CHAPTER 2
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A Pillow Unit Designed to Encourage Head Extension Exercise

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INTRODUCTION

An exercise pillow was designed and built with the purpose of exercising and strengthening the neck muscles for a certain teenage boy who has Cerebral palsy. This individual has difficulty holding his head in an upright position for any significant length of time. His weak neck musculature poses a problem because his main method of communication is a speak and spell type machine that he activates using an infrared emitter that is placed on a baseball cap on his head. It is not uncommon for his head to drop forward in exhaustion in the middle of a sentence. This individual also enjoys watching television, especially sports. He watches television while laying on his back on the floor.

The goal of this project was to design an exercise pillow unit that could be placed under his head while he watch's television. Upon hearing a trigger (e.g., once every 10 min.), the young man would be required to produce a designated force on the pillow within a designated time period (e.g., within 15 sec.). Ideally, the times that could be chosen would be variable to meet any changing needs over time (e.g., set by either the person's parents or his physical therapist). Additionally, the head extension force required during the exercise period would also be variable and could be changed by manual adjustment. If he was to fail to depress the pillow with required force before the designated time had expired, the television would be shut off (e.g., by a microprocessor that controls an infrared remote control unit). The television may be turned on again by depressing the pillow the required distance.

SUMMARY OF IMPACT

This pillow was designed to encourage the young man to exercise his neck extensor musculature. It also was designed to allow flexibility with regard to the required force and the relevant time intervals. Thus, it serves as an integral part of his physical therapy program, and can be modified by his therapist. However, it also provides a way for him to control his environment by turning the television off and on. As such, this device also benefits his primary care-givers, his parents.

TECHNICAL DESCRIPTION

This project consists of two main parts: i) design of the pillow which provides mechanical resistance for the patient to push against, and ii) design of the electrical controller, which provides a timer and triggers the remote control for the television.

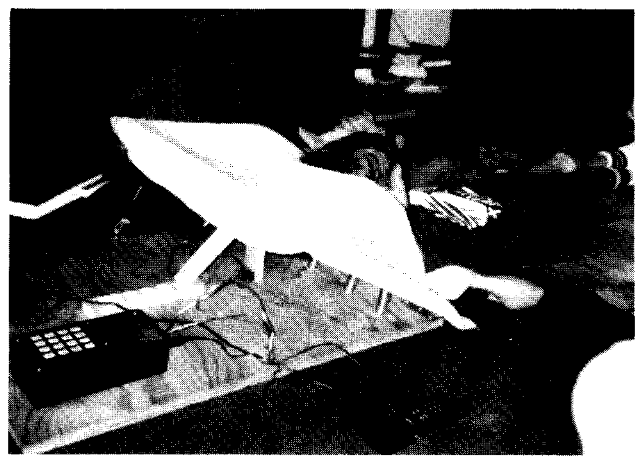

Fig. 2.1. Device to Encourage Head Extension Exercise.

Several different designs were considered for the pillow; the one that was implemented was chosen for its simplicity and user friendliness as shown in Figure 2.1. The frame for the pillow was constructed with two pieces of 3/4" plywood. The base, of dimension 2/5' x 2.0', lies flat on the floor. A top piece, 1.5' x 2.0', is hinged to the front edge of the base. Ten 3/4" diameter holes are drilled with even spacing across the width of the boards. The holes are in a line 4" from the hinges. Five of the holes are found on the top of the base board and five on the underside of the top board. When the boards are folded together, the 1/4" deep holes are directly on top of each other. Each set of holes houses a spring. The five springs offer the resistance to head extension. Each spring is 3/4" in diameter, 3 1/4" long, and has a spring constant of approximately 10 lbs./in. The springs are placed back four inches from the hinged joint between the two boards. This location was chosen because it made the boards rest at a comfortable angle for the patient's head. When the springs are in place between the two boards and no external force is applied to either board, there is about a 30 degree angle between the boards. These boards are also connected by a cable. This is to prevent the boards from opening so far that the springs would fall out. An eye-hook was inserted in each board. A cable runs through the eye-hooks and is clamped back on to itself at each end. The cable is prestressed to about 8 lbs., which prevents the top board from moving significantly due simply to the weight of the head. Instead, the head resting on the pillow just releases the tension in the cable (28 degree angle between the two boards).

Both the required force and the force-extension relation can be varied, the first by varying the required distance, the second by removing and adding springs (which are structurally arranged in parallel). A mechanism, consisting of two hinged links which form a triangle with the base board (see Figure 2.1), prevents the board from being depressed any further than is necessary. The end of the second link is placed in one of six stop slots that are also mounted on the bottom board. When the top board is depressed, it makes contact with the part of the mechanism where the two legs are hinged together. This prevents the board from being depressed any further. The stops are placed on the board such that the first stop prevents any downward motion of the board at all, the rest position. The position of each successive stops was calibrated to allow an additional vertical inch of depression, up to 5” total. The bottom of the baseboard has four rubber stoppers screwed into it. These stoppers prevent sliding of the pillow unit relative to the floor when it is in use. The top board is covered with terry cloth. A contoured foam pillow is placed beneath the cover which helps hold the head in the desired location, and provides a comfortable support for the head. The pillow and towel are prevented from sliding relative to each other by Velcro straps.

A timing component was needed to keep track of how often the pillow's user was exercising the neck muscles. There were several options considered: 1) a system using a dip switch; 2) a system using a ten-turn potentiometer; and 3) a microcomputer. The latter was chosen based on its potential for best meeting the needs of the parents and physical therapist with regards to ease of use and flexibility for modification.

The microcomputer uses a Motorola 68705 microprocessor. The assembly is a box placed at the back of the pillow that is about 7" long, 6” wide, and 2.5” high. This box houses a printed circuit (PC) board with the microprocessor and all of the other electronic components. The top of the box resembles the panel on a microwave oven. The only components that are visible from the outside of the box are a 16 key keypad and an LED display consisting of four digits (two on either side of a colon). The power switch on the remote control unit is controlled by the microprocessor. This switch is mounted to be triggered when the top board comes into contact with the prop. If not triggered within the designated time, the microprocessor sends a signal to the remote controller, turning the television off. To be turned back on, the pillow unit must be fully depressed. The remote control unit is powered by two AA batteries, while the rest of the electronic components are powered by a 9 V source which in turn is powered by line (120 V AC) power. Two piezo-beepers are among the components of the microcomputer. They are triggered in unison when an unacceptable time is entered into the keypad. One of them sounds when the pillow makes contact with the switch to let the user know that they have succeeded at their task and no longer need to push. The other sounds four seconds before the television is to be shut off, serving as a warning. The microcontroller is programmed in assembly language. A flow chart, schematic of the circuit, and the assembly code can be obtained from the authors (documented in Senior Design Project by Rice, 1991).

The total cost of this project was approximately $300, with the primary cost being the control unit.

Motorizing a Restorator for an M.S. Patient

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INTRODUCTION

The disabled individual was a 36 year old male with multiple sclerosis who also suffers from a prior head injury that reduces the mobility, strength and fine motor control of his limbs. He was contacted through an organization called Arizona's Bridge to Independent Living. He is highly motivated, and every morning goes to a gym for the physically challenged to work on his upper body, then every night uses his own equipment to keep a residual mobility and strength in his legs. He calls his home exercise equipment a restorator (Dakon, New York). However, because of spasticity and poor mechanical advantage, he often gets stuck at two locations in the pedal cycle. Consequently, a helper must be at his side to help him through each cycle. Unfortunately, helpers complain when he uses his restorator for 30 min. or more. The goal of this project was to motorize his apparatus and thus free up his helper to perform other tasks around the apartment. Additionally, he requested that the device not be bulky, be easily stowed out of the way, be battery-free, and have no unattached wires except the power cord.

SUMMARY OF IMPACT

The disabled individual, who is highly motivated, now has greater independence with regards to using his exercise bicycle. This has provided him with a higher level of independence and has minimized a prior source of frustration. Furthermore, this was done without adding significant bulk or wiring. The unit can easily be stored and reassembled by a helper, with the helper then free to perform other tasks.

TECHNICAL DESCRIPTION

Using a hand-held scale that was attached to the axle of the pedal and feedback from the disabled person, it was determined that the torque necessary to initiate and maintain cyclic pedaling was at most 36 in-lbs. A maximum design speed of 60 rpm's was also specified.

After a survey of available electomechanical motors, a 1/8 Hp DC permanent magnet gear motor that nominally runs at 60 rpm with a torque of 72 in-lbs. was chosen (part of Figure 2.2). A controller was chosen that provided an adjustable minimum and maximum speed, fuse and surge protection, on-off switch and power indicator light, IR compensation, torque limit, filtered input, dynamic braking, and both forward and reverse directions. All of these features were desirable except dynamic braking. This was effectively disabled by replacing a 3 ohm resistor with a resistor on the order of MΩ; the motor now coasts for 1/4 of a cycle when the brake switch is thrown.

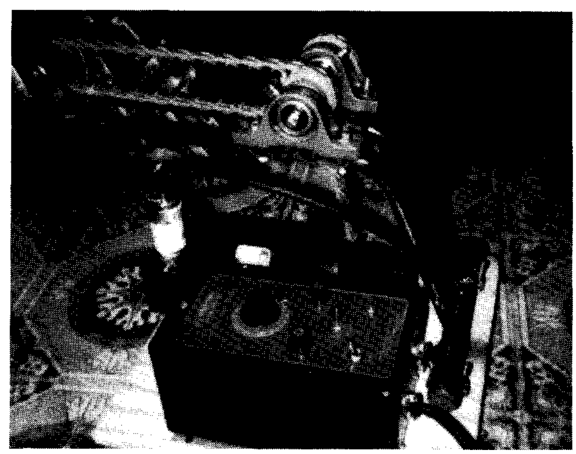

Fig. 2.2. Close-up view of Motorized Exercise Equipment for an MS. Patient.

To couple the motor to the exercise unit, the assembly providing (unwanted) resistance to cycling was replaced by a pulley. This allowed the gear motor to be coupled (via a belt connected to the pulley) with minimal potential for interference (Figure 2.2). After a few iterations between the designer and the disabled individual regarding how to mount the unit (various designs provided in Senior Design project by Anderson, 1990), the design strategy shown in Figure 2.3 was chosen. (This represented a classic case of the disabled person playing an active role in the design process.) Notice that the motor and controller are mounted on a board, that the pulley replaced the friction apparatus, and that the idler shaft was used to correct misalignment of the belt. With this design, the motor belt could be easily placed on the motor and idler shaft, with the other end of the restorator raised and attached to the chair. These components can then be stored separately when not in use.

The total cost for modifications necessary for this project was about $250, with the DC motor being the most costly item.

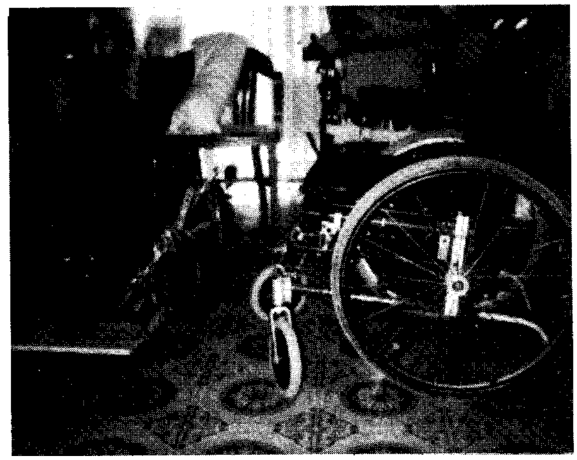

Fig. 2.3. Motorized Exercise Equipment for an M.S. Patient.

A Walker and a Seat in One

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INTRODUCTION

Most commercially-available walkers are designed to enhance mobility among the disabled population by providing a movable, stable, supporting structure. Walkers provide for balance recovery and/or compensate for weak lower-extremity musculature by enabling the upper extremity to exert stabilizing and propulsive forces on the ground. For practical reasons, the basal area of support which governs stability is typically limited by societal conventions (e.g., size of doorways, aisle-ways, etc.), whereas the weight of these walkers is usually minimized for reasons of energetics and ease of use. This describes a walker designed for a different purpose, namely to provide support for ambulation over a small area (e.g., the interior of the home or the classroom) and to encourage a stable, semi-erect, hands-free posture suitable for performing stationary tasks requiring the use of one or both hands (e.g., washing dishes, writing at the blackboard, etc.). The goals for such a device are therefore different from those addressed by typical walker designs. The advantage of the modified walker over a wheelchair is that the user's center of gravity is projected higher and further forward providing an extended forward reach for effective use at chalkboards, counters, sinks, workbenches, tools, and the like.

SUMMARY OF IMPACT

The modified walker allows the physically-challenged adult or child to participate in activities and exercises that would otherwise be difficult or impossible to perform using a standard walker or wheelchair. It enables a semi-erect, stable, kneeling posture by which the user's weight is supported by the feet, the knees, and the buttocks via padded, swing-away supports at the knees and seat. In this design, the addition of a seat does not dangerously unstablize the modified walker, as would happen if a seat were simply added to an existing walker. It is expected that the modified walker will be of greatest use in locations that the user regularly frequents, because the hardware required makes the walker relatively heavy compared to walkers utilized primarily for mobility.

Candidates for the modified walker must have good bone strength in the lower extremity, and gross motor coordination in both arms to operate the chair safely and effectively. The ability to sit upright is also desirable, though special padded supports could be custom-designed to augment residual trunk control. The modified walker could be used in conjunction with a standard walker or wheelchair.

Fig. 2.4. A Combination Walker and Seat.

Wheelchair users may also realize some benefits from the upright postures encouraged by the modified walker.

TECHNICAL DESCRIPTION

The modified walker was initially designed for a Cerebral-palsied girl who could not stand without the use of some support and pulled a standard walker backward to “run” and “walk”. As the subject moved out of state before the walker could be finished, it was adapted for a Cerebral-palsied boy, though the boy had less functional control of his trunk. Consequently, he required some help in holding his trunk upright and would have benefited from additional trunk supports (Figure 2.4).

One-half inch electrical conduit was used as the frame of the walker because it is fairly easy to form. The angles of the front and rear walker legs were determined to provide a large basal area of support, once the height of the walker and the position of the seat and knee rests were established. Fore-aft stability was evaluated by computing the center of mass of the user/walker system in two user configurations, leaning as far forward as possible and as far backward as possible. The system’s center of mass remained inside the base of support for these two configurations, and for reasonably large “leans” to the side. Wooden dowels filed, epoxied, and hammered into the conduit served as screw anchors for the joints in this prototype; welded construction would be preferable in a commercial application of this design.

When the walker is used as a mobility aid, the contoured wooden seat is locked in a vertical orientation. Kneerests are also locked in a posteriorly-pointing position (out of the way) during use in this mode. When the user wishes to use the system as a stationary support device, the seat is swiveled about a fixed horizontal hinge into a resting position, which is canted forward 22 degrees below horizontal to discourage the user from leaning backward excessively. The person then backs into the device, reaches down, and rotates the kneerests externally by 90 degrees to prepare them for load acceptance.

The kneerests were made from wheelchair footplates and spring-loaded hinges, arranged so that the orientations of the kneerests about a horizontal axis adjusted automatically to best support the loads borne by the anterior tibia and knee. A commercial device utilizing these principles should be constructed more rigidly, particularly at the joints, and should be made of durable, lightweight materials. An aluminum frame, molded plastic seat, and well-padded aluminum or graphite kneerests should be incorporated. Adjustability of the device would also be desirable, though provisions must be made to insure that unstable postures would not be easily attainable for a user of a given stature.

Materials and supplies for the walker/seat unit totaled approximately $70. A high-quality, customized, tubular aluminum frame with welded construction is estimated to require $300 to construct.

Fig. 2.5. Modified Walker and Seat.

Knee Brace Modifications

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INTRODUCTION

A Don Joy Combined-Instability functional knee brace was modified to rectify the following functional limitations of the existing Velcro straps as recognized by the wearer.

- Donning the brace was awkward and time-consuming due to the requirement to loop the Velcro straps through slots in the aluminum stays.
- Tightening the straps was difficult due to friction in the slots.
- The tightening procedure usually shifted the position of the brace, which then had to be readjusted.
- The thickness of the straps, in addition to an underlying 1/8" neoprene sleeve, restricted the range of knee flexion by over 30 degrees because of interference between the posterior straps just above and below the joint.

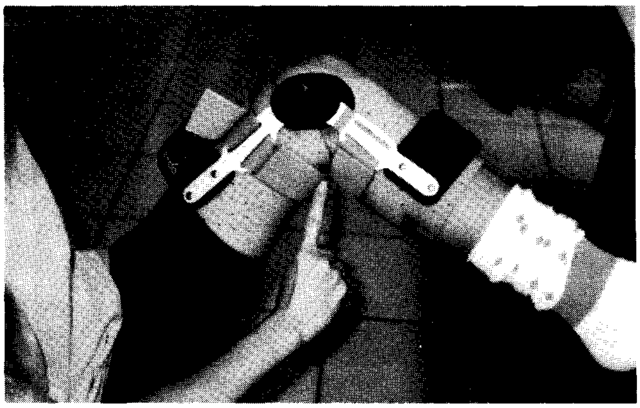

Fig. 2.6. Application of the Brace.

SUMMARY OF IMPACT

Cable-tightening systems similar to the design described here promise to provide brace-wearers with a more convenient, more functional way of tightening the knee braces. This should work to increase the usage of kneebraces among the population of disabled and able-bodied individuals who utilize them. For similar reasons, some principles developed here could also be applied to the design of tight-fitting, easy-to-don orthotics, possibly with immediate applications to the design of ankle-foot orthoses, knee-ankle-foot orthoses, and long-legged braces.

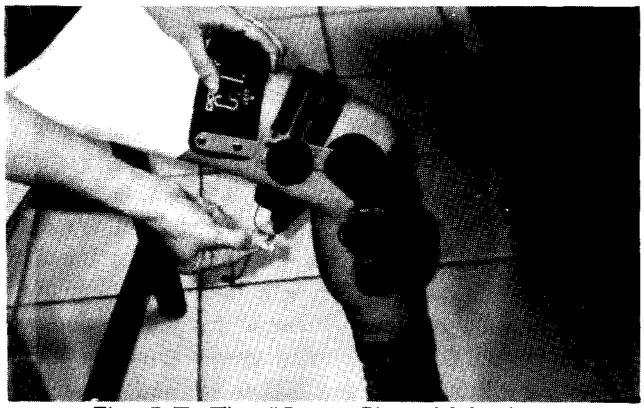

Fig. 2.7 The "Open-Close" Mechanism.

TECHNICAL DESCRIPTION

The overall design can be broken down into three functional components: the tightening mechanism, the straps, and the housing which provides interconnection and adaptation to the brace.

Tightening Mechanism. A commercially-available device for tightening 1/16" steel cable (from the Salomon ski boot; cost approximately $10 each) was utilized that met the requirements of adjustability, compactness, weight, and utility. The Salomon device is actually a simple lever which utilizes its lower end **as** its fulcrum. The cable to be tightened is attached between the upper and lower ends. Cable release is performed by pushing the upper end down and freeing the keyed lower end from its socket, which effectively detaches the device from everything but the cable. Cable tightening is performed in reverse, and is greatly facilitated by the mechanical advantage provided by the levering mechanism. Adjustability is provided by a 7/8" diameter knurled knob directly attached to a 1/4" screw, which acts like a worm-gear to pull a cable loop. The adjustment screw and cable attachment were self-contained within the levering device. The use of the commercially-available device simplified the construction of the tightening mechanism, but necessitated the custom design of a suitable housing for it.

Housing. Rigidly mounted to the aluminum uprights of the brace, the housing securely holds the tightening mechanism and provides a pathway for the tightening cables. This piece was machined from a piece of solid PVC, and allows the tightening mechanism to be operated just like in the Salomon ski boot. A slot at the bottom of the housing accepts the tab at the fulcrum (lower) end of the Salomon part. Another slot at the upper end was machined to lock the lever in place once the brace was tightened securely; locking was accomplished via a simple press-fit.

Straps. The overall goal of keeping the posterior straps thin (no thicker than 5/16") to reduce strap interference during knee flexion was met using a three-layer configuration consisting of a cable loop (on the exterior), 1/16" thick polyethylene straps, and dense foam (against the skin). These straps served to distribute the load from the cables to the skin surface well, and furthermore were hinged to allow the brace to be put on or taken off without requiring the tension setting to be changed. Nylon cable guides affixed to the polyethylene define the cable pathway on the posterior side of the brace. For the anterior straps, another layer of dense foam was used to cover the exterior surface of the polyethylene. Cable pathways on the anterior straps were then cut out of the foam. The cable itself was doubled and swaged to form a narrow loop, one end of which was permanently attached on the medial side of the knee brace to a cable guiding/locking fixture machined from a 2"-diameter, 1/2"-thick disk of PVC. The other end of the cable, disconnected for easy brace removal, is guided through slots cut in the disk and wrapped about the anterior side of the disk in a bollard arrangement

The cost of modifying the knee brace was approximately $100.

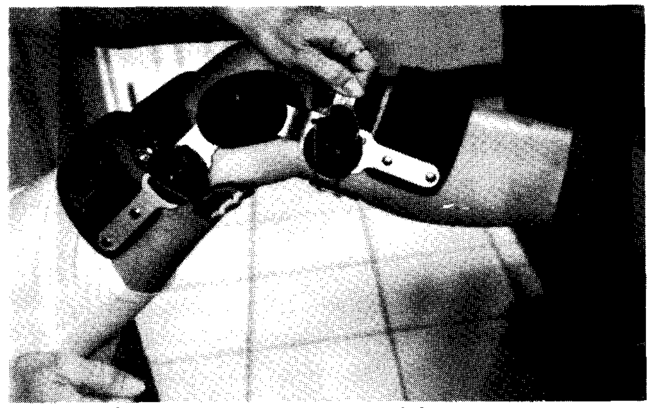

Fig. 2.8. Straps open/close.

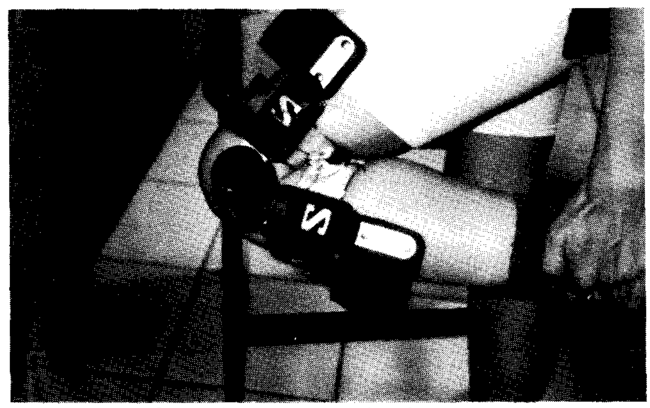

Fig. 2.9. Increased flexion.