CHAPTER 13

UNIVERSITY OF ALABAMA AT BIRMINGHAM

Department of Biomedical Engineering
1075 13th St. S.
Birmingham, Alabama, 35294-4461

Principal Investigator

Alan W. Eberhardt, PhD

(205) 934-8464

CHEETAH WALKER: TRANSITIONAL WALKING DEVICE

Designers: Jonathan Brightwell, Cara Rouse, and Nathan Fife
Client Coordinator: Scott Sall, Children's Hospital of Alabama
Supervising Professor: Alan W. Eberhardt, Department of Biomedical Engineering
University of Alabama at Birmingham
Birmingham, AL 35294

INTRODUCTION

The client coordinator is a physical therapist who specializes in working on motor coordination and balance with children who have cerebral palsy (CP). He has found that many of these children have a difficult time improving their gait with a traditional walker and even more difficulty transitioning from a walker to hand canes. The four-wheel pull-behind walkers that most of these children use are designed for them to hold their upper body rigid, placing all of their weight in their arms and dragging their feet along with them. The coordinator noticed that, after using the walkers for a prolonged length of time, many of the children develop a rigid upper body and are unable to adjust to the upper body movement required to walk with hand canes. The aim of the present project was to develop a transitional walker that permitted arm movement (flexion and extension) as in contrary walking (where the arm that swings forward is on the opposite side of the foot moving back).

The design was subject to several constraints. First, the device must emulate normal walking as closely as possible. If not, the child may be forced to make two transitions instead of one: a transition from walker to device, and a transition from device to hand canes. Second, the device must accommodate children with CP ranging from four to eight years old, up to 100 pounds, and a height range of 32 to 48 inches. Accordingly, the arm canes will need to be adjusted to the proper height for each child (16 to 32 inches). Third, the device must have adjustments for variable widths between the canes. Fourth, the handles of the canes should have a 360-degree adjustable range in the horizontal plane. This will accommodate any abnormal hand position caused by CP. Fifth, because children of different ages move their arms at different distances when walking, the length of forward and backward movement of the canes must also be adjustable. Also, these adjustments must require few tools. Sixth, the completed device should be transportable within the therapy room from the treadmill to the storage closet. The budget for this project was $1500 and the time allowed was approximately four months.

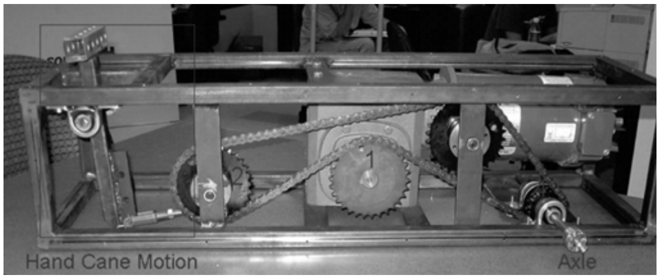

Figure 13.1. Drive Side of Cheetah Walker, Including Sprockets for Hand Cane Motion (Left), and Transfer Rotation to Non-Drive Side via an Axle (Right)

SUMMARY OF IMPACT

The walker will serve as a training device for children with mild CP, for use by the client coordinator at a hospital. It will provide a child-friendly device with which they may transition from a traditional, follow-behind walker to hand canes, thereby improving their quality of life and independence. This new walker will help children develop the upper body movement necessary to walk with a cane, while still providing the stability of a four-leg walker.

TECHNICAL DESCRIPTION

The device has two basic components: the drive-side and the non-drive side. Both are contained in rectangular boxes with a tube steel frame and are enclosed by 1/2-inch plywood. Each box is painted with a jungle theme and a cheetah, leading the children at the hospital to name the device the "Cheetah Walker."

The drive-side of the device (shown in Figure 13.1) has a 3/4-horsepower Baylor Industrial DC electric motor with a gear reducer and runs at a speed of 68 rpm. The motor is attached to the frame using 1/8″ steel. Sprocket 1 is attached to the gear reducer and is powered by the electric motor. Sprocket 1 turns the chain, resulting in the turning of three more sprockets that are attached to the chain. A pushrod is attached to sprocket 2, changing the rotational motion into linear motion. Sprocket 2 is bolted to ¼″ steel rod, which is welded to the frame. The other end of the pushrod is attached to a 3/8″ steel bar that is welded to a 1″ steel tube. The steel tube has a ½″ steel bar welded 7″ above the attachment, which is connected to the frame by two pillow blocks. At the top, and perpendicular to the 1″ steel tubing, is welded a 1.5″ steel tube that holds the cane width adjustment tube. Sprocket 3 is used to re-route the chain, preventing mechanical rubbing.

The non-drive side of the device is powered by the drive-side by way of an axle that runs underneath the treadmill. The chain on the drive-side turns sprocket 4, which turns the axle. The axle is attached to the frame by two pillow blocks. The axle has two breaks in its length. These breaks are linked together by mated couplings. The middle length of axle is supported by two pillow blocks that are attached to a separate 4.5″ x 29″ frame made of 1″ steel. The non-drive side has two sprockets, attached by a chain. One sprocket turns with the axle. The cane movement mechanism works in the same way as on the non-drive side. The cane mechanism has a retractable 1″ square tube pinned inside the 1.5″ steel tube from the drive- and non-drive side. This allows for the 13″ to 22″ width for cane placement, accommodating different sizes of children. At the end of the retractable bar is a clamp from a percussion stand. The adjustability of this clamp allows for the 360 degree rotation of the canes. Normal adult canes were cut in order to fit into the clamp and to fit the height adjustability specifications. The final design is shown in use by a child with CP in Figure 13.2.

The costs for the project totaled approximately $1260.

Figure 13.2. Client Using Transitional Walking Device

ELECTRIC ELEVATION ASSIST AND SPASTICITY CONTROL ARM

Designers: Steven Moore, Donald Burke, and Tiffany Borden
Client Coordinator: Linda Pierson, PT, Hueytown Elementary School
Supervising Professors: Alan W. Eberhardt, Department of Biomedical Engineering, Gregg M. Janowski, and J. Barry Andrews, Department of Materials Science and Engineering
University of Alabama at Birmingham
Birmingham, AL 35294

INTRODUCTION

The purpose of this project was to augment a mechanical arm support for an 11-year old boy who has dystonic cerebral palsy with choreoathetoid movement. The client coordinator had previously purchased an arm support system. This device was intended to provide the client with a more comfortable restraint system than being strapped to his wheelchair arm rest. That system was not comfortable, and movement was restricted to only the horizontal plane, preventing him from performing daily activities such as eating and brushing his teeth. A device was desired that would restrict the client's spasticity, but allow him to raise and lower his arm so that he is able to perform day-to-day tasks.

The device had to be able to be removed and attached to the client's wheelchair easily and quickly. In addition, the device had to restrain posterior abduction of the humerus at a force of 40 to 120 pounds. To accomplish daily tasks that involve hand-to-mouth motion of his right arm, augmentation of the device had to allow for 0^o-110^o flexion of the elbow, 50^o-60^o internal rotation of the shoulder, 30^o-45^o flexion, abduction of the humerus, and a lifting force of 25 pounds. In addition, the device had to restrain his dystonic spasms of 40 to 120 pounds. The device is to be controlled by the user, and any electrical and mechanical components had to be properly installed. A budget of $1500 was specified and the team had roughly four months to complete the design.

SUMMARY OF IMPACT

The resulting device provides a comfortable restraint system that restricts the user's spasticity, but allows him to control elbow flexion so that he can perform such tasks as eating, brushing his teeth, and other hygienic activities. While testing the device, the client exclaimed, "I can brush my teeth now." The client's physical therapist has also expressed her satisfaction with the final product.

TECHNICAL DESCRIPTION

The final design incorporated an AC linear actuator to provide the desired range of motion, a foot control for the user to control movement, and a control box to convert AC to DC power (shown in Figure 13.3). These devices were donated by LINAK (Louisville, KY), and were chosen based on size, weight, availability, appearance, and desired performance. The LINAK linear actuator was wired to the control box. Snap-connectors and heat-shrink tubing were added to secure the line. The original distal joint of the arm support was removed, and an aluminum conduit was used to fix the arm support segments into a set position. Locking the arm at this joint functions in spasm control and also provides a stable mounting position for the actuator. This positioning allows the user's arm to be relaxed, hanging slightly anterior to his body, from where the linear actuator can raise his hand to his mouth in a comfortable and natural manner. Steel bushings were placed in the piston rod eyes to accommodate for diameter size differences between the eyes and the mounting brackets. A hole was drilled as close to the proximal joint as possible to allow for full extension of the actuator piston. A conduit hanger was then bolted at the hole's location to allow for attachment of the stationary piston rod eye.

The forearm support was adjusted to allow for the proper pivot angle, and a stainless steel bolt was inserted through a mounting flange to attach the movable piston rod eye. Vinyl bushings were then used to prevent lateral movement and a stop-pinion was removed to prevent overshoot complications. The completed system is shown in Figure 13.3.

The linear actuator, control box and foot switch were donated, resulting in a total cost of $96.

Figure 13.3. Electric Elevation Assist and Spasticity Control Arm (Top). Foot switch (Bottom Right), Linked to Control Box (Bottom Left).

SAFE FLOORS FOR PREVENTION OF FALLS

Designers: Maile Kruse, Jared Haden, and Jonathan Quick
Client Coordinator: Uday Vaidya, Department of Materials Science and Engineering
Supervising Professors: Alan W. Eberhardt, Department of Biomedical Engineering,
Gregg M. Janowski, and J. Barry Andrews, Department of Materials Science and Engineering
University of Alabama at Birmingham
Birmingham, AL 35294

INTRODUCTION

A flooring system for passive prevention of falls resulting in hip fracture was the goal of this project. The constraints for the floor material were that the floor must withstand normal walking (i.e., the 385 N peak force caused by walking barefoot). Under impact of a 35-kg load at 2.6 impact velocity, the floor must attenuate 2.23 kN from the hip surrogate in order to prevent hip fracture of a woman. Hip padding systems were to be capable of lowering the femoral impact force well below 4 kN, the mean force required to fracture the elderly femur in vitro in a side fall loading configuration at realistic loading rates. Furthermore, all components of the surrogate were to be durable enough to withstand multiple impacts.

SUMMARY OF IMPACT

The most common cause of hip fractures is falls, usually in people over 65 years of age. Due to the prevalence of osteoporosis, women are up to three times more likely to experience a hip fracture than men. A flooring system to serve as passive prevention of hip fracture was the goal of the present work, to prevent hip fracture in women. Further design work is needed, as the current design was not successful in testing to simulate hip fracture prevention.

TECHNICAL DESCRIPTION

Floor

A layered sandwich composite structure was developed for the floor. A core subsystem is the primary energy absorber. Options for the core included honeycomb, prismatic, and foam/laponite mixture. The honeycomb core was chosen because of its in-plane properties. Honeycomb core made of aramid paper was chosen for its low weight and cost efficiency. The HexWeb HRH-10-1/8(in)-3.0(lb/ft3) absorbs approximately 60 J upon buckling and therefore was considered adequate for the flooring purposes. Epoxy was chosen for the resin

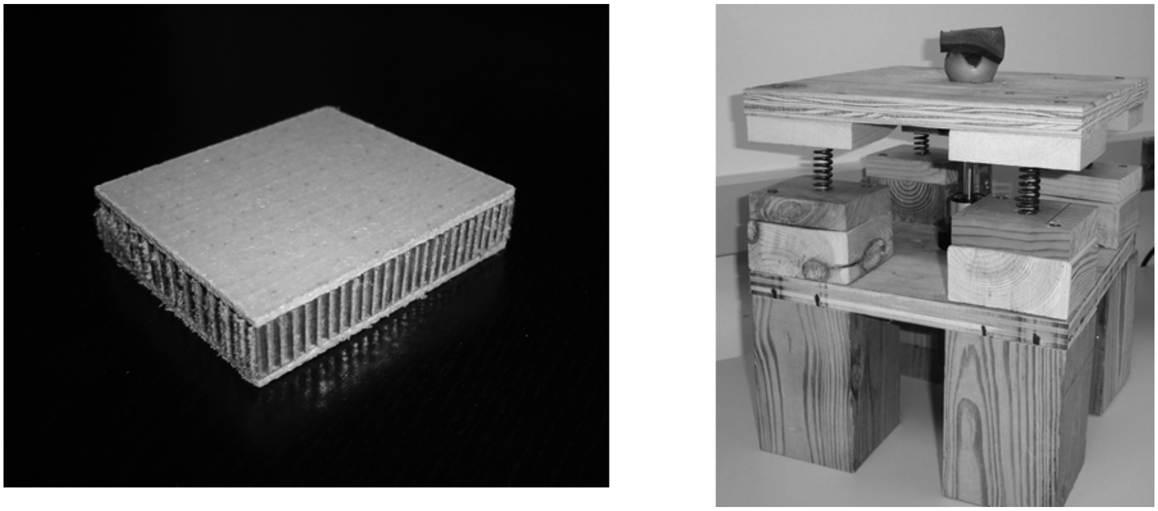

Figure 13.4. Sandwich Composite Floor with Hexweb Honeycomb Core Made of Aramid Paper (Left) Joined to Face Sheets of E-Glass Fiber and Coremat With Epoxy(Right)

subsystem. A series of E-glass fiber and Coremat were chosen for their high affinity to bond to each other. To impart rigidity to the face sheets, the layers were bonded together using Freeman's FMSC 690 epoxy resin followed by vacuum bagging and 24-hour cure. The honeycomb core was sandwiched between the two face sheets with 3M's Scotchweld DP – 125 Grey epoxy adhesive bonding. The floor was put into an oven at 160°F (71 °C) for two hours to attain full cure. The finished floor tile was then cut into 8.9″ x 11.4″ tiles for testing (Figure 13.4).

Surrogate

A hip surrogate was constructed using wood, springs and an adjustable shock absorber (Figure 13.4). The femoral head of a Sawbones 3rd generation composite femur was glued onto the center of the top plate's superior face. A layer of Sorbothane, .75 cm thick, was attached on top the femoral head by spray adhesive. A hole with a 3.8-cm diameter was drilled into the center of the 25.5 cm x 25.5 cm bottom plate to house the 25 cm tall damper. The damper was placed through this hole and fastened to the plate with two nuts, one on either side. Four 8.5 cm x 8.5 cm x 12.5 cm blocks of wood were attached to the bottom plate to provide clearance for the height of the damper. Then a hole with a 1.5 cm diameter (the diameter of the springs) was drilled into the center of eight 8.5 cm x 7.5 cm x 3.7 cm blocks of wood. Four of these blocks were screwed into the corners of the superior face of the bottom wooden plate. The other four blocks were screwed into the corners of the inferior face of the top plate. Furthermore, a block of wood with a 3 cm diameter hole in the center was screwed into the center of the inferior face of the top plate, to enclose the head of the damper. The springs were placed into each hole of the bottom plate. The top plate was placed on top of the springs and damper to unite all three subsystems. Two screws were tightened through the housing of the damper head to ensure that the three subsystems act as one system under impact.

Floor testing

After construction of the composite flooring, compression and point load tests were performed on the tile to determine whether the floor would be able to withstand everyday forces such as a typical walking. The floor stiffness was found to be independent of the loading rate. Point load testing was conducted to better understand the floor's response in situations such as a woman walking in high heels and someone sitting down in a chair. As expected, the floor failed at a lower force with the small indenters versus the large indenters, but none at levels below 400 N. The surrogate was then impacted with 35 kg raised 32 cm from the impact surface to generate a 2.6 m/s impact velocity. The data were filtered by a fast Fourier transform using a low-pass filter with a cut-off frequency of 140 Hz. The surrogate underwent a peak force of 6.4 kN within a response duration of 60 msec. Although the force peaked earlier than expected, the surrogate was used to validate the flooring system for hip fracture prevention. In floor evaluations, a 8.9 cm x 11.4 cm floor tile was attached to the 7.62 cm x 10.16 cm impact plate by spray adhesive and dropped onto the hip surrogate under the same mass and velocity conditions. The data were filtered, and the floor decreased the peak force experienced by the hip surrogate by 1.4 kN, which did not decrease the peak force to the target 4.1 kN. The flooring system, therefore, was not successful in the prevention of hip fracture.

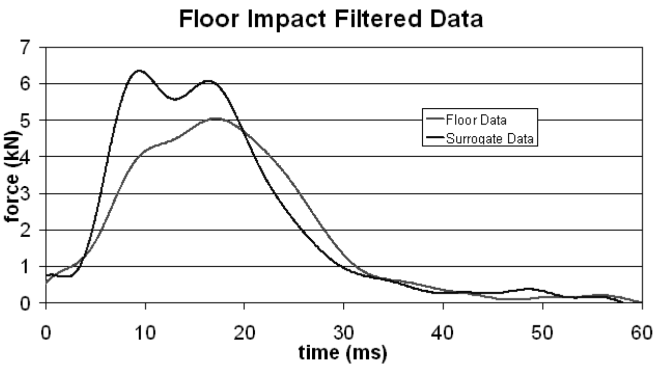

Figure 13.5. Impact Force Data for Hip Surrogate (6.3 kN peak force (dark line), with sandwich composite flooring (gray line), reducing peak force to roughly 5 kN)

Total cost for materials was approximately $820.

STAIR TRAINER FOR CHILDREN WITH CEREBRAL PALSY

Designers: Harleen Khanijoun, Dina Halwani, and Monalisa Ghosh
Client Coordinator: Marliese Delgado, UCP Hand in Hand
Supervising Professors: Alan W. Eberhardt, Department of Biomedical Engineering
University of Alabama at Birmingham
Birmingham, AL 35294

INTRODUCTION

A stair trainer device was built to promote gross motor function in children with cerebral palsy (CP), aged two to five years old. The ascending and descending of stairs employs an increase in the lower-limb movement and more intense muscular activity than walking (Figure 13.6). Currently, stairs on the administrative side of a CP program's building are being used to train the children. A previous stair trainer designed by a previous senior design team was abandoned due to safety concerns. A modification of the previous stair trainer was requested, differing from the previous in size, material, and appearance.

An isolated stair trainer that provides an incentive for children to repeatedly climb a set of stairs was the goal. The stair trainer had to allow for easy adult supervision, and be easily disassembled and stored when needed. Based on the safety standards for playground equipment, the railings were to have an appropriate height of 24″ for toddlers and were designed to be 24″ apart to disallow holding of both railings during climbing. A height of three feet was designated for the platform with a minimum of 24″ of railings, as dictated by safety standards. Additionally, wood was the material preferred by the client, and the use of metal was to be avoided due to its hospital-like appearance.

The space for use of the stair trainer was a corner of a room with an area of 18′ x 18′. The minimum final structure height as instructed by representatives at the UCP was designated as 36″. The design was to be disassembled into large modular components, each of which could be moved by two adults who could lift a combined weight of 150 pounds. The components had to fit into a storage area with a single door entryway. The maximum number of children expected on the set of stairs was three per stair and five on the platform, and a safety factor of two was employed. The following dimensions for the stairs were prescribed: a height of 8″, a width of 10″ and a length of 24″.

The smallest child on the stair trainer would be 19″ tall, weighing 20 pounds, while the largest would be 46″ tall, weighing 68 pounds. Appropriate fall zones had to be taken into account at a minimum of 6′ in each direction. To avoid head entrapments, openings could not exceed 9″ and could not be smaller than 3.5″. Additionally, the structure could not have any sharp edges or corners, the supports had to be sturdy, and the device stable. According to the Safety Standards for Playground Equipment produced by the Consumer Product Safety Commission, the angle of the stairs could not exceed 35 degrees. The angle of the slide could not exceed 50 degrees at any portion and had to maintain an average angle of 30 degrees. The ideal slide would re-orient the child to a sitting position at the exit. The project had to be completed within four months and within a $1,500 budget.

SUMMARY OF IMPACT

Through treatment, muscle coordination in CP can be improved, and secondary conditions can be avoided. Children of various levels of ability will be able to practice stair climbing, and receive the reward of a ride down the slide. The staff commented that the concentration of children playing on the stair trainer will allow for easier supervision of larger numbers of children. The trainer has not yet been delivered.

TECHNICAL DESCRIPTION

The final design consists of the three following subsystems: one set of stairs, one platform, and a slide (Figure 13.6). Wood comprised the primary material because of its well-known properties, low cost, and ability to be machined. The team used a lightweight commercial polyethylene slide component as an incentive to climb the stairs.

The density of ¾″ birch plywood (0.01987 lbs/cu in) was used in the calculations. To reduce bulkiness, a small platform of 26″ x 26″ was designed. The completed weight of the structure was 200 pounds. The slide was lightweight, at approximately 20 pounds. The final structure was carpeted, per the client's request, and to reduce noise created. As dictated by the design criteria, the stair trainer was built as an isolated structure. Given its 90-degree angle against the corner of a wall, it allows for easy adult supervision. It is of the requested 36″ height with additional 36″railings on the platform, promoting safety. There are no places where children might crawl through and no sharp edges. The device is stable, and the railings are placed for safety and supervision. The project met all safety standards with the stairs and slide angle.

Due to higher-than-expected cost of labor, the project exceeded the $1500 budget by $260.

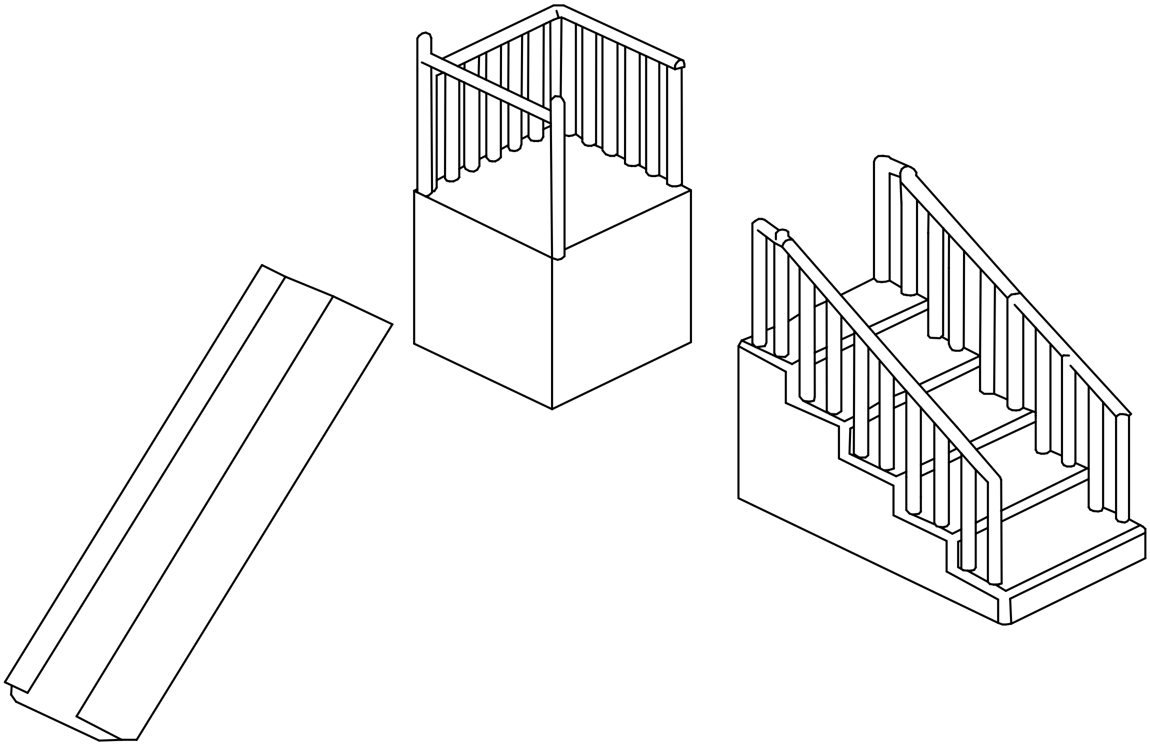

Figure 13.6. Schematic of Stair Trainer (Slide, Platform and Stairs)