a ratchet and gears. For the prototype, oak was chosen for the box material due to its ease of manufacturing and accessibility. The ratchet mechanism consists of a handle attached to a sliding rack, which converts the users input force to a rotational torque by interacting with a ratchet. That ratchet in turn is connected to a small gear via a steel shaft. That small gear then transmits the torque to a larger gear which is attached to the cable via an aluminum spool. The gears and rack are made out of steel to prevent wear. A quick release feature is included for safety. In short, each seven pounds of linear input force from the user is converted to a rotational motion that coils the steel cable under 75 pounds of tension. By doing this multiple times, tension in the cable draws the bottom half of the leg-brace closer to the user's midsection while the steel sheath prevents the cable from pulling at the entire leg brace. In total, the cost of parts and material used for manufacturing is approximately \$300.



Fig.10.8. Client using the leg stretching device.

## TRASC: WHEELCHAIR STAIR CLIMBER

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### INTRODUCTION

The Tracked Stair Climber (TRASC) is designed to provide a means for manual wheelchair operators to climb up and down stairs. The user attaches their manual wheelchair to the TRASC device (see Fig. 10.9), and then powers the motor to turn the treads and carry the user up or down the stairs. This device allows for increased mobility for the user, allowing them to access areas that were not previously available. Our client is an individual with paraplegia who uses a wheelchair for transportation. The TRASC now allows our client to access areas where he was previously unable to go.

### SUMMARY OF IMPACT

The design criteria for the TRASC are defined by the capabilities and the needs of our client, which were established during a meeting. As a result, the wheelchair stair climber device needs to be safe, independently operated, cost effective, and portable. The TRASC allows our client to climb stairs, allowing him to be more independent and access areas unavailable to him. Overall, it allows him to access even those areas that are not handicap accessible.

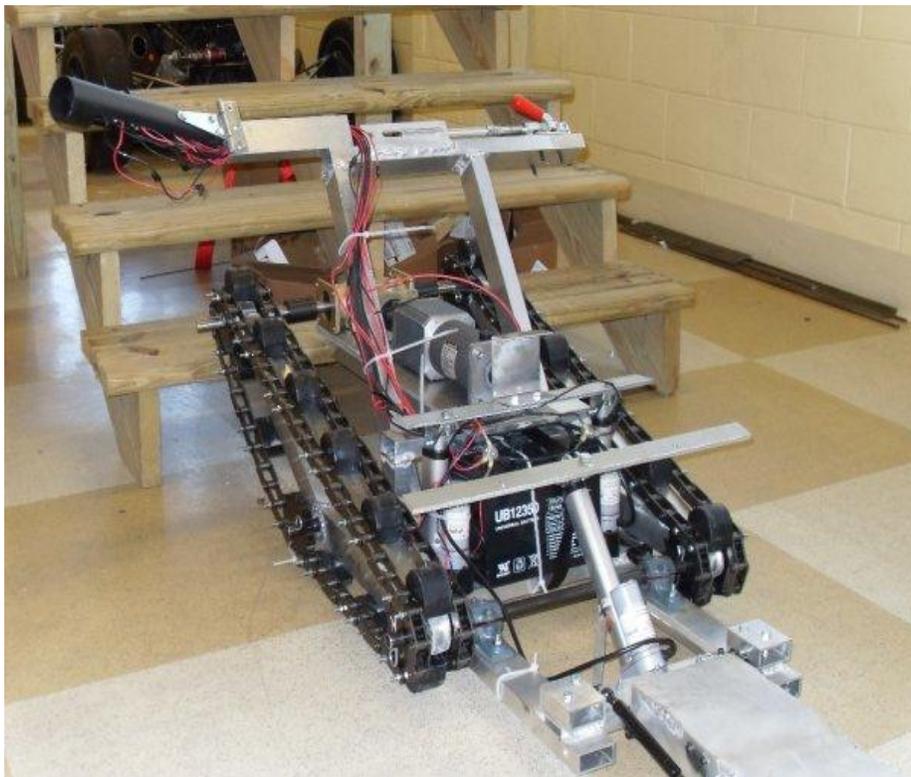


Fig.10.9. The Tracked Stair Climber.

## TECHNICAL DESCRIPTION

The overall structure of the frame is constructed using 2" x 1" rectangular aluminum tubing with a wall thickness of 1/8". Aluminum is used for many reasons including the fact that it has an extremely low cost, high strength, is light weight, and easily machinable and weldable. Hollow tubing is chosen to achieve the lowest weight with the highest possible strength. This size was chosen not only for strength, but also to provide the ability to bolt other components to the frame without the stress concentrations becoming too high. Most of the frame is welded together with a few components fastened with bolts.



Fig.10.10. The treads of the device.

The manual wheelchair is locked onto the TRASC device. This is achieved by backing the wheelchair over the device and initiating the actuators. Two 2 inch actuators lift the wheelchair off the ground and one 6 inch actuator tilts the wheelchair back into a four bar locking mechanism. A 4 point safety belt is fastened to prevent the wheelchair and user from detaching from the device. This safety belt is essential in preventing any injury that may occur if the wheelchair were to detach from the device.

The device accomplishes climbing stairs by using an AISI 2060 double pitched hollow pin roller chain with an Aluminum tread fixed in between two of these roller chains. The roller chain is driven by a 650 lb-in, 10 RPM, 12 volt motor. The low speed of the motor allows the device to climb the stairs at a controlled speed. A one to one gearbox is used to allow one motor to power both tracks on the TRASC. As the tracks rotate the tread profile catches the edge of each stair, pulling the device upward.

The TRASC is operated by three three-position switches that are mounted on a rubber coated tube to prevent any chance of electrical shock. These thumb switches provide an easy way for an individual with paraplegia to operate the device. The three switches operate both in the forward and reverse positions, which allow the user to climb up and down the stairs, and raise and lower the actuators.

The cost of parts and materials is about \$3000.

# LIFT ASSIST: A DEVICE THAT LIFTS A CHILD WITH MULTIPLE HANDICAPS OUT OF THEIR WHEELCHAIR TO AID CAREGIVERS

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## INTRODUCTION

The Lift Assist device is designed to raise a child in a wheelchair around 10 inches in the air to aid the caregiver lifting the child out of the chair (see Fig. 10.11). Currently, caregivers must bend down very low to pick children up from their wheelchairs, which creates many back problems for the caregiver. The Lift Assist device works by using a pulley system with three main components: the basket, pulley, and clutch. The basket sits inside the wheelchair seat and is connected with a rope. In normal operation the caregiver can push the wheelchair around as they would a regular manual wheelchair. When the caregiver wants to lift the child, a hand lever is pulled which engages the clutch. Then the caregiver pushes the wheelchair forward which raises the basket and the child. The wheelchair brake is activated to safely lift the child from the chair.

## SUMMARY OF IMPACT

This device greatly improves the quality of life of caregivers that aid children confined to wheelchairs. By safely lifting the child just above the wheelchair armrests, the caregiver is able pick up the child from the side and does not have to bend down as far as they normally would without the Lift Assist device. The project client, Nancy Ehrlich, was thoroughly impressed and expressed that the Lift Assist device could help many of her colleagues.

## TECHNICAL DESCRIPTION

A computer model of the device (see Fig. 10.12) displays the final design of the Lift Assist device. To accomplish the design goal of keeping the device



Fig.10.11. The Lift Assist Device.

lightweight,  $\frac{3}{4}$  inch aluminum tubing was used for the basket frame which is both light and strong.

Some features of the device that make it user friendly, are the detachable pulley and cam mounts. The cam mount holds the cam which presses against the clutch to engage it. The pulley mount is at the top of the wheelchair and holds the pulley in place. By making both mounts detachable, the wheelchair can be folded for easy storage and transportation. Due to careful design and material selection the final product is affordable and effective. The cost of parts and materials is about \$325.



Fig.10.12. The computer model of the Lift Assist device.

# MEDICATION REMINDER TOOL: A SYSTEM TO REMIND MEDICAL STAFF OF MEDICATION ADMINISTRATION TIME

*Designers: Caroline Frantz, Krista Kerch, Kelly Mehno, and Sean Smith*

*Client Coordinator: Skills of Central PA, Inc.*

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## INTRODUCTION

Skills of Central PA is a human services provider that supports patients with physical, developmental and emotional disabilities. The objective of this medication reminder system is to prompt the staff to administer the clients' medication following the Five Rights of Medication Administration. The reminder system consists of a laptop interfaced to a TracFone (Fig. 10.13). A computer program, written in MATLAB, serves as the alarm system. At the time of medication administration, the computer screen

displays a dialog box with the time and patient name. This dialog box has the capability to be "snoozed" for ten minute intervals up to an hour and a half to accommodate the busy schedule of the staff members but reduce the risk of medical omissions. The program also sends a text to the staff TracFone which emits a reminder that a client's medication is due. Ultimately, the reminder system is designed to reduce medical omission errors, increase patient safety, and improve the quality of care at Skills of Central PA.



Fig. 10.13. The Computer and the TracFone with Alarm and Reminder Text Displayed.

## SUMMARY OF IMPACT

The design criteria were compiled from several employees at Skills of Central PA including the Director of Quality Improvement and Training, the Medical Director, and the Residential Director. An on-site visit to a group home, where the team observed the staff administering medication to the patients with the current system, also aided in the investigation of client needs. The staff is often very busy, and at times needs a regularly scheduled reminder to administer medication at the appropriate time. In an effort to meet the needs of our client, the design includes an alarm that is inconspicuous to the patients of the facility, requires little input from the staff, and continuously alerts the staff until the medication is administered to the correct patient at the appropriate time.

The design part of our project focuses on coding several functions in MATLAB. An individual function is written that creates the alarm dialog box that displays the name of the patient that needs medication. The dialog box is coded to appear on the screen at the appropriate time with the correct patient name. The staff member can enter the patient name and medication time using a graphical user interface created in MATLAB. Finally a send-to-text function is produced in MATLAB that sends a text message to the cell phone carried by the staff at the same time that the dialog box appears on the screen (Fig. 10.14). These three scripts function simultaneously to create the system. The program creates a link between the computer alarm and the cell phone carried by the staff. Staff can easily run

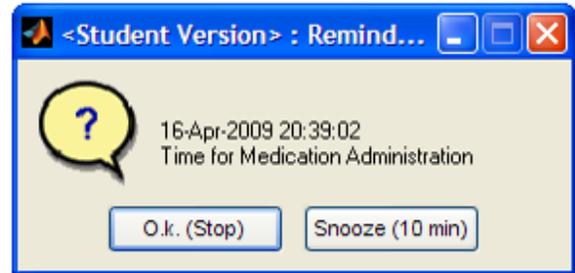


Fig.10.14. Dialog Box Displaying Medication Administration Time.

the alarm program and text function in MATLAB with the assistance of an instruction manual that contains detailed steps for initiating the program as well as troubleshooting tips.

## TECHNICAL DESCRIPTION

To keep the design simple, dependable, precise, and low cost, several pre-manufactured products are used to aid in the assembly of the final product. These products include an ACER laptop computer, MATLAB programming CD, and a TracFone. With this strategy, the focus remains on the design of a customized computer program without the worry of making many modifications to the other components. Pre-purchasing components also allows the product to be easily produced in large quantities. The approximate cost of this system is \$475.00 for a laptop, cell phone, and MATLAB program.

# DIET MONITORING DEVICE FOR DIABETES MANAGEMENT

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Supervising Professor: Dr. Nadine Smith, Department of Bioengineering  
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## INTRODUCTION

The Diet Monitoring Device is a program targeted to assist newly diagnosed diabetes patients as an educational tool for understanding the effects of dietary habits and exercise on blood glucose levels. It is made for in-home use and operation. The user provides personal inputs (gender, age, height, weight, level of physical activity) to calculate the basal metabolic rate (BMR) and determine their daily caloric needs. From this, a dietary meal plan is given to the user which includes the necessary food groups: starch, fruit, skim milk, vegetable, lean meat, and fat. Throughout the day, the patient enters their blood glucose level to make sure they are making the correct dietary choices. Based on user inputs and a timestamp of when the inputs were entered, the program determines the patient's next course of action.

## SUMMARY OF IMPACT

Diabetes mellitus is a metabolic disease in which the body has difficulty producing or using the hormone, insulin. Diabetics need to monitor their blood glucose levels throughout the day by three methods: an insulin plan, dietary pattern, and physical activity program. For newly diagnosed diabetic patients, this involves a dramatic change in lifestyle. These changes include refraining from certain types of food, following a routine medication plan and engaging in more physical activity. Many of these tasks require more care and dedication to following a strict plan than they may have in the past. One of the major problems for newly diagnosed patients is this drastic change in lifestyle.



Fig. 10.15. Home Screen which provides access to all of the program's features.

## TECHNICAL DESCRIPTION

The maintenance of a steady blood glucose level is essential for diabetics. The traditional range of blood glucose levels in normal healthy adults is 90 – 130 mg/dl during the day. This program provides specific recommendations based on the blood glucose level input by the user and the time of day (before or after a meal). For calories, the user inputs their gender, height, weight, and age and the computer calculates their basal metabolic rate (BMR). The daily caloric needs are calculated by multiplying the activity factor by the BMR. In our program we chose an activity factor of 1.3 based on the fact that most Type II diabetics are overweight and less active.

There are many different types of dieting plans that diabetes patients use to help manage their glucose levels. The type of plan that is implemented by our

program is a hybrid of traditional Carbohydrate Counting and a Diabetic Exchange diet. A carbohydrate counting plan is simply for the patient to count the grams of carbohydrates in the food that they are eating. The diabetic exchange diet is based on the different food groups. The user is given a meal plan based on a set amount of servings from each category that they should fulfill in a day. Any food selection can be made from each food group as long as they meet that category's requirement. Our program serves both of these dieting functions (Fig. 10.16). The user of our device is told to eat a certain amount of carbohydrates from six food categories: starch, meat, non-starchy vegetables, fruits, milk, and fats. Any foods of the user's choice can be eaten as long as they meet the specific carbohydrate requirements for each category for the day. The cost of the computer and software is about \$750.

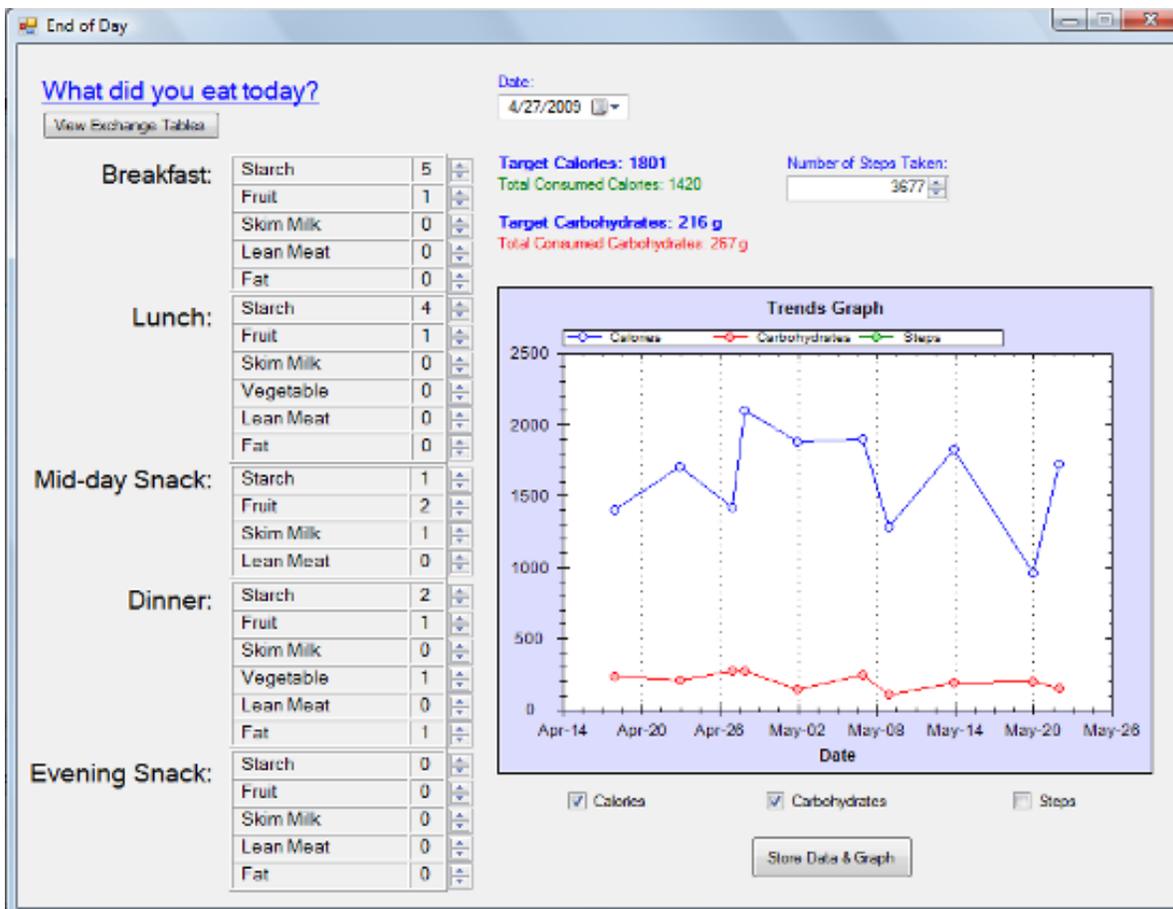


Fig. 10.16. Calorie and Carbohydrate Tracking

# WEIGHTED BODY GARMENT

*Designers: Elyse Adams, Staci Boretzky, Daniel Calderon, Yuanyi Li, Anna Kobb, Maria Rozploch*

*Client Coordinator: Tim McCorry, Maximus V*

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## INTRODUCTION

In the United States, stroke is the leading cause of serious, long term disability. Much of this disability may include partial paralysis of arms, legs or both. This causes nearly 40 percent of stroke survivors to have balance problems that lead to falls each year. Most commonly, stroke survivors experience muscle weakness and atrophy. It is recommended that mild exercise be conducted each day to improve muscle function. These exercises can be as simple as walking or stretching using resistance bands. Currently, physicians and physical therapist work with weight training and resistance bands to help improve muscle movement and growth to improve the quality of life of stroke victims. Patients may struggle with such exercises due to balance difficulties. There are no current materials to help improve this aspect of a stroke patient's recovery. A weighted garment that supports the muscles as it helps to build them is a revolutionary way to improve the lives of thousands of stroke patients each year.

## SUMMARY OF IMPACT

A stroke can affect a person greatly and completely change their way of life. It can take months or even years to recover through muscle training and physical therapy if the patient is even able to recover completely. Dozens of exercises and rebuilding of muscle memory is involved in re-learning daily activities from walking to something as simple as holding a pencil. Many times stroke recovery patients suffer from a loss of balance. It takes much time and work in order to train the body to operate as it originally did. In addition to the standard physical therapy techniques, there is a need for a product that will allow for faster recovery. A weighted, thermo-regulating, fluid, form-fitting body garment can aid in the recovery of stroke patients to increase muscle mass and decrease recovery time. This project focuses on the design of

a body garment that uses these characteristics and the idea of muscle compression and alignment in order to keep the muscles in place during exercises and recovery. Adding weight in particular areas can allow the user to complete simple exercises suggested by a physical therapist, allowing for faster recovery. Using this jacket for recovery after a stroke will provide balance to the patient, speed up recovery, and assist in physical therapy.

## TECHNICAL DESCRIPTION

In the design of the garment, the main focus for the design specifications is the patient. The garment is designed with the specific patient in mind at all times. If the jacket is too light or too heavy, the patient will not benefit from its implementation or may even experience a delayed recovery or injury. With safety being the number one concern in every application, this jacket will not be designed until torque calculations are performed on the user. Problems are not expected to arise, as the additional weight due to the garment is very small, but it is still important to ensure the user's safety in design calculations. To construct a jacket prototype, the following materials are needed: Maximus V gel, Polyethylene bags, heat sealer, 1.5-2mm neoprene, 2.5 yards black 80/20 polyester/spandex, 1 yard Teal 80/20 polyester/spandex, black thread, a 24 inch sports zipper, a 10 inch invisible zipper, a 10 inch sports zipper, a jacket pattern and a sewing machine capable of handling 4 mm of neoprene. The final design meets the patient needs and addresses the project's objectives. The garment incorporates many different disciplines including kinesiology, rehabilitation, architecture, engineering, sales, and design that add to the credibility and marketability of the product. Having these different views and expertise allow us to ensure quality and efficiency of a much needed product.

The cost of parts/material is about \$200.



Fig. 10.17. Weighted jacket for stroke patients.

# DEVELOPMENT OF AN EMG-BASED MUSCLE SWITCH FOR COMMUNICATION VIA COMPUTER

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## INTRODUCTION

For patients with degenerative neural diseases or those who have experienced trauma such as multiple sclerosis (MS) or stroke, conventional methods of communication can be difficult. One viable option for communication, for these individuals, involves the use of speech generating software programs through a human-computer interface (HCI). The objective of this project is to develop a low cost electromyography (EMG) muscle switch that uses only voluntary muscle signals to simulate left and right clicks of a mouse. These clicks will allow the user to communicate with family and friends via BLINK© software developed by the nonprofit organization, Volunteers for Medical Engineering, Inc. (VME) located in Baltimore, MD. Ultimately, this device provides a general solution to communication problems for patients with limited capabilities.

## SUMMARY OF IMPACT

In order for the switch to be effective, it must accurately identify voluntary muscle movements from any noise or involuntary muscle spasms. Controlled by muscle movements alone, the device must also be adaptable so that two separate areas of the body can be used to simulate the two separate mouse clicks that will be input into the VME communication software. The system is most useful to the client, if it is able to be used for long periods of time and in the comfort of the user's home. Therefore, the system must be easily applied, removed, and sanitized by non-technical individuals. Additionally, the device must require minimal upkeep. The device is limited to muscle control and can only simulate two mouse clicks, but this is effective for controlling the BLINK© software that allows for basic communication from the clients.

## TECHNICAL DESCRIPTION

The overall conditioning of the EMG signal is dependent upon the initial signal characteristics from the human body. As distinguishing between voluntary and involuntary signals is one of the primary objectives of the device, several alterations to the input signal are required. The targeted area for left mouse clicking is the temple, where a click can be simulated by clenching the jaw and teeth or by pressing the tongue to the roof of the mouth. Right clicking is recorded on the bicep of the user, where tensing arm muscles successfully registers as a click. All conditioning circuitry is tailored to these characteristics.

The EMG signal is received by stainless-steel, pre-amplified surface EMG electrodes, which are both reusable and do not require the use of electrolytic gel. From the electrode, the signal first is conditioned by a non-inverting amplifier with a gain of 100. This high gain is necessary due to loss of signal magnitude during downstream conditioning. Due to the polarized nature of the EMG signal, fluctuations in both the positive and negative realm are theoretically able to trigger a mouse click. Therefore, the signal is further conditioned through a full-wave rectifier, which effectively takes the absolute value of the signal, resulting in an entirely positive output. The final characteristic that must be accounted for is the fluctuating nature of the signal.

To interface the EMG signal to the computer and activate mouse clicking for the BLINK© program, a simple USB mouse circuit board is connected to the EMG conditioning board. A mouse circuit operates by mechanically closing a given circuit which in turn sends a click to the computer. In the EMG conditioning circuit, a reed relay is used to mimic the closing of the mouse circuit. If the output signal from the averaging circuit reaches the triggering threshold of 1.4 Volts, a magnet is activated inside

the relay which connects an open circuit. This circuit is then attached to the mouse circuit board, passing a mouse click when the EMG signal is greater than the threshold voltage of the relay. By combining the

conditioning circuitry and relay trigger, EMG muscle signals are able to accurately replace the physical action of clicking a mouse. The cost of parts and materials is about \$750.

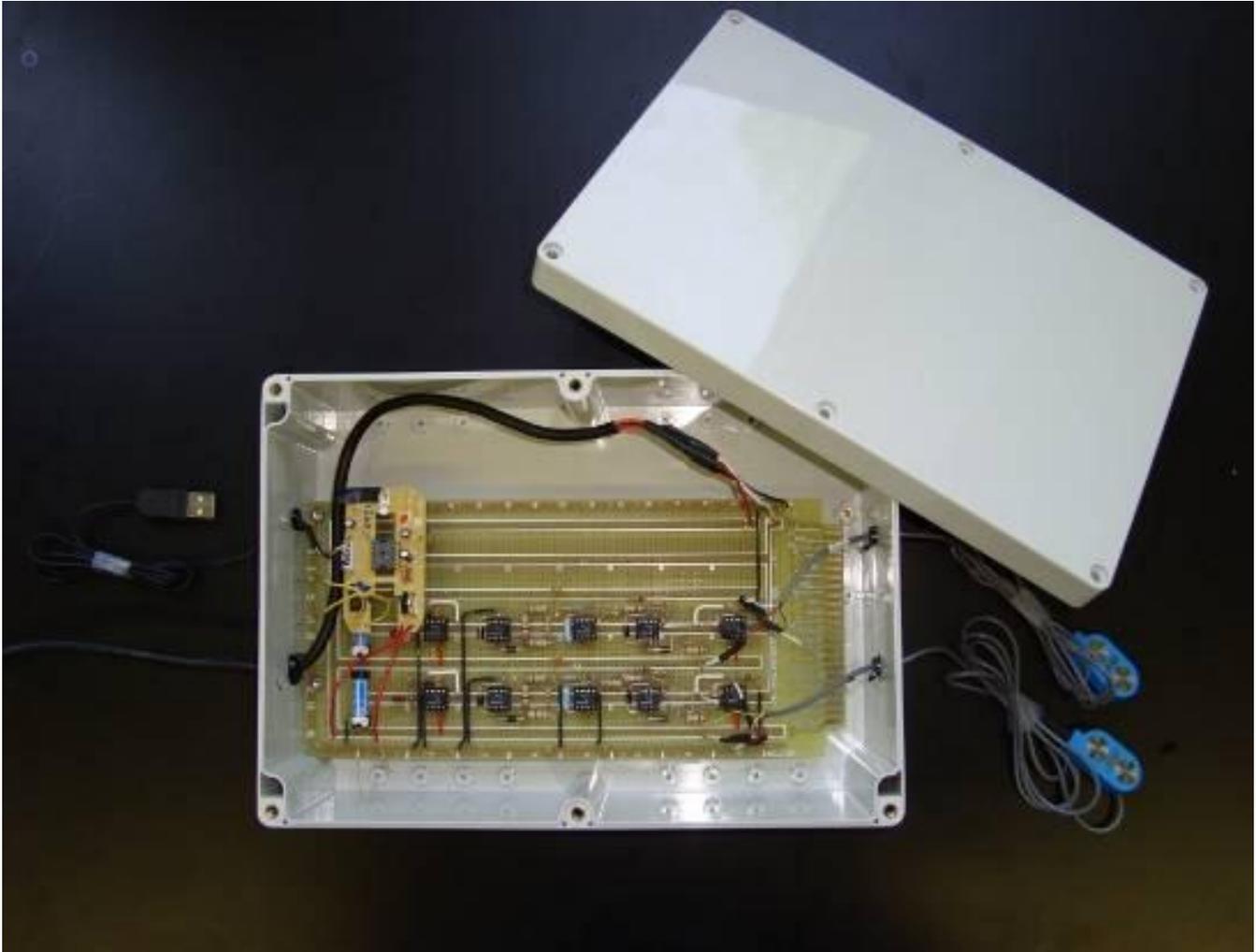


Fig. 10.18. Completed EMG muscle switch device.

