# CHAPTER 18
# UNIVERSITY OF TOLEDO


**College of Engineering**
**Department of Mechanical, Industrial and Manufacturing Engineering**
**Toledo, Ohio 43606-3390**

**Medical College of Ohio**
**Department of Physical Medicine and Rehabilitation**
**Toledo, Ohio 43614**

## Principal Investigators:

*Mohamed Samir Hefzy, Ph.D., PE. (419)-530-8234*

*mhefzy@eng.utoledo.edu*

*Nagi Naganathan, Ph.D. (419)-530-8000*

*Nagi.Naganathan@utoledo.edu*

*Gregory Nemunaitis, M.D. (419)-383-3527*

*gnemunaiti@mco.edu*

# ADAPTATION OF A WHEELCHAIR WITH A PAINTING STAND

*Designers: Jeff Allen, Kyle Bergman, Matt Erickson*
*Mechanical Engineering Students*
*Client Advisor: Ms. Jill Caruso*
*The Ability Center of Greater Toledo*
*Faculty Advisor: Dr. Mohamed Samir Hefzy and Dr. Mehdi Pourazady*
*Department of Mechanical, Industrial, and Manufacturing Engineering*
*The University of Toledo*
*Toledo, OH, 43606*

## INTRODUCTION

A wheelchair was adapted for a man with a traumatic brain injury. The client loves to paint and draw while sitting in his wheelchair. Before receiving this device he could only draw when there was a flat table that he could reach. The purpose of this project was to develop a painting stand to allow the client to paint and draw while sitting comfortably in his wheelchair. The stand includes a drawing board that is attached to a frame mounted to the wheelchair. The board can be easily adjusted by an assistant in three directions and tilted away from the client for a more comfortable drawing plane. The stand includes magnetic templates that accommodate various paper sizes and also keep the paper from moving, distorting, or tearing. The stand is portable and lightweight so the client may take it wherever he desires. It can be easily attached and detached from his wheelchair (see Fig. 18.1).

## SUMMARY OF IMPACT

The client is now able to paint and draw comfortably from his wheelchair. The stand improves his position and reduces stress in his neck and back (see Fig. 18.2 and Fig. 18.3). The device prevents the client's paper from moving, which makes it easier for him to paint and draw. The device also brings the painting surface closer to the client and allows for a more enjoyable painting experience. The stand is portable, lightweight, and easy to set up. It can be easily transported from the home of the client to other locations where he paints.

Fig. 18.1 (a) and (b). Painting Stand Attached to Wheelchair.

## TECHNICAL DESCRIPTION

The stand utilizes existing holes that are used to mount the wheelchair's footplates, which increases stability. The design includes a feature that allows the board to be tilted for more comfort while painting or drawing (see Fig. 18.4). Quick-release button connectors that are reliable and user friendly were used for attachment purposes. The quick-release button connectors prevent the wheelchair from being marred. Screw clamps were also used along the horizontal guide rails (see Fig. 18.4).

The board design has magnetic templates to hold the paper on the board. A very thin steel sheet was recessed into the board for a better appearance and to allow the magnetic template to lay flat. All of the templates can be stacked on top of each other, which provides easy storage and portability. A cup holder design was used for storage of painting and drawing supplies. This design allows the client easy access when grabbing brushes or pencils.

The material used to construct the frame was aluminum 6061 alloy. A sheet of Ultra High Molecular Weight Polyethylene (UHMWP) was used to make the drawing board. The weight of the board and the tilt bracket attached to it is nine pounds. The weight of the frame is 5.75 lbs; the total weight of the stand is 14.75 lbs.

Solidworks, a CAD software package, was used to model the painting stand. A force of ten pounds was applied to the board to represent the client pushing on it. The finite element analysis was also conducted using Solidworks to perform the structural analysis on the stand and the maximum stresses were calculated. The overall factor of safety of this structure determined by the software was 3.589.

The total cost of the parts was about $350.

Fig. 18.2. Client's Previous Method of Painting with a Table.

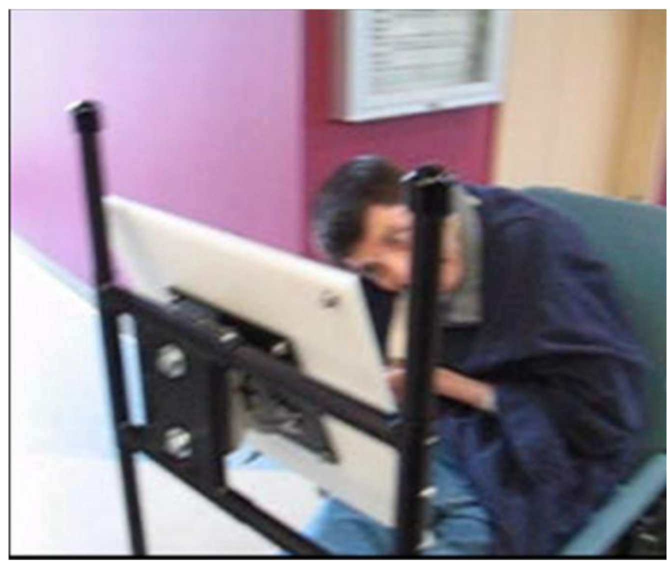

Fig. 18.3. Client Painting with Stand Attached to Wheelchair.

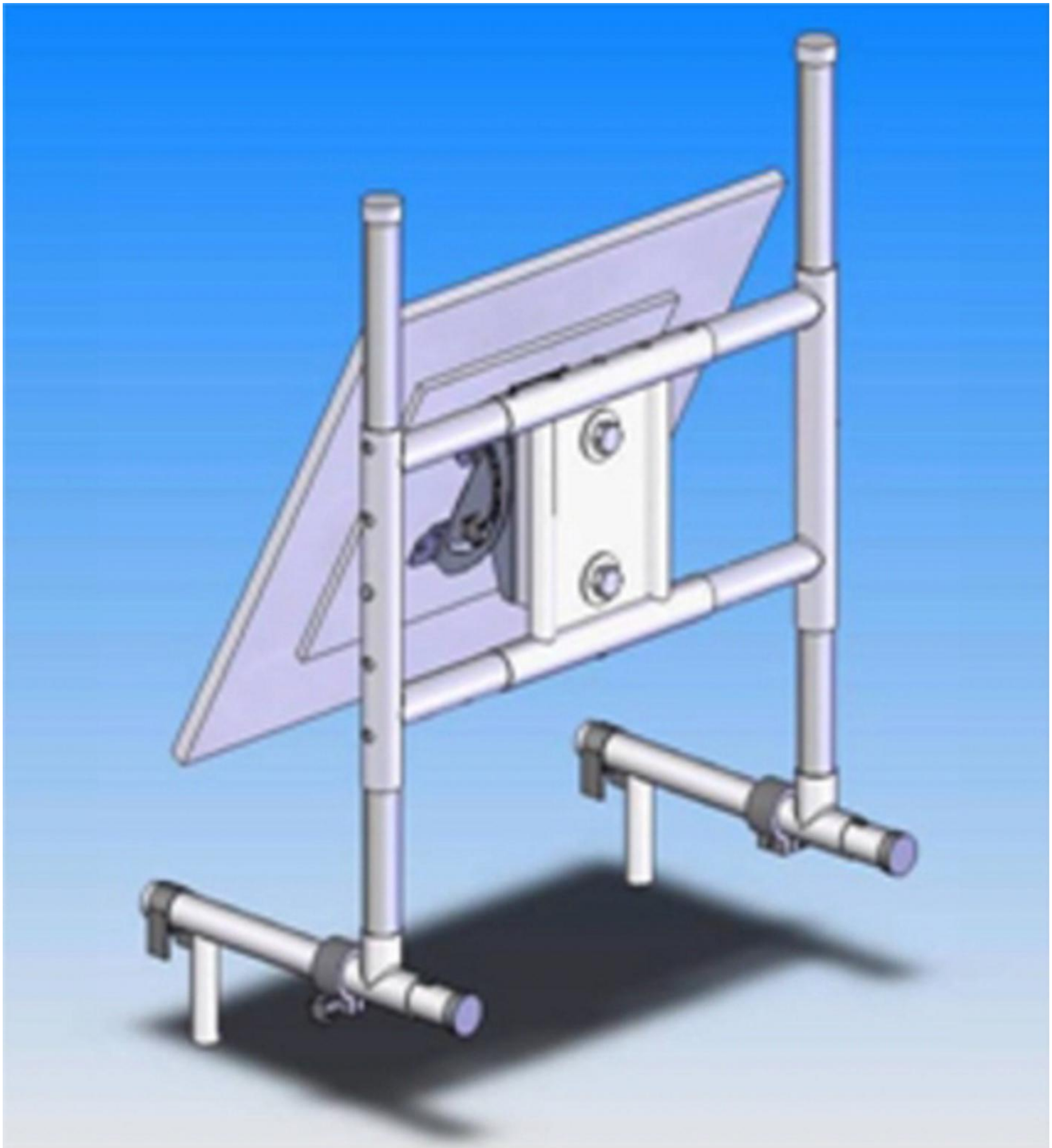

Fig. 18. 4. Computer Model of Stand.

# WHEELCHAIR LIFTING SYSTEM FOR A PT CRUISER

*Designers: Jason Balint, Joshua Michalak, Carmen Ricco, and Andrew Bishop,*
*Mechanical and Industrial Engineering Students*
*Client Coordinator: Ms. Jill Caruso*
*The Ability Center of Greater Toledo, Toledo Ohio 43560*
*Supervising Professor: Dr. Mohamed Samir Hefzy and Dr. Mehdi Pourazady*
*Department of Mechanical, Industrial, and Manufacturing Engineering*
*The University of Toledo*
*Toledo, OH, 43606*

## INTRODUCTION

The goals of the project were: 1) to design and fabricate a lifting system that allows a woman to raise and lower her wheelchair in and out of the rear hatch of her PT Cruiser; 2) to reduce reliance on assistance from others; and 3) to enable continued use of the backseats. The lifting system is securely mounted in the rear of the PT Cruiser. It includes a main fixed post and a rotating cantilever arm attached to the post. A pulley is attached at the end of the arm for lifting and lowering the chair. Bearings in the main post allow the arm to rotate freely, which makes it easy for the client to maneuver the chair in and out of the PT Cruiser. The system includes a 12-Volt DC gear-motor unit that is used to lift the wheelchair and is powered by the car battery. The system is operated using a controller that is mounted on the motor. Fig. 18.5 shows the lift system in the closed position and Fig. 18.6 depicts the wheelchair being lifted into the car with the lift system in the extended position.

Fig. 18.5. Lift System in Closed Position.

Fig. 18.6. Lift System in Extended Position.

## SUMMARY OF IMPACT

The lifting system meets all of the client's needs and increases the client's independence. It also allows enough room for full vehicle occupancy.

## TECHNICAL DESCRIPTION

The lift provides a total vertical lifting distance of 26” to clear the rear bumper of the PT Cruiser. A power in/power out electric motor, controlled by a free hanging two-button controller, provides the lifting power. The handheld control for the motor allows the client to be positioned away from the system while lifting and lowering the wheelchair. The client can also rest on the rear bumper during the process. A single degree of freedom cantilever beam setup provides ease of use during manual rotation into and out of the vehicle.

The lift assembly consists of a rotating cantilever beam inserted into a main post mounted to a 0.25″ thick base plate made of 1018 steel (see Fig. 18.7). The main post has two circular tubes made of 1018 steel. The outside stationary tube has an outside diameter of 2.5″ and 0.25″ wall thickness. The inner rotating tube has an outside diameter of 1″ and 0.120″ wall thickness (see Fig. 18.8). The cantilever beam consists of an angled shaft and a horizontal arm. The horizontal arm was made from 1018 steel square tubing: 1.5″ x 1.5″ x 16 gauge. A connecting plate was used to weld the inner rotating tube with the cantilever beam. A 12V DC motor and pulley were then attached to the arm of the cantilever. The motor and housing were salvaged from an existing Bruno wheelchair lift system. Two ABEC-1 steel ball bearings capable of handling a dynamic load of 2,405 lbs and rated at 9000 rpm were inserted into the main post (see Fig. 18.8). One integrated steel thrust ball bearing, rated to withstand a dynamic load of 6,700 lbs at a maximum speed of 3800 rpm, was used at the bottom of the main post to support the total weight of the lifting system. The motor was tested to lift a 45 lb weight. A dual-pin setup was installed on the main support post of the lift. It allows the lift to be locked in the loading and storing positions, and it prevents the lift from rotating out unnecessarily.

I-Deas 12, a finite element analysis package, was used to perform the structural analysis. The most stressed points are on the inner rotating tube of the main post.

The total cost of the parts was about $450.

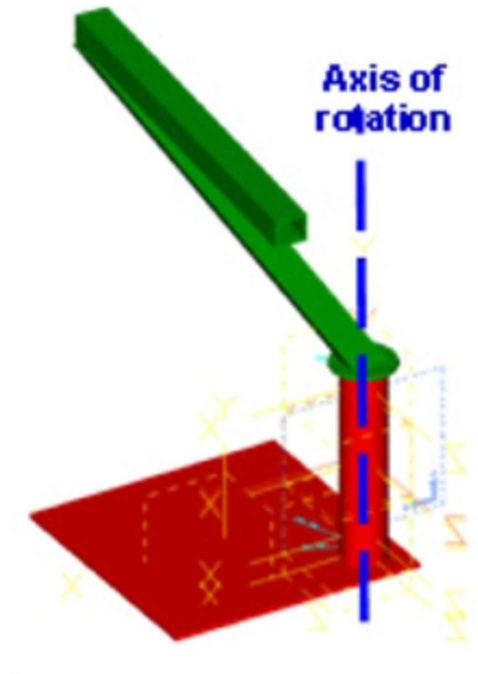


Fig. 18.7. Lift Assembly.

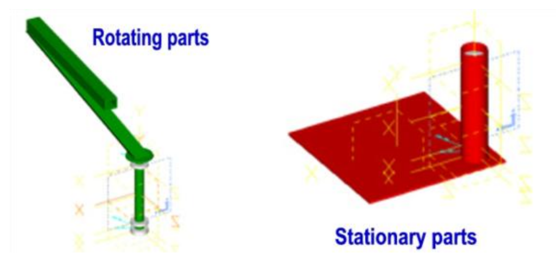


Fig. 18.8. Rotating and Stationary Parts of Lift Assembly.

# WHEELCHAIR ATTACHED DEVICE FOR SHOPPING CARTS OR BABY STROLLERS

*Designers: Devon Forney, Adonis Eid, Thiago Simiao, and Amy Oxenrider*
*Mechanical and Industrial Engineering Students*
*Client Coordinator: Ms. Jill Caruso*
*The Ability Center of Greater Toledo*
*Supervising Professor: Dr. Mohamed Samir Hefzy and Dr. Mehdi Pourazady*
*Department of Mechanical, Industrial, and Manufacturing Engineering*
*The University of Toledo*
*Toledo, OH, 43606*

## INTRODUCTION

The purpose of this project was to develop a device that enables a woman with a manual wheelchair to safely move a shopping cart or a baby stroller (see Fig. 18.9). The device allows the client to steer, and connect her wheelchair to a cart or stroller. The device consists of two flat aluminum plates, each with three small swiveling casters on which the rear wheels of a cart or stroller are mounted. The wheels beneath the plates are on swiveling casters, which enable the client turn the cart. The two plates are held together by a crossmember that has two pivoting connecting arms attached to it and to the front of the wheelchair.

## SUMMARY OF IMPACT

The device allows the client to easily push and maneuver a baby stroller or a shopping cart in a safe and controlled manner, and it leaves the client's hands free to drive her wheelchair. The device also ensures safety for her child when the client is pushing the stroller. The client is able to keep her hands on her wheelchair while guiding the cart or stroller and maintain constant linear motion. The device meets the client's needs and she is very happy with it.

## TECHNICAL DESCRIPTION

Design requirements for the device included: 1) it should provide the user with complete control over a shopping cart or baby stroller while offering increased maneuverability of both; 2) it should quickly attach to and detach from the wheelchair; 3) it should be lightweight so the client can easily handle the device when it is detached from the wheelchair and not in use; 4) it should be compact; 5) it should be simple to operate and, if collapsible, easy to assemble and disassemble without the use of tools.

Fig. 18.9. Client Using Device to Move a Shopping Cart.

The device locks the rear wheels of the shopping cart and raises them off the ground. The device consists of two flat 11" x 9" x .25" aluminum plates, one for each of the cart or stroller's rear wheels. A long narrow groove is cut out of the middle of each plate. The rear wheels of a cart or stroller fit in these grooves and are cradled in place by two pins. Each grooved plate sits on three small swiveling casters. The two grooved plates are held together by a telescopic cross member to allow the device to accommodate a variation in widths. Two pivoting connecting arms extend from the cross member to the wheelchair. Each connecting arm attaches to the front of the wheelchair by means of a small clamping block that tightens down around the tubular frame of the wheelchair. The entire assembly weighs approximately 13 lbs. The device quickly attaches to, and detaches from, the wheelchair by means of two quick-release pins. The pins attach each connecting arm to one of the clamping blocks.

Only the clamping blocks remain connected to the wheelchair when the device is not in use. The device is completely collapsible with four additional quick- release pins that hold the entire assembly together.

A 3D model of the device was created and refined using computer-aided drafting software. The strength of the device was evaluated using stress calculations for static loading conditions and confirmed through the use of finite element analysis software.

The total cost of the parts and materials was about $450.

# ADAPTATION OF A WALKER

*Designers: Adam Calkins, Matthew Hannan, Jamie Kuhlman, Andrew Miller, and Phillip Peltier*
*Client Coordinator: Ms. Jill Caruso*
*The Ability Center of Greater Toledo, Toledo, Ohio, 43560*
*Supervising Professor: Dr. Mohamed Samir Hefzy and Dr. Mehdi Pourazady*
*Department of Mechanical, Industrial, and Manufacturing Engineering*
*The University of Toledo*
*Toledo, OH, 43606*

## INTRODUCTION

A man with cerebral palsy uses a Reverse K walker for mobility. This walker is placed behind the user and is pulled rather than pushed. The walker makes it difficult to carry items around independently. A previous senior design group developed a removable tray that attaches to the walker, but it is heavy and has many pinch points (see Fig. 18.10).

Fig. 18.10. Original Design.

The objectives of this project were to: 1) adapt the reverse walker to carry books, a laptop computer, and other various items; 2) minimize difficulty; 3) reduce weight; and 4) reduce the number of pinch points. The heavy aluminum tray was replaced with a vinyl basket, which reduced the weight of the unit significantly (see Fig. 18.11). Thin aluminum tubing was used to construct a frame to hold and support the basket. Quick-release pins were used to connect the frame to the walker.

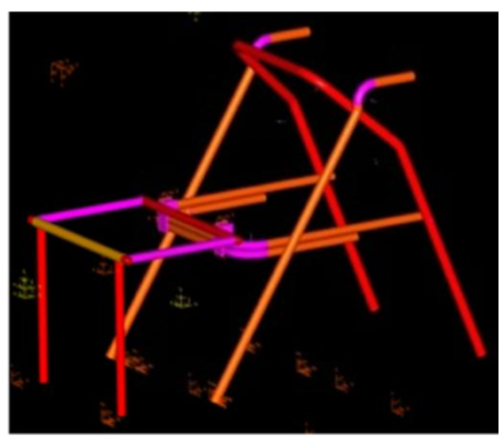

Fig. 18.11. Computer Model of New Design.

## SUMMARY OF IMPACT

The removable and collapsible vinyl basket construct stores items for the client and increases the client's mobility and independence. The design allows the client to easily remove the vinyl basket construct from the walker and store it independently at his convenience.

## TECHNICAL DESCRIPTION

The vinyl basket is secured to a frame that is attached to the walker. The frame is 20" wide and 17" long. It was made of one inch diameter 6061-T6 aluminum tubing, 0.25 inches thick. The basket frame rests on two 19.5" long metal poles that provide stability (see Fig. 18.12 and Fig. 18.13). Two casters were mounted on the metal poles.

The axle tube for the construct is 1.25". This tube has two bearings pressed at each end with one inch diameter bores, so it can rotate around the basket frame. The poles fold up when the basket is being stored. The vinyl basket was secured to the frame with button snaps and is 6″ deep. The basket construct weighed four pounds, which is significantly less than the weight of the tray construct. Quick release pins, 0.25″ in diameter, were used to attach the frame holding the basket to the walker at two locations.

I-DEASTM (Integrated Design Engineering Analysis Software) 12, a finite element analysis (FEA) software package, was used to perform the structural analysis. A 150 lb load was applied to simulate the client holding down the walker (75 lbs on each handle), and a 50 pound load was applied to the basket. A minimum factor of safety of 1.5 was calculated.

The total cost of the parts was about $350.

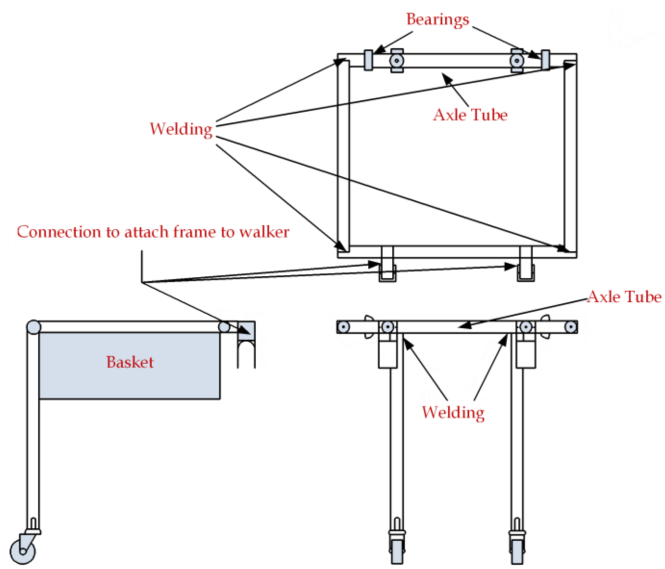


Fig. 18.12. Components of Construct.

Fig. 18.13. Basket Construct Attached to Walker.

# SEAT BACK CLEANER AND ERGONOMIC BROOM

*Student Designers: Lynette Torres, Adam Weininger, and Pam Wohlfarth*
*Client Coordinator: Ms. Jill Caruso, The Ability Center of Greater Toledo (ACT)*
*Ms. Diane Witt, Project SCOUT Coordinator, University of Toledo*
*Supervising Professors: Dr. Mohamed Samir Hefzy and Dr. Mehdi Pourazady*
*Department of Mechanical, Industrial and Manufacturing Engineering*
*Dr. Charles Armstrong*
*Department of Kinesiology*
*The University of Toledo*
*Toledo, OH, 43606*

## INTRODUCTION

Two devices were created for a custodian with a traumatic brain injury to reduce stress on his back while working. The client experienced difficulty sweeping and cleaning the back of theatre style seats in an auditorium. The tools include a device to clean the back of seats and an ergonomically designed broom.

## SUMMARY OF IMPACT

The client is now able to perform his work tasks more independently and efficiently. The cleaning tools alleviates discomfort caused by repeated bending and prevent the aggravation of his existing back injury.

## TECHNICAL DESCRIPTION

The first device is a seat back cleaner (see Fig. 18.14b). Previously, hand washing the seat backs with a cloth rag required the client to bend approximately 90 degrees at the waist (as shown in Fig. 18.14a). The seat back cleaner allows the client to clean the back of the chairs while standing upright (see Fig. 18.14a).

The material used to build the seat back cleaner was 1″ PVC pipe. The unit consists of two segments: a vertical handle and an angled handle that is connected by a 45° elbow. It has a replaceable mop head with a threaded connection. The vertical handle is 36.5″ long while the angled handle is 10.25″ long. The mop head is 12″ x 3.5″ x 1.5″. The geometry of the cleaning surface provides adequate space to properly clean each seat back.

The second device is a modified version of a straight handled broom made from 0.75″ PVC pipe. The design is very similar to the seat back cleaner. Angles were added to the handle to enable the client to reach completely beneath a chair for sweeping without strenuous bending and reaching (see Fig. 18.15a). The ergonomic broom handle consists of two main components (see Fig. 18.15b). The first component is the angled handle, and the second component is a replaceable broom head with a threaded connection. The angled handle is divided into three links: 1) 35″ long; 2) 15.5″ long; 3) one inch long. These links are connected by two 45 degree elbows (see Fig. 18.15b). The replaceable broom head is 9″by 2″ by4.875″.

Design calculations were performed in order to determine the maximum stresses and the factors of safety in both parts of the unit. Surface electrodes were located above and below the L2 and L3 vertebrae, and muscle activity was recorded. The EMG data showed that a user experiences fatigue faster when using the old rag method to clean the back of the seats than when using the seat back cleaner.

The total cost of all parts was about $100.

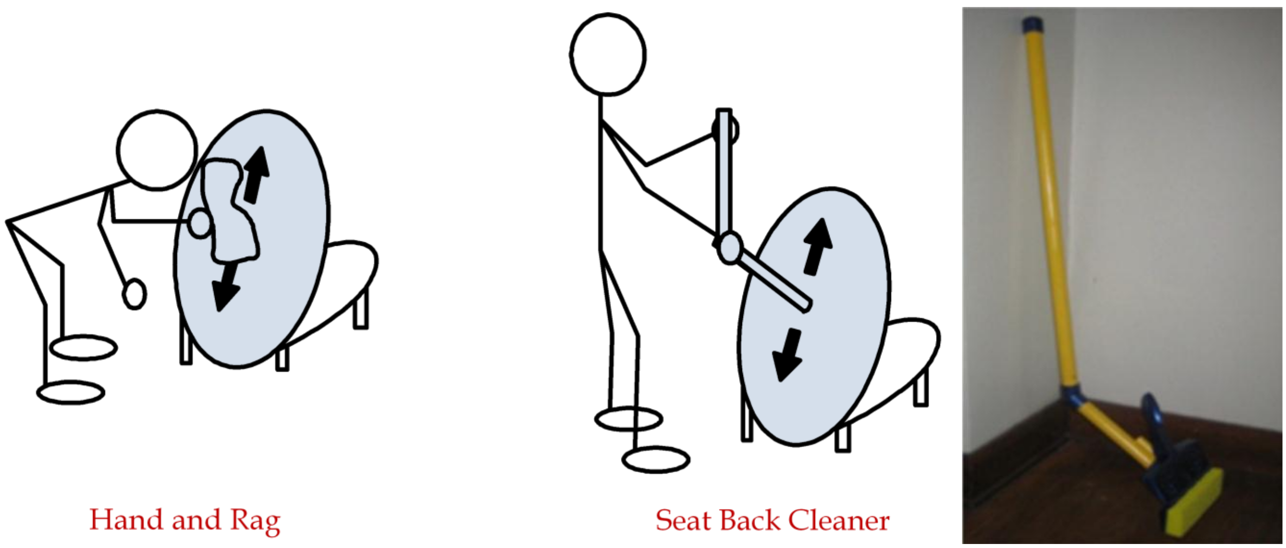


Fig. 18.14a and 14b. (a) Body Posture Improvement with Seat Back Cleaner; (b) Picture of Seat Back Cleaner.

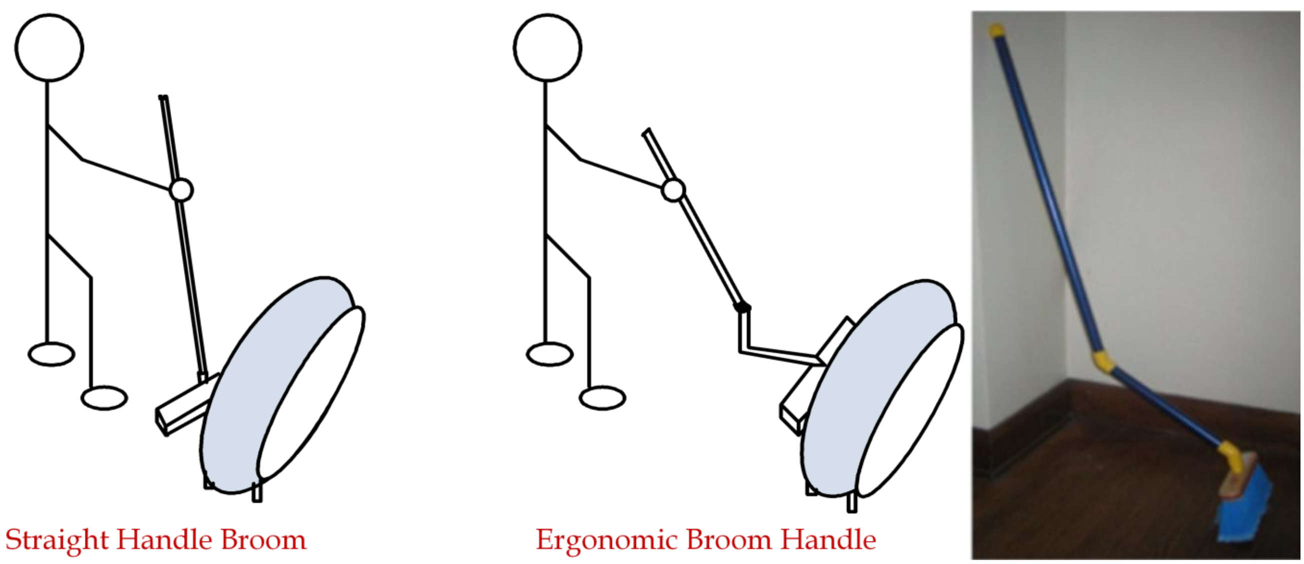


Fig. 18.15a and 15b. (a) Ergonomic Broom Handle and Straight Handle Broom; (b) Picture of Ergonomic Broom.

# IMPROVING WORKPLACE ERGONOMICS

*Student Designers: Timothy Fry, Adrian Grapenthin and Kaleb Packer*
*Client Advisors: Ms. Jill Caruso, The Ability Center of Greater Toledo (ACT)*
*Ms. Diane Witt, Project SCOUT Coordinator, University of Toledo*
*Supervising Professors :Dr. Mohamed Samir Hefzy and Dr. Mehdi Pourazady,*
*Department of Mechanical, Industrial and Manufacturing Engineering*
*The University of Toledo*
*Toledo, OH, 43606*

## INTRODUCTION

An individual with cerebral palsy works as an office assistant. When taking inventory, she has difficulty accessing overhead cabinets used for storage (see Fig. 18.16). The goal of the project was to adapt the client's work environment to allow her to easily reach the two overhead cabinets. This was accomplished by lowering the cabinets to her level

Fig. 18.16. Cabinets before Modification.

instead of raising her to the cabinets. The cabinets were modified to create cabinet inserts that slide out of the bottom of the existing cabinet structures and can be lowered down vertically to countertop level using linear actuators (see Fig. 18.17 and 18.18). Both of the cabinets move independently and are controlled by two switches.

## SUMMARY OF IMPACT

The client is now easily able to take inventory of office supplies and access the cabinets. Her adapted work environment allows her to safely raise and lower the overhead cabinets that are used to store office supplies. She is able to now perform her work more independently.

## TECHNICAL DESCRIPTION

The two commercial grade cabinets were temporarily removed and modified to satisfy the following design requirements: 1) the client must be away from the cabinets when they are in motion in order to prevent the possibility of injury; 2) reduction of storage space within the cabinets must be kept to a minimum; and 3) the cabinet modifications must not interfere with the suitability of the workplace for others.

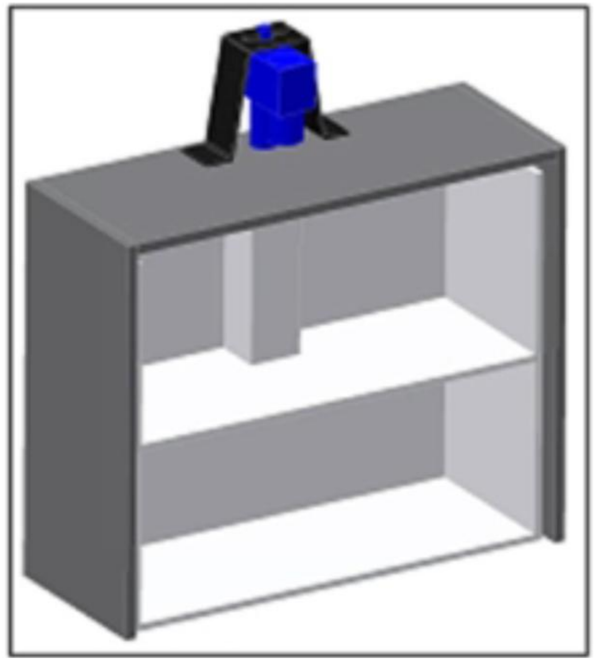

Fig. 18.17. Computer Model of Modified Cabinets with Insert in Raised Position.

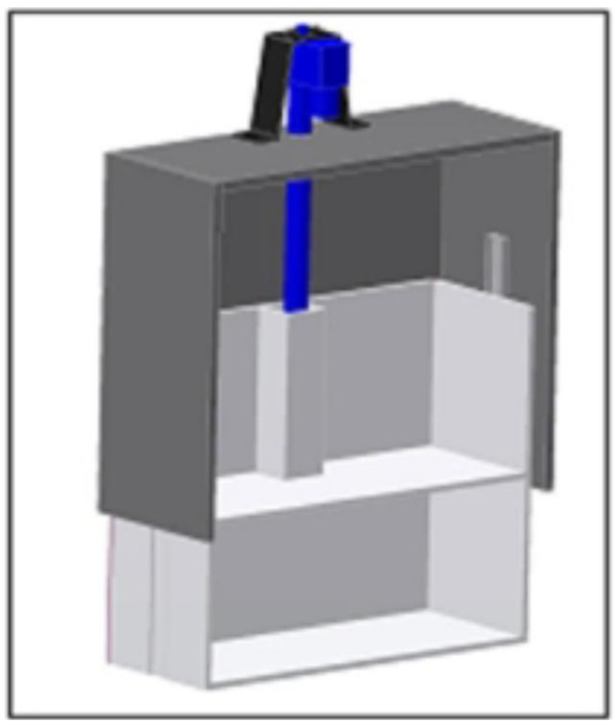

Fig. 18.18 Computer Model of Modified Cabinets with Insert in Lowered Position.

The bottom of each cabinet frame was removed and a cabinet insert was designed and developed. Each insert can carry a load of 260 lbs. Two Warner Linear B-Track K2P1.0G10-90V-BR-18 actuators were used to raise and lower the inserts. Each of these actuators has a static holding capacity of 2000 lbs., 18″ stroke, 1″/sec travel speed and is powered by a 90 VDC motor. Both actuators are controlled by a single SBC-AC-90V control box with two switches. The unit converts 115 VAC to 90 VDC and contains the wiring necessary for the control switches. The control switches are Double Pole Double Throw "momentary on-off momentary on." The controls allow each cabinet to move independently and are mounted on the wall adjacent to the cabinets. Each actuator uses its electric motor and a set of reduction gears to turn a threaded shaft mounted inside a tube. Each actuator was mounted with its motor on the top and outside of the cabinet structure (see Fig. 18.17 and Fig. 18.18). The tube runs through the inside of the cabinet insert and attaches to the middle shelf. A cover was constructed in the cabinet insert to protect the tube of the actuator. Each insert is guided by industrial grade drawer slides mounted between the insert and the cabinet frame (see Fig. 18.17 and Fig. 18.18). Upper and lower mounting fixtures were designed and constructed to mount the actuators. The lower fixture includes a ¼″ thick steel plate that is screwed underneath the middle shelf and attached to the actuator with a ½″ 1018 CD steel clevis pin (see Fig. 18.19). The upper fixture was also made of ¼″ thick steel plate, 8″ tall, and was attached to the

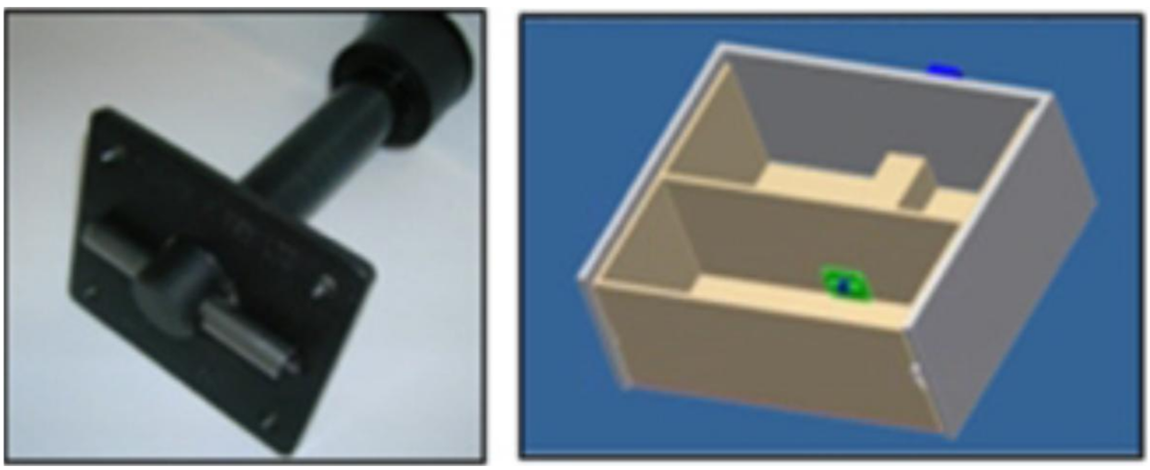

Fig. 18.19. Lower Fixture.

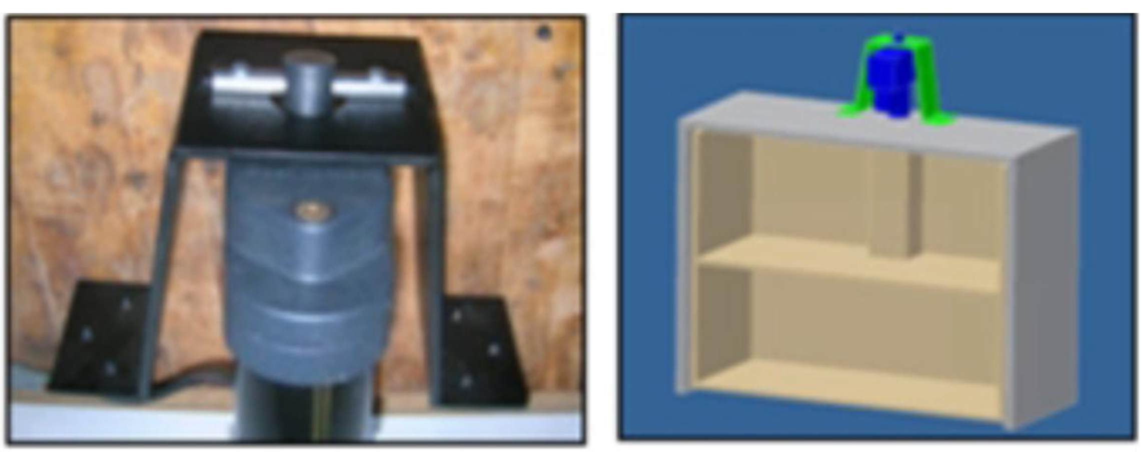

Fig. 18.20. Upper Fixture.

actuator with a ½" steel clevis pin (see Fig. 18.20).

I-Deas 12, a finite element analysis package was used to perform the structural analysis of the unit. The most stressed point was found to be on the top of the cabinet frame where the upper fixture is mounted, and a factor of safety of five was calculated (see Fig. 18.21). The total cost of the parts was about $1,050.

Fig. 18.21. Modified Cabinet During Testing.

# WHEELCHAIR ACCESSIBLE PASSIVE LEG EXERCISER UNIT

*Student Designers: Natalie Bate, Kristin Aagenas, Colin Chapman, Andrew Schramm, and Casey Harms*
*Mechanical Engineering Students*
*Client Advisor: Ms. Jill Caruso*
*The Ability Center of Greater Toledo*
*Faculty Advisors: Dr. Mohamed Samir Hefzy and Dr. Mehdi Pourazady*
*Department of Mechanical, Industrial, and Manufacturing Engineering*
*The University of Toledo*
*Toledo, OH, 43606*

## INTRODUCTION

An individual with spina bifida uses a wheelchair. She is very active and wanted a way to work out her legs. A wheelchair accessible passive exercise unit was developed to allow her to work out while seated on her chair (see Fig. 18.22). The unit allows the client to perform both arm and leg movements. The unit uses a motor to power the motion of the legs and arms. A control box was mounted to the side of the client's wheelchair. It allows her to control the speed of the machine and to quickly stop it with an emergency stop button. The pedals of the unit were made to accommodate for the client's different leg lengths.

## SUMMARY OF IMPACT

The unit accommodates the client's different leg lengths and provides her with a way to exercise her arms and legs. The exercise builds muscle strength in her legs and provides her with the ability to stand for a reasonable length of time to do the dishes and other household chores. The unit is accessible to a wheelchair and is safe for her to operate. It secures her feet to the pedals, and the controls are easy to reach. The unit is also lightweight and portable.

## TECHNICAL DESCRIPTION

The passive leg exercise unit has a large rear base, made of plywood, which allows the user's wheelchair to rest on it during use for stability (see Fig. 18.22). It includes a side-mounted electric motor that rotates a crankshaft to which foot pedals and handlebars are attached. The handlebars rock back and forth due to a linkage that attaches the handles to a smaller crank on the crankshaft. With the electric motor driving the system, this option provides a completely passive upper and lower body workout. However, with the motor disengaged, the user's upper body can actively drive the system. This can be accomplished by rocking the handles back and forth, which in turn rotates the crankshaft and pedals. A thicker footrest was developed to allow for the client's different leg lengths.

Fig. 18.22. Client Using Exercise Unit.

The crankshaft was made of steel. The throw of the pedal crank was specified to be five inches. The pedals are made of wood and are ten inches apart from each other. To reduce the chance of splinters, the pedals were sanded, stained, and treated with three coats of lacquer. Rollerblades were used to secure the client's feet to the pedals. The boot of a rollerblade holds the entire foot, ankle, and lower calf of the leg in a secure position. By using a large enough rollerblade, the client is able to leave her shoes on. The wheels were removed from the rollerblades, which created holes that were used to secure the boot to the pedals. Creform pipes were used for the handlebars. Angle brackets were used to connect the upper and lower sections of the handlebars. The motor operates at a maximum of 50 rpm with 45 in-lbs. torque. The motor is wired directly to the control panel.

Based on the client's body weight, it was estimated that a load of 20 lbs is applied to each pedal. Also, a load of 20 lbs acts on each handle. Handle loads are transferred to the crankshaft through connecting links. Solidworks software was used to develop a computer model of the unit and to calculate the stresses in the crankshaft, its vertical supports, and the handlebars (see Fig. 18.23).

The total cost of the parts was about $450.

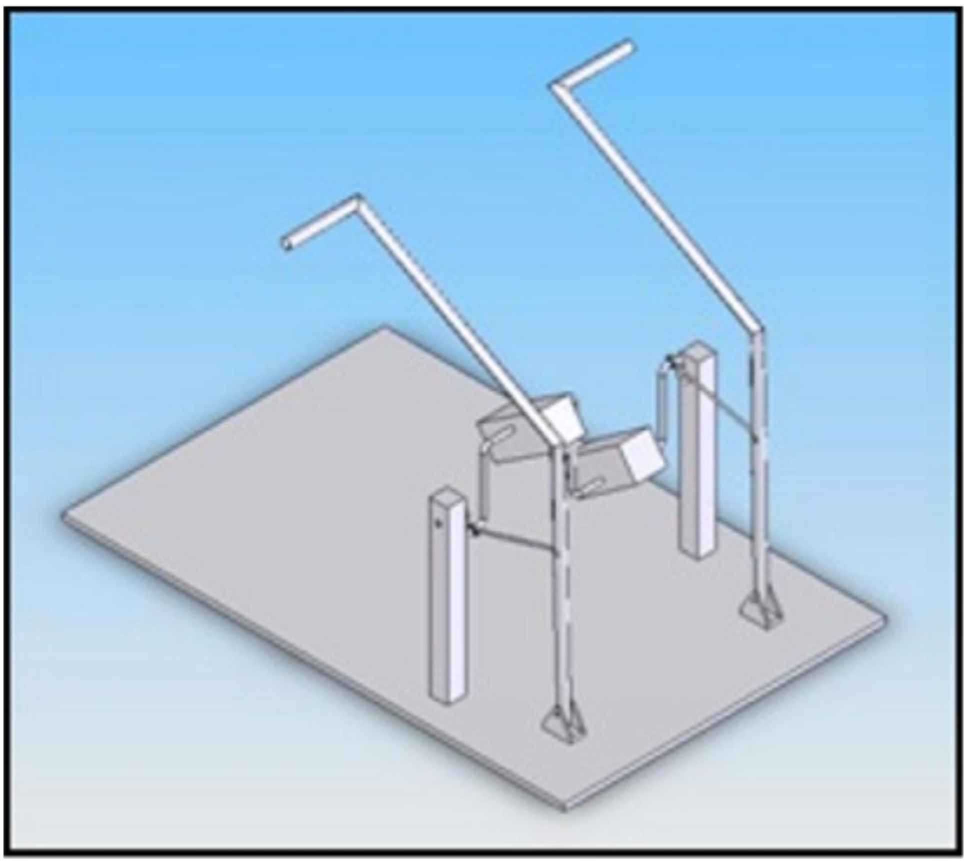

Fig. 18.23: Computer Model of Exercise Unit.