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DESIGN OF A STAND-UP MOBILITY DEVICE UTILIZING A HARNESS SUPPORT

by

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Submitted to the Department of Mechanical Engineering in Partial Fulfillment of the Requirements for the Degree of

Bachelor of Science

at the

Massachusetts Institute of Technology

May 1994

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Abstract

The Stand-Up Mobility Device for Paraplegics is an aid that helps disabled people to stand. The device consists of a harness suspended upon a U-shaped frame mounted upon a pneumatic cylinder which set on a five-legged wheel base. The user is supported by the harness. His feet are secured in footrests fixed upon a bar six inches above the ground. The device is propelled by pushing with modified four prong canes. A pneumatic cylinder vertically displaces the harness seat by 12 inches when activated.

The device allows the user a greater degree of physical freedom when at the raised level. The user is able to perform tasks that are difficult from the seated level, such as reaching a high shelf. Increased confidence in physical abilities is psychological benefit obtained from this device.

Thesis Supervisor: Ernesto Blanco
Title: Adjunct Professor of Mechanical Engineering

Acknowledgements

I wish to thank Professor Ernesto Blanco for his ideas and guidance in this project, as well as Joseph "Tiny" Calogerro and the mechanical engineering lab staff members. I also wish to thank those who assisted with this project, including those who tested it and gave me a new perspective as to where the design should go.

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Chapter 1

Introduction

1.1 Background

There is a continually growing number of people in our country that require the assistance of wheelchairs and other such mobility aids to move about. Wheelchairs have been available since the last century, but recently the combination of better technology and a greater sensitivity to the handicapped peoples' needs have led to a wider range of mobility aids to suit different purposes, and increased mobility and comfort in them. Some of these mobility aids are used for specialized purposes, such as sports.

Spending one's life at the seated level can make some tasks difficult to accomplish. The seated person is unable to perform tasks that necessitate reaching high areas, such as writing on a chalkboard or grabbing items from a high shelf. There are also psychological problems that occur from being in a wheelchair. To carry on a conversation a with a standing person, one must continually look up. Also, the fact that many tasks are impossible to accomplish from a seated position gives the feeling of being confined to only what the mobility aid is capable of doing, not the person.

1.2 Project Description

The "Stand-Up Mobility Device for Paraplegics" is designed to increase the comfort and mobility of the user, while giving him or her the option to be at the standing level of unimpaired people. The basic concept of the device is to enable the user to be mobile and comfortable, while allowing the user to raise and lower himself into a position that allows him to perform tasks at the height of standing people. The mobility device is propelled manually by two four pronged canes, similar to the style of cross country skiing.

In the original design, a mountain bike seat had been used with lumbar support (Plummer). The second design of the "Stand-Up Device for Paraplegics" involved an improvement in the suspension used in the first prototype by introducing spring loaded casters. It also introduced a saddle seat type of design, form fitted to the user's body. In each, the seat design was mounted upon a pneumatic cylinder that raised and lowered the user.

The goal of the project was to design and construct a different style of support for the user of the mobility aid. This project involved the addition of a harness style support in place of the seated styles used in previous projects. The harness style allows the users legs to be free and that gives more of a standing up effect when the device is in the raised position. The harness is mounted upon a U-shaped supported. In addition, the footrests were redesigned and mounted upon the existing wheelbase. These footrests offered more leg support than the original footrest designs. Also, a portable air supply was lacking from the original prototypes. This made actual use of the device impossible when away from a fixed air supply. A portable air supply was chosen that could be mounted to the device and transported easily.

An analysis of the project was made. This design was tested, and compared to the original prototypes. An evaluation of the possible designs, and improvements have been suggested. In addition possibilities for other designs have been included.

Chapter 2

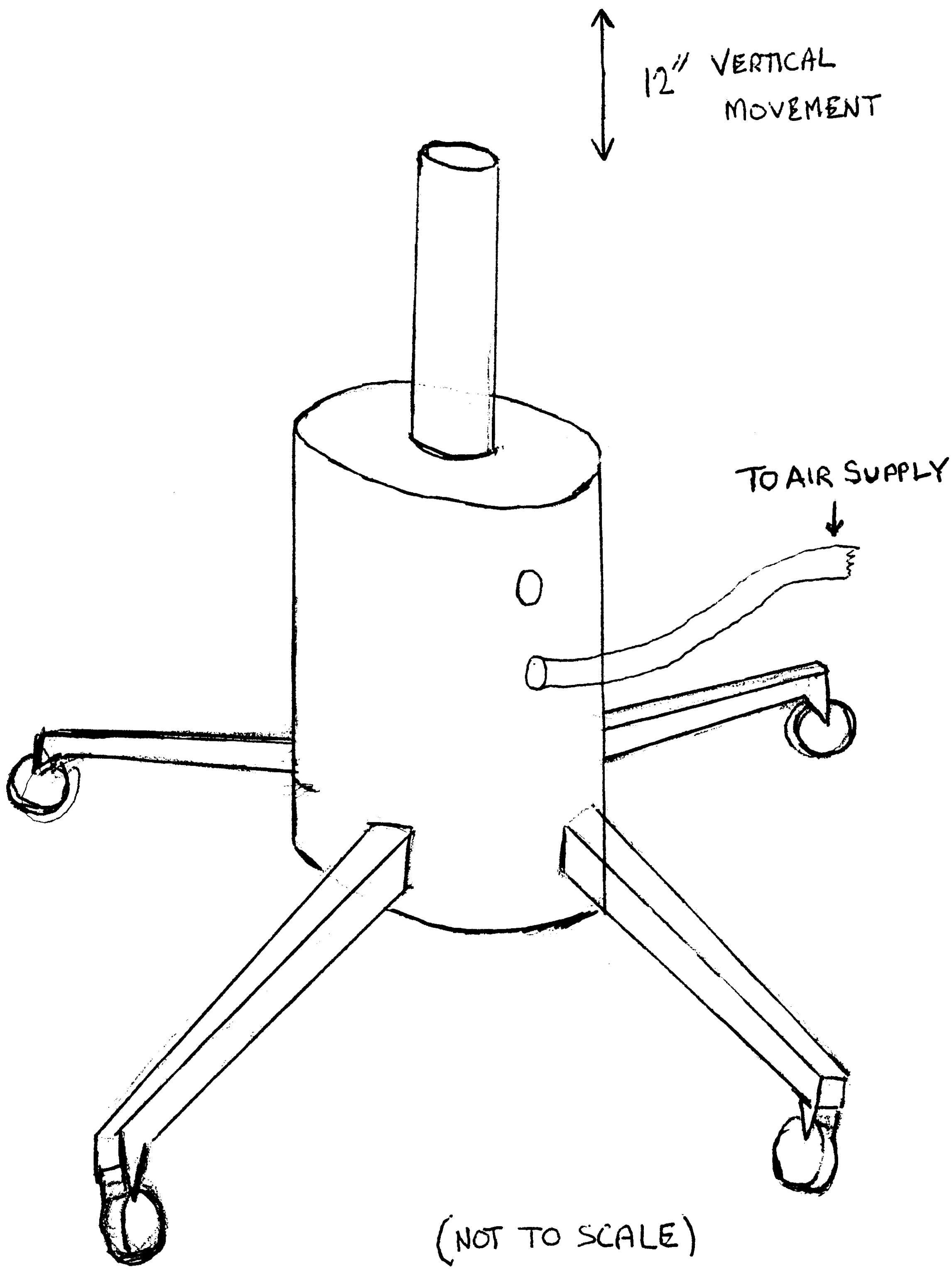
Prototype Designs

2.1 Basic Concept

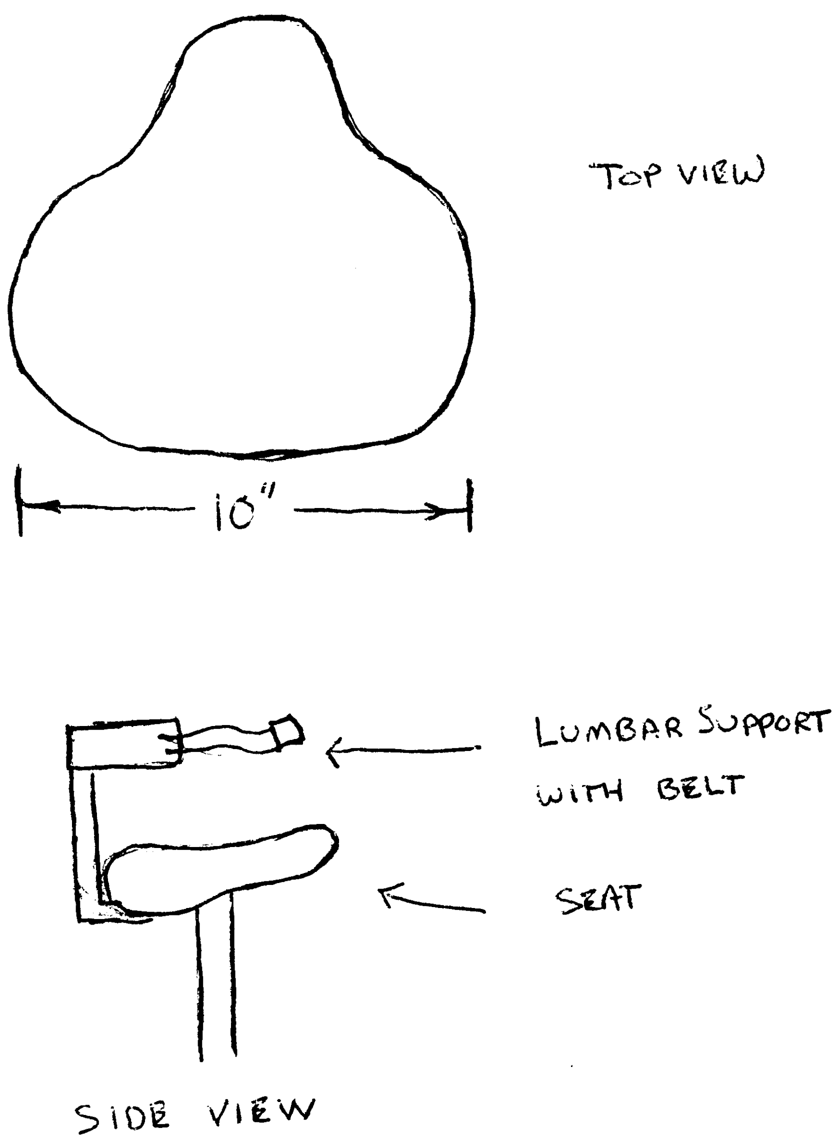
This mobility aid consists of a five pronged wheel base, similar to that of a desk chair. The wheels are castered in order to allow easy movement in all directions. On top of this base a pneumatic cylinder is mounted. This is connected to an air supply which causes the cylinder to extend and raise the user to standing height. The user is supported by different means, in the case of this design a harness was used. In other designs, some sort of seat was used. An illustration of the wheel base is shown in Figure 2.1-1.

2.2 Preliminary Designs

The original design of the "Stand-Up Device for Paraplegics" was created by Penny Plummer. The seat design in this case consisted of a bicycle seat with a lumbar support. The design can be seen in Figure 2.2-1 This design was adequate for those with limbs that were able to bear some weight. The



2.1-1 Stand-Up Mobility Device Wheelbase

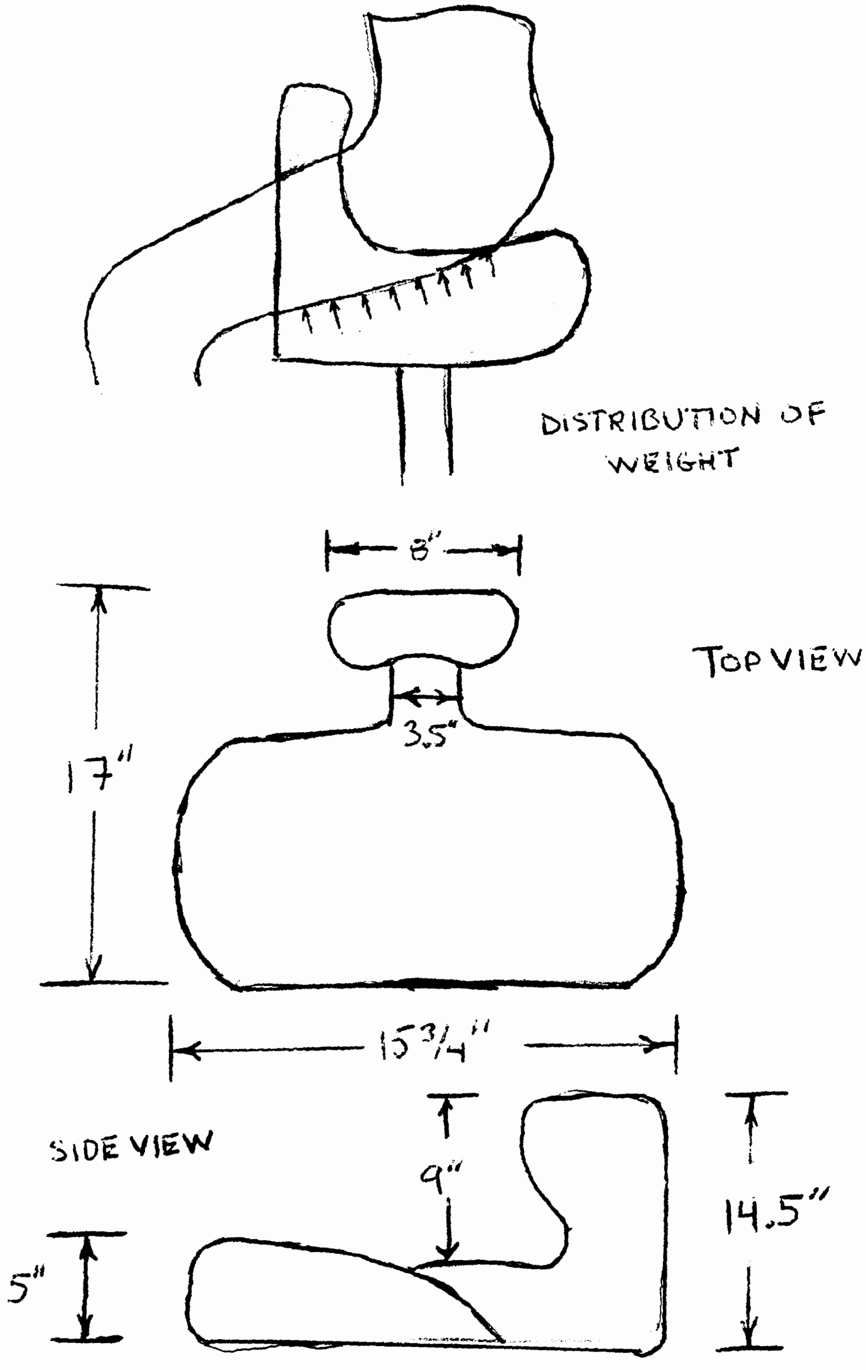


2.2-1 Bicycle Seat with Lumbar Support

lumbar support was basically a back brace with a belt to prevent the user from falling off. The problem with this design was that the weight was not well distributed. All of the weight support was in the buttocks. If the user had legs that could support some amount of weight, then this would have been a more effective design. Also, the sharp angles in the mountain bike seat combined with bad weight distribution caused pressure sore after extended use.

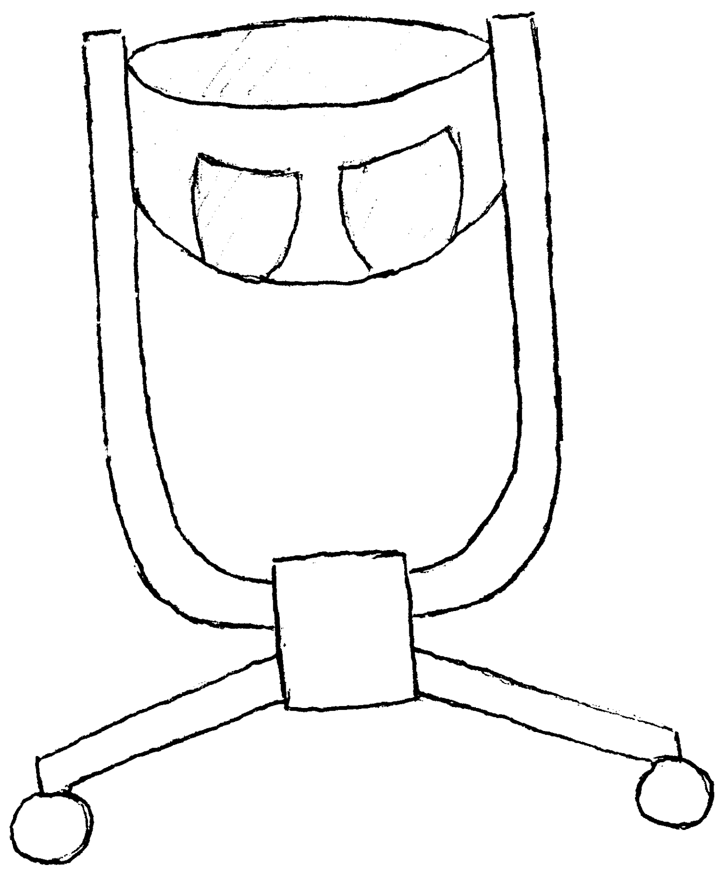
The saddle seat design, shown in Figure 2.2-2, was created to address the pressure point and weight distribution problems found in the mountain bike seat (Au, pp. 8-9). The saddle seat was built similar to the form of a large horse saddle. This offered weight distribution over the thighs and the buttocks, instead of solely in the buttocks. It also used a frontal support to prevent the user from falling off. The saddle was tilted forward with a wide piece in front to support the users chest. This created a large, cumbersome saddle that gave better support, but also drew attention to the user's handicap.

The harness design was created to give the user full support through the buttocks and thighs, while not attracting unnecessary attention to the user's disability. By analyzing the ergonomics of the human body and researching various methods of harness support a design was created. The basic design is a harness system slung in between four posts.



2.2-2 Saddle Seat Design

The advantage of this design is the full body support offered and that it can be supported for long periods of time in this position. The harness supports the full body weight with no exertion by the users body. It also allows the user's legs to dangle when in the raised position, giving the effect of standing up. In the other two designs, the motion of the legs was constrained by the geometry of the seats themselves. In this design there is no seat because the weight is distributed over flexible straps. An illustration of this concept is shown in Figure 2.2-3.



2.2-3 Harness Support Concept

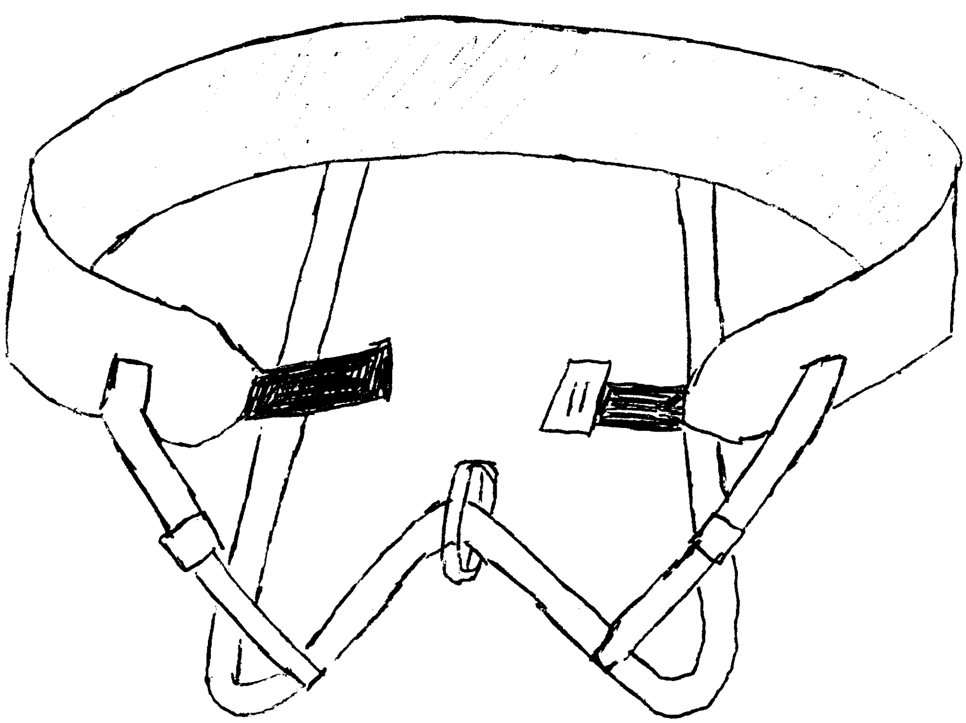
Chapter 3

Final Design

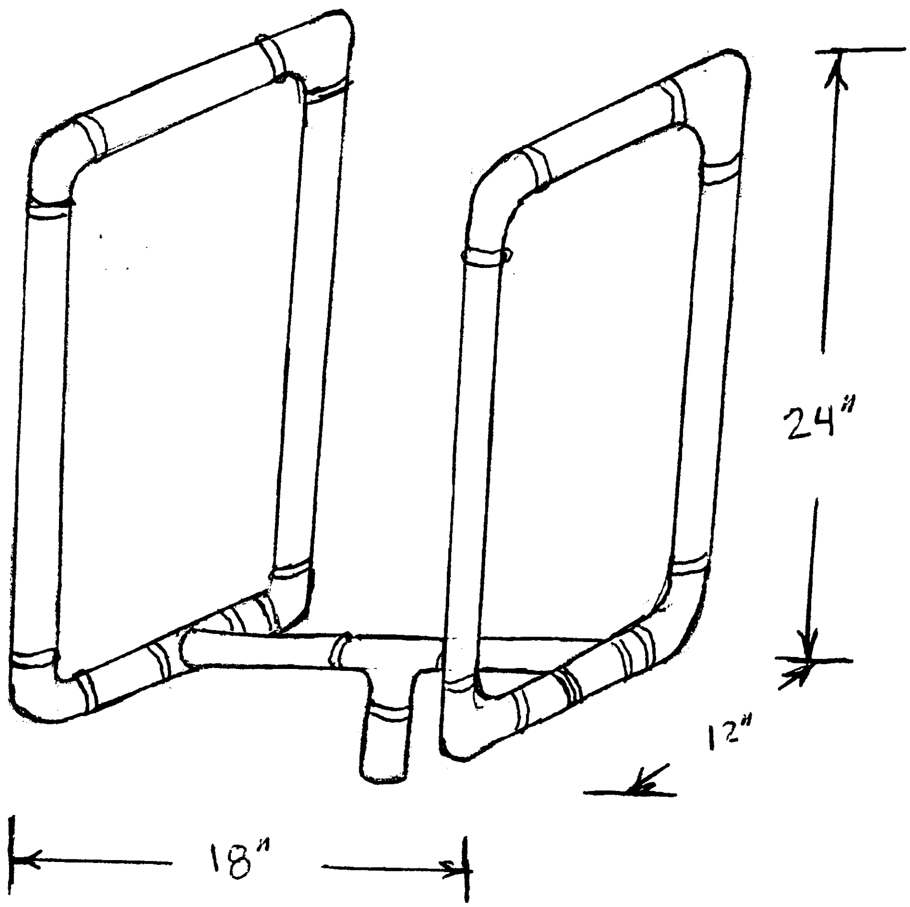
3.1 The Harness Support System

The mountain bike seat and the saddle seat were rejected and the harness support system was utilized because of its better ergonomic design and aesthetics. The harness was designed by examining harnesses that were used in rock climbing. An example of such a harness is shown in Figure 3.1-1. Although rock climbing harnesses are constructed to support weight on rope that is attached to its front, the it was fairly to adapt it support weight on four symmetrical points around its belt. A rock climbing harness is very good for this purpose because it is design to hold people of varying heights and weights for extended periods of time. The webbing of the belts should be padded to insure against chafing, pressure sores and constriction. Also the harness used was fully adjustable for people of almost any size. The harness used was a swami style, which means it straps onto the legs thereby eliminating the need to step in and out of the harness.

The harness was mounted upon a U- shaped frame that was created from four posts. An illustration of this concept can be found in Figure 3.1-2. In the prototype the posts were



3.1-1 Rock Climbing Harness



3.1-2 U-Shaped Frame Design

constructed from one half inch steel pipe. The frame was built to a fixed height to accommodate a person of my size, 5 feet 10 inches, comfortably. This height would work for anyone 5'10" and below. The height was determined by locating the tops of the posts 3 to 4 inches below the armpits. This was done in order to keep the arms free to propel the device with the four-pronged canes. The width of the U-shaped frame was determined to be slightly larger than the widest point of the torso, in this case the chest. By keeping the frame close to the body, it also allowed the arms to be free. The four posts were connected in pairs of twos across the tops on the sides. This created more stability in each side of the frame, and also gave the user a place to support himself while mounting and dismounting the harness support.

3.2 The Improved Footrest

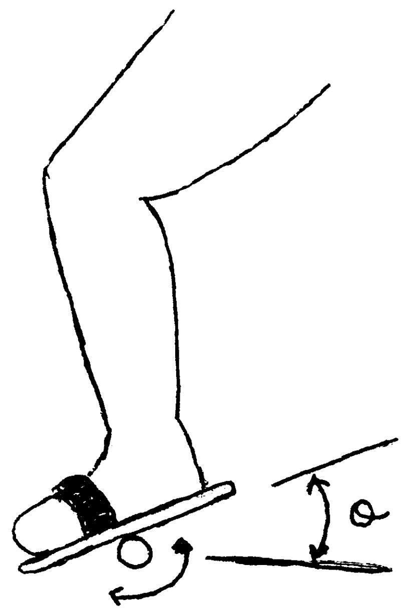
In the original design no actual footrest was created to test, but a design for one was detailed. The design consisted of a plate that rotated about a bar six inches above the floor. The foot was pointed downward and allowed the foot to rotate slightly as the legs changed position. The foot was secured in place with a velcro strap. An illustration of it is shown in Figure 3.2-1.

The improved footrest design was based upon that of conventional wheelchairs. In the original footrest the toes were pointed down and this caused most of the leg weight to be supported by the top of the foot resting in the velcro strap. By creating an angle that pointed slightly upwards, the weight of the legs was supported by the soles of the feet. A strap was placed between two small posts for the heels of the user to rest in. This kept the foot from sliding back off of the rest and also gave some lateral restraint. The base of the footrest was coated with slip-proof rubber in order to insure traction and prevent slipping.

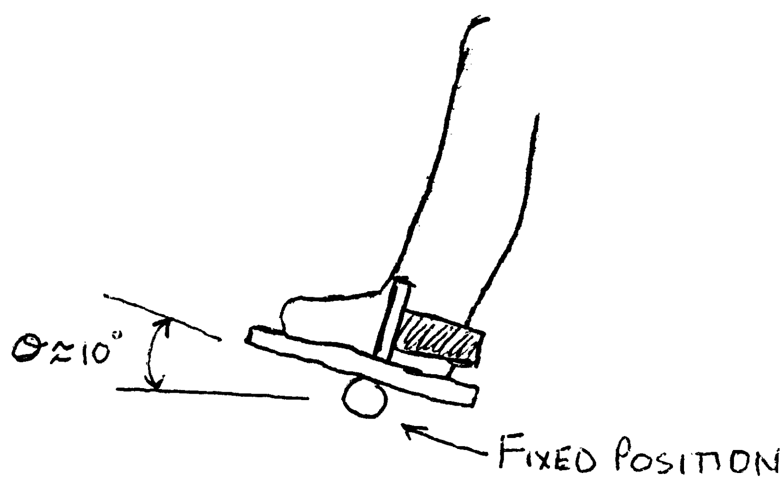
The footrest was placed upon a bar approximately six inches from the ground. It was unnecessary to create a footrest that rotated in this case, so the footrest was placed in a fixed position. The footrest was welded in place to insure a strong bond. An illustration of the improved footrest is shown in Figure 3.2-2

3.3 Portable Air Supply

In order to make the mobility device easy to use, some sort of air supply must be found that is portable. In the



3.2-1 Original Footrest Design



3.2-2 Improved Footrest Design

laboratory, the air supply used to activate the pneumatic cylinder came from a fixed tank. For convenient use of the mobility device, the air supply must come from a portable tank.

The requirements for the air supply were as follows:

1) Conveniently portable
2) Able to be mounted upon chair
3) Capable of repeated use before recharging
4) Capable of producing pressures between 40 psig and 80 psig (for people 120 lbs to 250 lbs) (Plummer pp19)

By researching various forms of pressurized air containers a suitable tank was found. An emergency air supply for SCUBA diving, better known as a 'pony bottle', is a hand held breathing device. The tank is one foot to one and one half feet long and roughly six inches in diameter. These tanks are mounted upon the sides of regular SCUBA tanks. In the event of an air supply emergency, these tanks can be removed and will supply the diver with five to ten minutes of air. The pressure in these tanks is roughly 1500 to 2000 psig, and the air flow is easily controlled with a regulator (Walsh).

This type of tank meets all of the above requirement. It is of reasonable size and has enough air to be used numerous times. It is also easily rechargable at a local dive store. Since it was created to be mounted upon a SCUBA tank, it can easily be mounted upon the side of the wheel base. The cost of the tank is in the range of $150 to $250. Due to the lack of funding, it was impossible to obtain and mount such a tank and test it out.

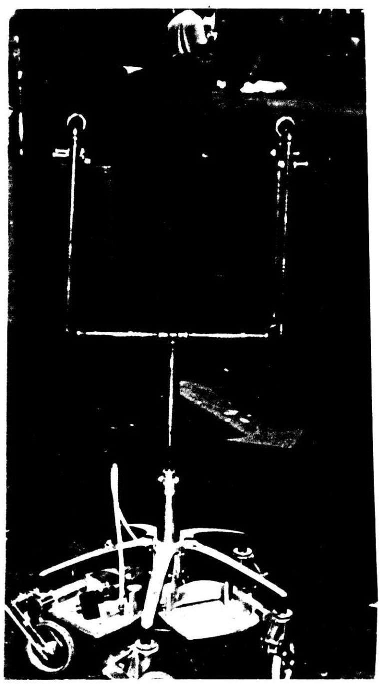
Chapter 4

Prototype Construction

4.1 U-shaped Frame

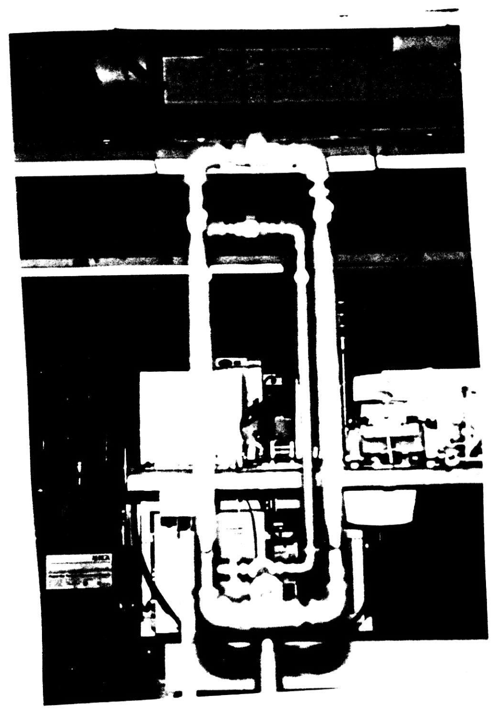
At the start of this project, a prototype of the Stand-Up Mobility Device for Paraplegics had already been constructed. It consisted of a wheelbase with spring loaded caster wheels and a pneumatic cylinder within the base. Two different seats had been also constructed, a mountain bike seat with lumbar support (Plummer) and a saddle seat (Au). For the prototype of the harness support system, the wheel base and pneumatic cylinder were utilized from the previous projects.

The U-shaped frame was constructed using 1/2" steel pipe. Steel pipe was chosen for the prototype because of its strength, price, and it is easy to work with. The frame in the prototype was designed for a person with a height around 5' 10". The pipes had to be individually cut and threaded and put together to form the U- frame. Bolts were placed in the top four corners so that the harness may be suspended in the frame. A transition piece of pipe had to be lathed down in order to fit the U-shaped frame onto the pneumatic cylinder piston. In the actual production model, four sturdy, telescoping posts would be used to accommodate users of all heights. Telescoping posts could not be made because of a lack of resources. A front, side, and top view of the U-shaped frame are shown in Figures 4.1-1 through 4.1-3.



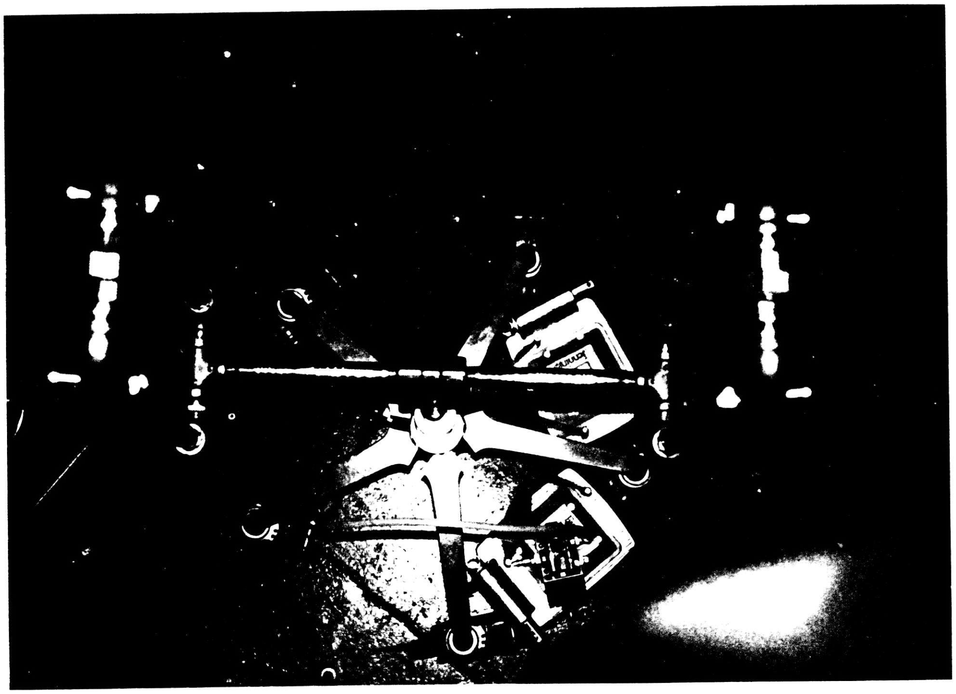
4.1-1 U-Shaped Frame

(Front View)



4.1-2 U-Shaped Frame

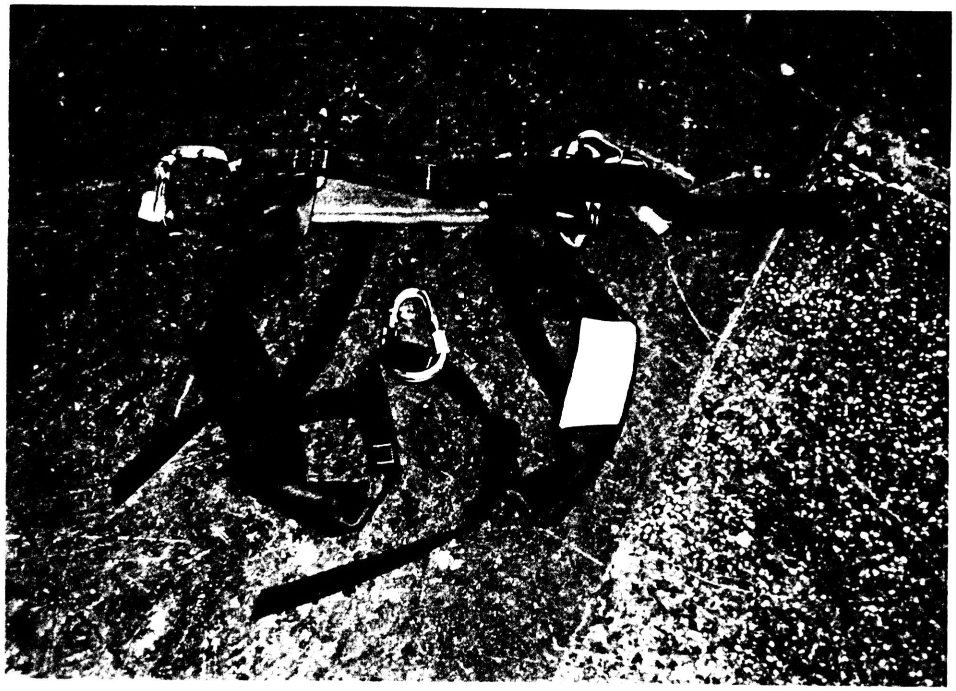
(Side View)



4.1-3 U-Shaped Frame (Top View)

4.2 The Harness Support

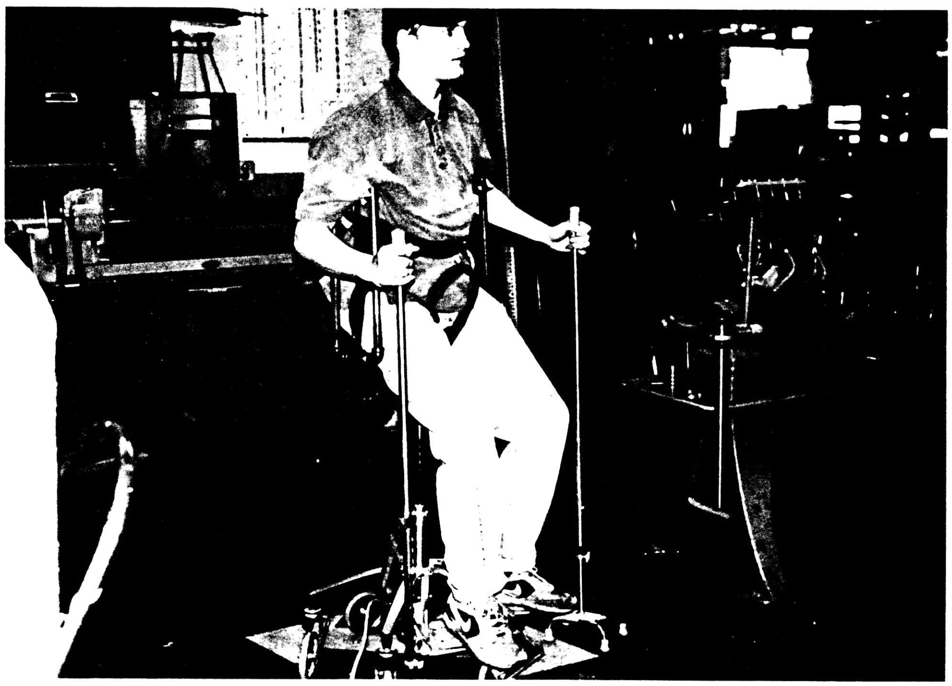
The design for the harness support was adapted from that of rock climbing harnesses. After talking to people at a local rock climbing gear store and researching different styles of harnesses, it was decided that an adaptation of a swami style harness would be used. An attempt at constructing an actual harness was attempted, but due to problems encountered while stitching the



4.2-1 Harness Support

webbing together the decision to purchase a harness was made. The harness used in the prototype was a Misty Mountain Climber©. It is a swami style harness that fits people of almost any size. A photograph of the harness is shown in Figure 4.2-1.

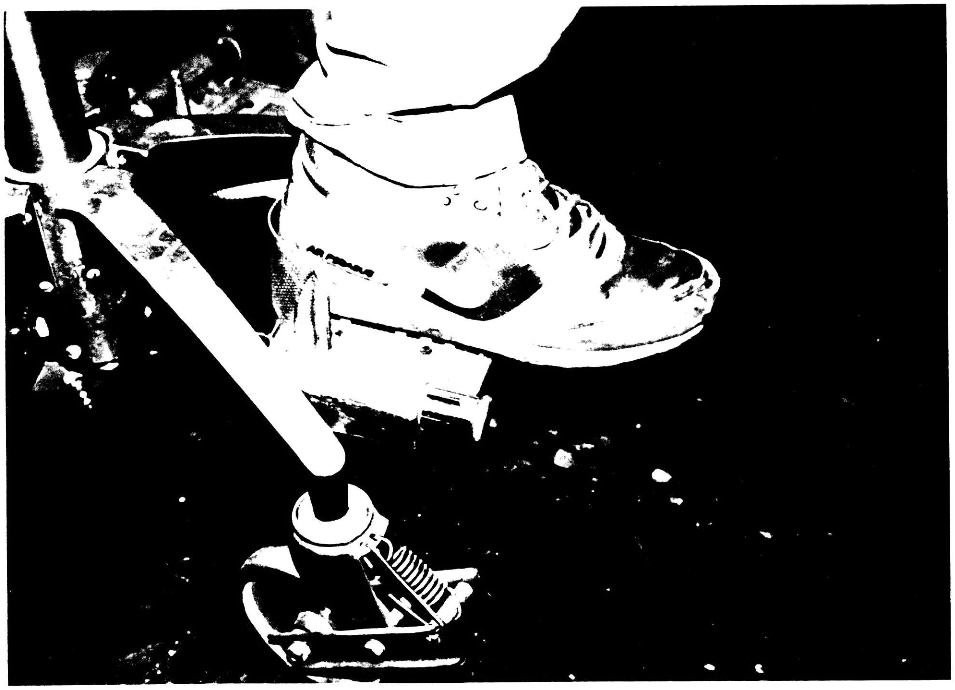
The harness was adapted by cutting openings in the webbing at the four symmetrical points around the waist. Nylon tube straps ran through the webbing at these points and were looped at the ends. The user mounted the mobility device by first putting on the harness. Then the user would support himself in the U-shaped frame and place the looped ends over the bolts in the frame. A user riding the mobility device utilizing the harness support is shown in Figure 4.2-2.

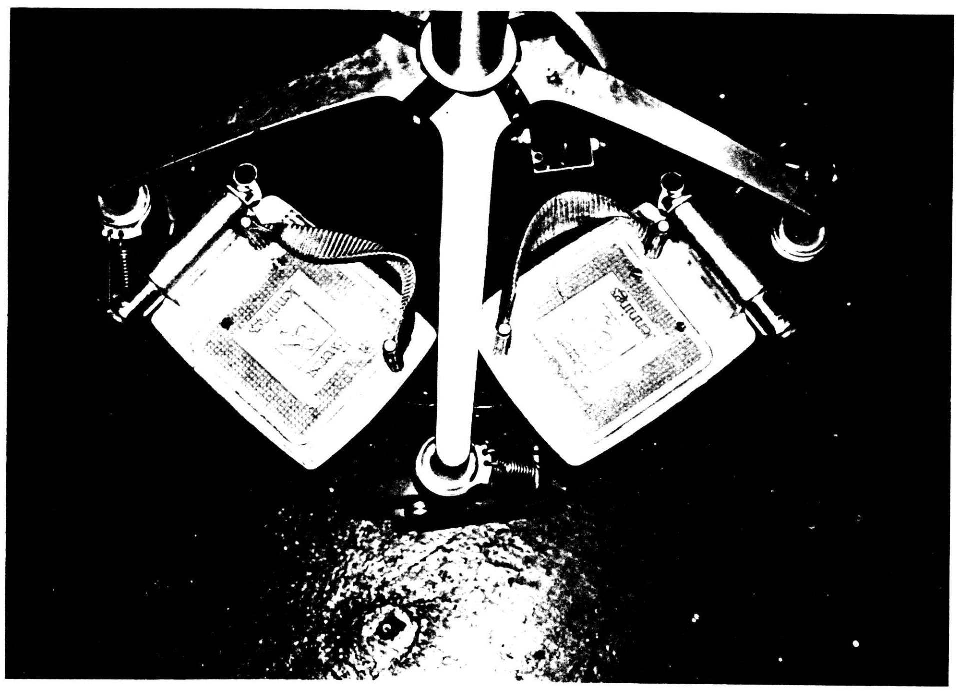


4.2-2 User Riding Mobility Device

4.3 The Improved Footrest

The improved footrest design was adapted from a conventional wheelchair footrest. Two footrests were removed from a wheelchair and cut down to meet the needs of the mobility device. A steel bar was welded to the wheelbase six inches above the ground. The footrests were welded to the steel bar tilted back at an angle of approximately ten degrees. Because the footrest was made of aluminum and the support bar was made of steel, a transition piece had to be created to perform the welding. A piece of steel was used as the transition piece and the aluminum footrest was fixed upon that by screws. The rubber coating to prevent foot slippage and webbing to keep the heel in place is included on the footrest. Photographs of the improved foot rests have been included in Figure 4.3-1.





4.3-1 Improved Footrest

Chapter 5

Testing

5.1 Testing Method

The Stand-Up Mobility Device was tested by having subjects ride it and giving feedback pertaining to its comfort, stability, ease of use, and overall performance. Fourteen subjects participated in the testing, all of various sizes. The weights of the subjects ranged from 130 to 230 pounds, while the heights ranged from 5'5" to 6'1. Both males and females were included in the testing. The testing was conducted on a smooth surface for mobility. In order to test performance in the raised position the device was connected to the fixed air supply in the mechanical engineering shop.

5.2 Comfort

The consensus of the subjects found the harness system to e quite comfortable. The harness was well padded and caused no chafing. Also, there was no problem with harness fit for people of different sizes. The swami style of harness was also described as very simple to get in and out of.

A problem encountered with the harness system was found when people over 180 pounds suspended themselves in the U-shaped frame. The nylon tube straps stretched to the point where the users buttocks were touching the bottom of the frame. A solution to this problem would be to make adjustable suspension straps or make the height of the posts adjustable.

The footrests provided adequate support for all the users and kept their feet in place fairly well. The problem with fixed foot rests is that the harness support is able to spin a full 360 degrees. The range of motion must be limited in order to prevent the feet from being pulled free of the footrests.

5.3 Dynamic Stability

The stability of the mobility device was the chief problem in the design. The design of the U-shaped frame and its connection to the pneumatic piston was quite solid. The problem was that the pneumatic piston was slightly loose and caused a small amount of motion in the whole U-shaped frame.

The subjects found the major flaw in the harness support system was encountered when trying to move using the four-pronged canes. Because the harness was suspended in the frame, the users body swayed quite a bit. As the user pushed with the canes, the force applied caused the users body to sway forward instead of pushing the device forward. The wheel base was not wide enough to remain stable when heavy people swayed in the frame.

5.4 Ease of Use

Once mounted in the mobility device, it was found to be fairly easy to use, outside of the stability problems outlined in Section 5.3. The major problem relating to the ease of use lies in the mounting and dismounting of the device. Because a paraplegic cannot support himself with his legs, he requires a great deal of assistance when mounting the harness on the U-shaped frame.

The harness chosen was a swami style. This made putting the harness on and taking it off very easy, even for someone with no use of the lower body. Instead of having to step into the harness, this harness straps onto the legs utilizing buckles to fasten it. All of the testers felt that this made harness system easier to use.

5.5 Overall Performance

The overall response to the harness support system was very interesting. The users found the comfort and freedom of movement to be quite good in the harness, but stability was a major concern in all who tried the device. This design was found to be alot less stable than the seated designs made previously. Since paraplegics are unable to counter this instability with leg support, this can create a serious problem.

Chapter 6

Conclusion and Recommendations

6.1 Conclusions

The Stand-Up Mobility Device performed well in some areas and poorly in others. The aesthetics and comfort of the design were improved over previous designs, but the design fell short in the important area of stability. The harness design should be improved and combined with other ideas in order to create a more stable device.

The mobility device is not a design for all people that require wheelchairs. The user must have good upper body control and strength in order to remain upright and to propel the device. Users of the device must insure that the harness support system and the caster suspensions are designed with their weight and body dimensions in mind. It was found that the performance of these varied with those parameters.

In order to develop a production style Stand-Up Mobility Device, improvements must be made upon the harness support system. Also, a portable air supply as described in Section 3.3. must be obtained for further testing.

6.2 Recommendations for Future Designs

The harness support system needs to be improved for future designs. This design proved that the comfort and aesthetics of such a design are improved, but future designs must have greater stability. An idea that would offer the stability of a seated support would be to combine the harness support system with a small seat. This would displace some of the user's weight from the top of the posts to the seat area, thus resulting in improved stability while retaining the advantages of the harness support system.

In order to prevent the hassle of connecting and disconnecting an air tank every time it needs to be recharged, alternate methods of raising the seat may be looked at. One such idea is a hand pump to actuate the pneumatic cylinder. Another idea is to mechanically raise the seating area by using a system similar to a car jack. The user can easily operate it by hand, and it requires no form of regulator or portable air supply to worry about.

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