CHAPTER 15
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DESIGN OF A UNIVERSAL CONTROL PANEL FOR A WHEELCHAIR ACCESSIBLE TREADMILL

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INTRODUCTION

Wheelchair users are living longer, fuller lives as the result of innovative medical and technological advances. While the progress has been considerable, there are still areas of significant need in this population. Wheelchair users are at high risk for becoming obese, which can lead to secondary health conditions, such as cardiovascular disease or upper extremity pain and injury. The solution to obesity in the wheelchair user population is the same as it is in the general population, a healthy diet and regular exercise. The limited availability of wheelchair accessible cardiovascular exercise equipment may be contributing to a lack of regular exercise in this population. To address this need of a wheelchair accessible treadmill, a proof-of-concept prototype

Fig. 15.1. The original wheelchair accessible treadmill prototype and control panel.

was developed and then evaluated in a six-week exercise study by three manual wheelchair users. Results suggest that paraplegics can improve cardiovascular fitness and increase push strength from exercise on the treadmill. Results and feedback from the subjects also revealed a need to redesign the control panel to better accommodate both ambulatory and wheelchair user populations.

SUMMARY OF IMPACT

A wheelchair accessible treadmill, one that is universally designed for both ambulatory users and wheelchair users, offers a promising opportunity for a gym to provide accessible cardiovascular equipment that has broad usage expectations across its membership. The development of a new control panel further enhances the overall design and accessibility of the treadmill.

TECHNICAL DESCRIPTION

The new control panel represents a significant advancement in the design of the wheelchair accessible treadmill. The most notable difference between this and others are the buttons to distinguish between ambulatory and wheelchair users (top to either side of the MAX logo). The maximum speeds and grades appropriate for wheelchair users are considerably slower and lower than those of ambulatory users. This may not seem like a problem since users only go as fast or as steep as they are capable of going. This is true if the users are in manual control mode but it may be out of their control for the random, hills, sprints, fat burn and max exercise programs. By differentiating between ambulatory and wheelchair users, it allows for the development of exercise programs that are distinctly designed to accommodate the two types of users.

The original control panel incorporated a work level control that changed the speed and grade settings together at the same time. Ideally, if the grade is increased, the speed should stay the same or even be reduced to allow the user to keep up. To address this concern, the work level control was eliminated and replaced with independent speed and grade controls, resulting in a more appropriate system for wheelchair users.

Fig. 15.2. The new treadmill control panel.

The control panel and grab bar structure was completely redesigned. The original design is similar to most commercial treadmills consisted of a bridge across the width of the treadmill. While this makes sense for a standard narrow treadmill, it is less ideal for a wide treadmill because the span is significantly increased. Ours has a single upright structure that is simple, aesthetically pleasing and structurally sound. The design is widest at the base where the moment is greatest and narrow at the top, resulting in minimal material and weight.

The estimated costs of the prototype are $4,300.

RESEARCH AND DEVELOPMENT OF THE STAYCLEAN DIAPER

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INTRODUCTION

Incontinence or loss of bladder or bowel control is a serious medical issue experienced by a large population of individuals with disabilities. Extended exposure to such wastes places these individuals at high risk for the development of skin breakdown, ulceration, and infection.

SUMMARY OF IMPACT

Incontinence is likely to lead to the development of self-esteem problems, feelings of shame or humiliation, disruptions in work life, and social withdrawal and isolation. For cases in which medical treatment can not completely eliminate incontinence or for periods of time until a treatment takes effect, protective under-garments such as diapers can provide relief in incontinence management.

TECHNICAL DESCRIPTION

In order to address the issue of maintaining a high level of skin integrity, the StayClean Diaper prototype was developed. The StayClean Diaper has an additional liner on the interior of the diaper that creates a layer between the waste and the skin. This layer keeps the individual clean and prevents diaper rash as well as “blow outs”. Multiple design iterations led to a prototype that includes a small rectangle with a thin strip of light adhesive in a U-shape that seals the liner to the skin. This adhesive is a hypoallergenic porous medical tape made by 3M adhesives. The prototype is scaled down to the size of a baby diaper for evaluation. With parental consent, the diaper prototype was evaluated on 10 babies at a local child daycare. The results were split between successes and failures leading to the confirmation of the quality of certain design characteristics, while indicating other weaknesses and areas of needed improvement within the design. Specifically, there is a need to optimize the adhesive such that it removes easily for dry diaper conditions, but can remain in place under conditions of low viscosity solid waste.

Fig. 15.3. StayClean diaper prototype.

The estimated costs to develop the prototype are $450.

Fig. 15.4. Waste isolating pocket.

DEVELOPMENT OF AN INSTRUMENTED WHEEL FOR MANUAL WHEELCHAIR PROPULSION ASSESSMENT

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INTRODUCTION

The development of upper extremity (UE) pain and/or injury is a prevalent health concern amongst manual wheelchair users. The UEs serve as the principle means for mobility, therefore, any impeding factors, such as pain or injury, leads to a decreased quality of life. The development of UE pain and injury may be a result of improper propulsion biomechanics or poor wheelchair seating configurations. To quantitatively assess a manual wheelchair user's propulsion technique for training or seating purposes, there is a need for an affordable instrumented assessment tool.

SUMMARY OF IMPACT

The goal of the project is to develop an instrumented wheelchair wheel utilizing strain gauges that has the capability of quantitatively measuring resultant force during propulsion. Essentially, the instrumented wheel serves as a means to quantitatively compare various wheelchairs and seating configurations to optimize the degree of comfort and propulsive capabilities of MWUs. With comparative propulsion data, the instrumented wheel also serves as justification for the selection of particular wheelchair equipment.

TECHNICAL DESCRIPTION

Strain gauges are placed on the top and bottom of each of the three push rim tabs that couple the wheel to the push rim. The strain gauges are then wired into a Wheatstone bridge circuit. When force is applied to the push rim, the strain gauges go into tension or compression based upon their position in relation to the location of the applied force. This results in changes in the resistance of the strain gauges, which are reflected in changes in the two voltage outputs from the Wheatstone bridge. These

Fig. 15.5. Strain gauges attached to the push rim tabs.

changes in the output voltages are then amplified through an instrumentation amplifier. The Wheatstone bridge circuits and instrumentation amplifiers for the three tabs are contained on a single printed circuit board. The amplified output voltages corresponding to the three push rim tabs are then sent, via a data acquisition unit with Bluetooth capabilities, to a local computer to be recorded, processed, and analyzed in LabView. A standard curve was created relating resultant force to output voltage.

The prototype wheel developed demonstrates the ability to assess wheelchair propulsion by measuring strain created by resultant force. Small changes in voltage created by flexion in the push rim are sufficiently amplified in order to gain the appropriate sensitivity to clearly track the resultant force applied to during propulsion.

The estimated cost to develop the prototype is | $1,850.

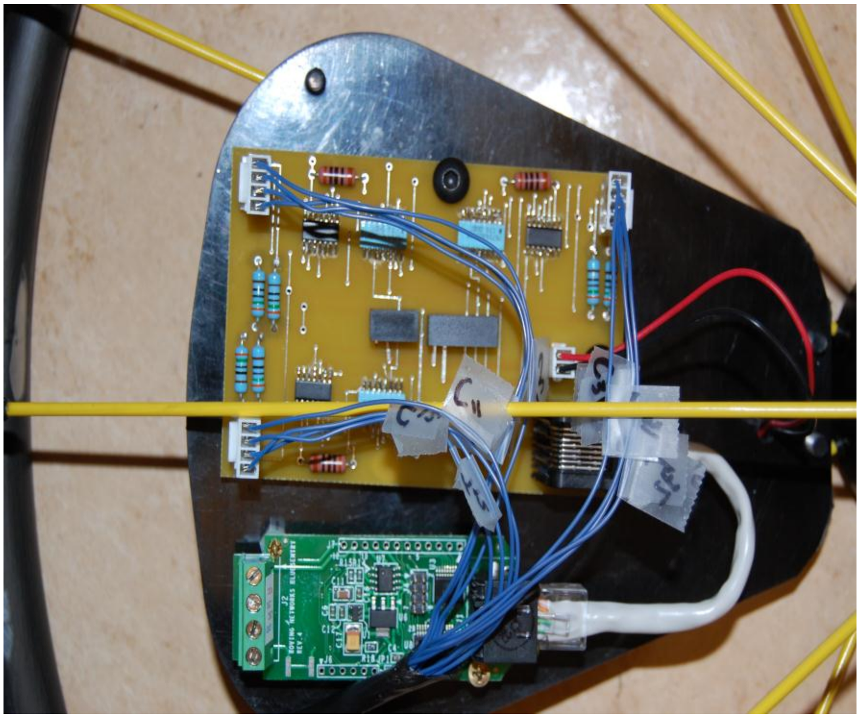

Fig. 15.6. The printed circuit board and data acquisition unit mounted to the wheel.

Fig. 15.7. The instrumented wheel prototype.

CROSS SLOPE COMPENSATION FOR WHEELCHAIRS

Designers: Alex Abraham, Marc Moore, David Dar, 2007-2008
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INTRODUCTION

The ADA requires public walking areas not possess a cross-slope greater than 1.1°. This stipulation often goes unenforced, creating troublesome surfaces for wheelchair users. As a result of the slanted condition, more torque needs to be applied to one wheel to maintain straightforward motion. Thus, the manual wheelchair user spends a significant amount of time exerting a greater pushing force with one arm, or the other, when outside. As a consequence, prolonged usage increases the potential to cause damage to the arms due to overuse. Due to a large target market (more than 1 million manual wheelchair users in the United States), a solution is needed.

SUMMARY OF IMPACT

The development of a cross slope compensation mechanism allows users to self-select normal flat-surface movement or constrained sloped surface movement with decreased need for corrective re-centering motions involving (typically) the downhill arm. Use of such an item will improve the quality of life for wheelchair users.

TECHNICAL DESCRIPTION

The following design criteria were applied:

- Add-on application to existent wheelchairs
- Inexpensive (<$150 per mechanism)
- Aesthetically appealing
- Lightweight (<1 lb. per mechanism)
- Mechanically simple
- Robust, durable, must withstand 7.3 N*m torque - calculated downhill moment on 6° cross-slope, mean plus standard deviation (5.2+2.1 N*m)

The final design includes a locking pin mechanism that restricts rotational movement of a front wheel. It forces the wheelchair to travel in a single direction without deviation. It is applied only when the subject deems it necessary. Upon activation, the pin snaps down and interlocks with the lower plate due to a preceding spring loaded potential. The mechanism is initiated by a lever, transmitted via a bike cable through a sleeve, which attaches to the top of the pin housing. The released cable allows for the spring to move a stroke length of 0.6 in., pushing the pin down through the rotor.

The cost of the prototype (labor and materials) is approximately $1,000. Estimated cost per manufactured item will be less than $200.

Fig. 15.8. Image of the cross-slope compensation mechanism.

SMART ANTI-TIP SYSTEM FOR MANUAL WHEELCHAIRS

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INTRODUCTION

Manual wheelchairs are traditionally outfitted with anti-tip bars; bars that protrudes from the rear of the chair and prevent the user from flipping over. The bars are very effective in preventing tips in situations such as inclines, drop-offs, and unintentional wheelies. However, while the traditional anti-tip bar is advantageous from a safety standpoint, it greatly hinders the mobility of the user. The standard anti-tip bar may catch when moving on uneven terrain or off a curb. It can also prevent the user from maneuvering in tight areas. Many beginner wheelchair users may feel unsafe and unstable in their wheelchair while trying to

Fig. 15.9. New anti-tip system.

become comfortable with it. The problem remains however that these new users remove anti-tip mechanisms from their wheelchair because of hindered movement. Without these tip bars, a sense of security is lost.

SUMMARY OF IMPACT

This effort developed an innovative anti-tip system that maintains the functional safety of the current anti-tip bars but will not hinder the mobility of the user in performing common maneuvers and day-to-day obstacles, leading to improved mobility and safety, while performing normal wheelchair activities.

TECHNICAL DESCRIPTION

The design solution consists of a three position replacement bar and contact ball system that replaces the current anti-tip mechanism. It consists of:

- An anti-tip bar leg attached to a collar fitted with side plates with guiding grooves designed to provide stopping points to the tip system.

- Addition of copper springs to solenoid system allowing the solenoid to return to the extended state when de-energized.

- A collar designed to attach the anti-tip system to the wheelchair.

- Bar leg length was determined by measuring the distance between the wheelchair axle and the ground, while maintaining an angle designed to keep the tracking wheel flush against the ground at all times.

- Aluminum side plates are attached to the sides of the collar. Each plate has a custom designed groove through which the solenoid pins travel.

- A 90 degree torsion spring of 42 in-lb. force attached to the anti-tip system via the shoulder bolt to provide resistance to the user and to bring the system back to the ground after wheeling off a curb.

- Solenoids are attached to U-brackets bolted to the anti-tip leg.

- Tipping measurements were made and traced on side plates to determine slit locations for standard and hill settings. Side plate slits cut accordingly.

Stress/strain and maneuverability tests were performed to ensure safety and proper functionality of design.

New design allows for 3 settings (standard, hill, curb) for flexibility, while maintaining safe operation.

Estimated cost of the device is $203.

IMPROVEMENTS IN INDUSTRY FOR DISABLED WORKERS

Designers: Brian Piazza, David Sharvin, Walter Yehl, Austin Healy, 2007-2008
Supervisor: Tommy Hall, New Horizons, Inc., Nashville TN
Instructor: Paul H. King, PhD, PE, Vanderbilt University

INTRODUCTION

The purpose of this project is to enable persons with disabilities to perform tasks that were previously not feasible and to improve the performance of the workers. This project involves working with New Horizons to explore a solution for persons with disabilities to assemble cardboard boxes. The cardboard inserts, initially are flat and require the worker to bend, fold and insert tabs to form it into a box (15 steps). Currently, people with limited cognitive and dexterity skills can assemble the basic design, but the goal is to improve the performance by examining ways to assist and stimulate the workers.

SUMMARY OF IMPACT

This project was one of several suggested by an engineer at NISH. The students were given an introduction to the supervisor at New Horizons Inc. in Nashville TN, the goal of the work was to:

- Improve of the performance of workers assembling cardboard box inserts; improvement of their income was a resulting impact.
- Improvement of the quality of work environments for the severely handicapped via assistance in the completion of tasks assigned was another impact.

TECHNICAL DESCRIPTION

Some of the workers at New Horizons are given the task of folding boxes for a local computer manufacturer. The unfolded box is of a fairly complicated shape, as seen in Figure 15.10.

The final assembled box may be seen in Figure 15.11.

The final device consisted of a combination of a folding device, here shown as a section of plywood with metal bending points, a series of clips to hold the partially folded box structure during various of the steps involved in the folding process, and a laptop computer with a series of graphics, which when initiated, showed the worker the next folding stage to try to achieve. The prototype device (prior to cleaning up and painting) is shown in Figure 15.12.

Fig. 15.10. Unfolded box.

Fig. 15.11. Folded box.

The device was tried by the students, then taken to New Horizons

http://www.newhorizonscorp.com/

and used by three of their workers. Improvements in assembly speed were documented in two of three workers; the third was one of the few already proficient workers.

The cost of materials for the prototype is approximately $50. The computer system is a retired Vanderbilt laptop system, the system was donated to this project and New Horizons.

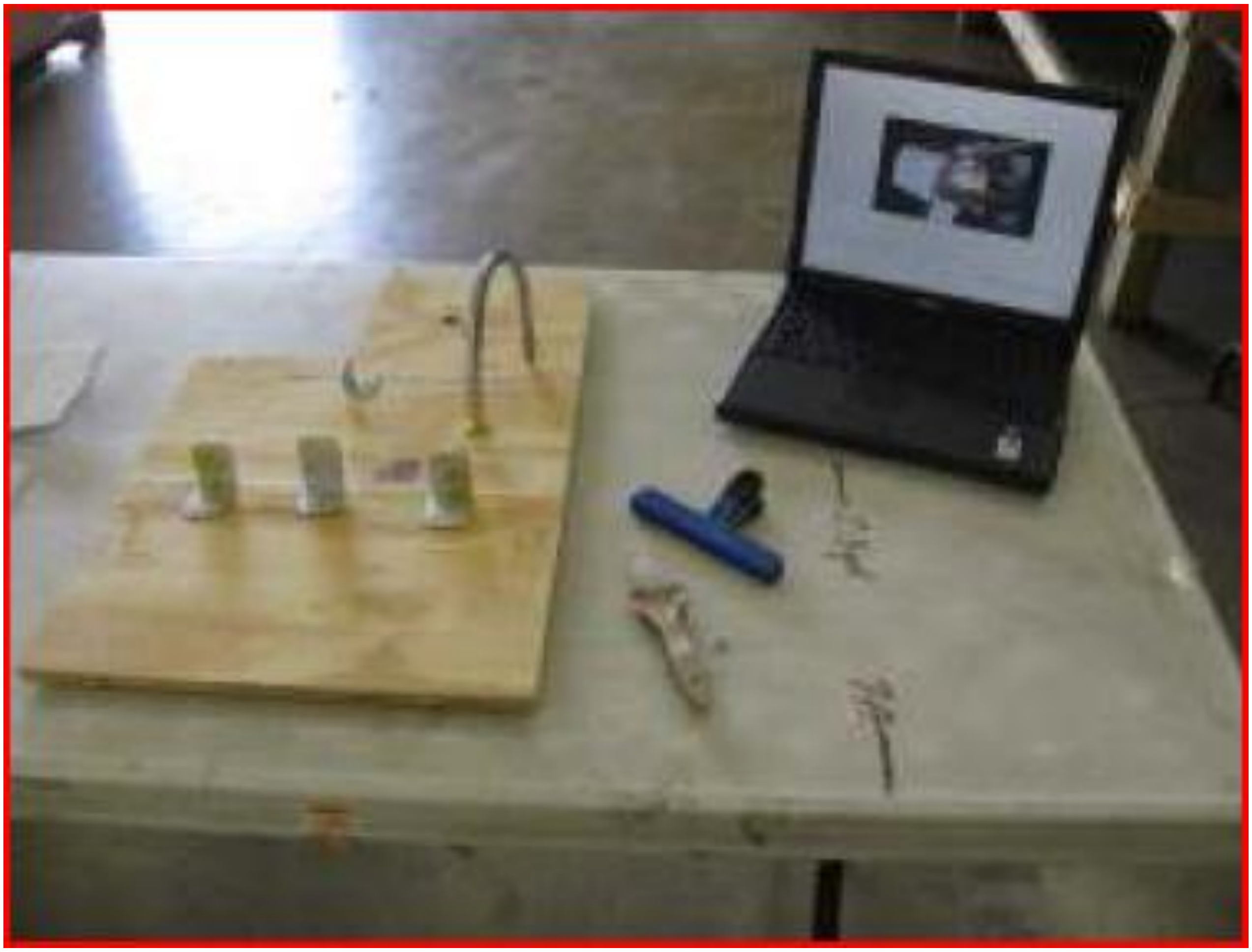

Fig. 15.12. Prototype folding device on left, clips and computer system on right.

WALKER REDESIGN

Designers: Tanya Holubiak, Jordan Landreth, Sam Barclay
Supervisor: Teresa Plummer, OT, Vanderbilt University., Nashville TN
Instructor: Paul H. King, PhD, PE, Vanderbilt University

INTRODUCTION

Current walker designs do not account for the fact that individuals need to go up and down stairs. When trying to navigate stairs, these walkers have to be carefully positioned. However, walkers are often too wide to fit on a single step. Stability is the key when trying to ascend and descend stairs, and current walkers are very unstable. Also, using a walker in this manner requires the use of a handrail and often there are not hand rails on stairs, which further takes away from stability. As a result, individuals who use walkers feel dependent on individuals to aid them in climbing stairs. This feeling of dependence may hinder and individual's progress in rehabilitation.

SUMMARY OF IMPACT

If walkers can be redesigned such that users may safely ascend and descend stairs, the quality of life for walker users may be enhanced. Further, as the need for elevators may be diminished with a successful solution, patient mobility and overall health may be improved. No similar products are generally available, though there are over 6 million people per year who use walkers. This work represents a first attempt at a solution. This project will remain on the list of potential projects for next years' design classes.

TECHNICAL SOLUTION

The final prototype developed by this team involved the development of a walker with an adjustable parallel column for the back legs of a standard walker's back legs, such that these legs may be extended. To keep the legs in place during normal or stair mode the device utilized a hook-locking system, with a hand brake lever system to attach/detach the detents. Industrial springs are used to power the extension of the legs when released.

A photograph of one mode of ascending stairs with current technology is shown in Figure 15.13. A proposed method, using the above technology, for descending stairs is shown in Figure 15.14.

Costs for the prototype are approximately $200 in parts, including a standard walker from Ed Medical.

Fig. 15.13. One method of ascending stairs with a walker.

Fig. 15.14. Walker with extended legs for descent.