Spring 5-31-2000

Biomechanical evaluation of patient transfers

Charles Costa
New Jersey Institute of Technology

ABSTRACT

BIOMECHANICAL EVALUATION OF PATIENT TRANSFERS

by
Charles Costa

The purpose of this study is to identify the problem encountered when a patient with limited strength and mobility needs assistance in transferring from a wheelchair to another location.

This study took advantage of ergonomic techniques to isolate the source of stress, and limited these stresses according to the standards of the National Institute of Safety and Health Administration.

A device was developed whereby the stresses of a patient transfer were eliminated. By using a conventional wheelchair and a recliner as a starting point, effectively combining these components into a single multifunctional unit the goal of reducing stress was achieved. The design allowed people with limited strength and mobility to transfer more independently, reducing the amount of assistance necessary from a caregiver. This design means a safer transfer for patient and caregiver.

BIOMECHANICAL EVALUATION
OF PATIENT TRANSFERS

by
Charles Costa

A Thesis
Submitted to the Faculty of
New Jersey Institute of Technology
In Partial Fulfillment of the Requirements for the Degree of
Master of Science in Biomedical Engineering

Biomedical Engineering Committee

May 2000

Blank Page

APPROVAL PAGE

BIOMECHANICAL EVALUATION OF PATIENT TRANSFERS

Charles Costa

Dr. Raj S. Sodhi, Thesis Advisor — Date
Associate Professor of Mechanical Engineering, NJIT

Dr. David Kristol, Committee Member — Date
Professor of Chemistry, NJIT

Dr. One-Jang Jeng Committee Member — Date
Assistant Professor of Industrial and Manufacturing Engineering, NJIT

BIOGRAPHICAL SKETCH

Author: Charles Costa

Degree: Master of Science in Biomedical Engineering

Date: May 2000

Undergraduate and Graduate Education:

- Master of Science in Biomedical Engineering
  New Jersey Institute of Technology, Newark, NJ, 2000

- Bachelor of Science in Mechanical Engineering
  Fairleigh Dickinson University, Teaneck, NJ, 1990

Major: Biomedical Engineering

To my beloved family

ACKNOWLEDGMENT

I would like to express my appreciation to Dr. Raj Sodhi, who served as my research supervisor, providing me with resources and advice. I would also like to thank Dr. David Kristol and Dr. One-Jang Jeng for actively participating in my committee.

TABLE OF CONTENTS

TABLE OF CONTENTS
(Continued)

Chapter **Page**

LIST OF TABLES

Tables **Page**

LIST OF FIGURES

Figures **Page**

CHAPTER 1
INTRODUCTION

Back problems are prevalent in nursing personnel. Nursing assistants in a nursing home or in hospital stated that transferring a patient from bed to wheelchair or wheelchair to bed is a very stressful task; they manually lifted patients to transfer Garg (1991).

Back problems resulting from over-exertion are prevalent among nursing personnel. found that nursing personnel ranked fifth in occupation, claiming worker compensation for back injury; only heavy labor occupations such as garbage-collector, miscellaneous laborers, and warehouse workman ranked higher than nursing personnel, Klein(1984). The lifting and transferring of patients has been perceived by nursing personnel to be the most frequent precipitating factors or triggers of these of back problems, Garg (1992).

Many approaches to decreasing back problems have been tried in general industry as well as in health care institutions and home care. Emphasis has been primarily on education and training with a definite focus on body mechanics. However, these approaches have had little impact on the problem. Studies have indicated that an ergonomic approach involving the assessment of stressful tasks and development of alternative methods can reduce the potential for over-exertion problems.

Ergonomics is the scientific study of human work. This generally involves of matching the job to the worker rather than trying to fit the worker to the job. The goals are to identify those aspects of the job which are particularly hazardous and to redesign them so they are safer. This may be done through such avenues as redesigning of the task, the work station , the environment , the work organization or overall of course, redesign the product by biomedical engineers.

Therefore, in order to decrease the back stress problem in nursing, nursing personnel must begin to look at the tasks which they feel are stressful to the upper and lower back. This group of health professionals should delineate approaches to decreasing that stress. They must be encouraged to problem-solve and work with management in striving for changes that could impact on the problem which is costly in relation to human suffering, staffing and financial cost.

This project is focused on the task of patient transfers. It used an ergonomic approach to isolate and evaluate the particular stresses involved. It also used studies to quantify the amount of stress required to transfer patients and develop a prototype to make this task safer to the patient and the caregiver.

CHAPTER 2
LITERATURE REVIEW

Lifting and transferring patients takes a heavy toll: Nurses have been ranked fifth among all workers nationally filing compensation claims for back injury, and even that estimate may be low. A study found that only one-third of those nurses who said they had episodes of occupation - related back problems (63 out of 189) actually filed an incident report; most accepted back pain as part of job and took sick days(Owen & Garg, 1989).

Commonly, health - care- facility managers have relied on education in back care and lifting techniques to help prevent back injuries. There is no evidence , however, that this approach by itself does any good. Equally or more important is an ergonomic approach-that is, altering the design of the wheelchair.

The National Institute for Occupational Safety and Health studied the effect of reducing the physical demands of the job; specifically, those involved in transferring patients. They conducted studies in two units of a large country nursing home. The 140 patients averaged 84.7 years old and 136 pounds weight. Of the 57 nursing assistants (NAs) , more than half about 38 volunteered to be in the study. The average volunteer was female, 32 years old, 142 pounds, five feet four inches tall, and had worked for nearly eight years as an NA. Twenty-nine of the volunteers means about 75% said they had suffered job-related back problems within the past three years. While 60% of those lost no work time due to back problem,15% missed one to seven days, and 25% lost eight days or more.

2.1 The Source of Stress

The NAs ranked transferring wheelchair patient to and from the bed as most stressful to the lower back. On average, each NA carried out 24 of the "most stressful" patient-transfer tasks per eight-hour shift. Even with two NAs lifting the average 136-pound patient, each NA required to lift 68 pound 24 times every shift; which is far more than the 46 pounds recommended for women in the 90th percentile of strength, a limit based on lifting a compact box with handles, 14 inches wide, for a distance of 10 inches (starting with the box at knuckle height while standing).

Obviously, nurses are not lifting under these ideal conditions. Hardly a compact object with handles, the patient also may pose problems like combativeness, rigidity, spasms and unpredictable behavior that reduce the amount of weight that can be safely lifted.

Using the Borg scale for rating of perceived exertion 6(very-very light) to 20 (very-very hard), the NAs rated the patient-handling tasks they classified "most stressful" at an average of 14, or "somewhat hard to hard" for the lower back.

The study shows that the nurses performing the most stressful transfer tasks, estimated the actual pressure on the disc between the fifth lumbar and the first sacral vertebrae(L5 S1),using a three dimensional static biomechanical model. Transfer from wheelchair to bed (mean = 4,877 newtons) created the most compressive force to L5S1. None of the transfers had an average force in newtons lower than 3,430-newton limit recommended as acceptably the U.S. Department of Health and Human Services.

There are many devices are now available in market today. But my goal was to determine if the patient or transferor was comfortable? There are many different techniques being used by transferors :

- manual transferring

-gait belt

-walking belt with handles using one subject to make the transfer

-walking belt with handles using two to make the transfer

-a soft; rubber-like flexible sling that could be trucked securely around the patient just below the waist

In addition to these, there are many mechanical hoists now available to transfer

-the C3 sling lift/transfer system (Arjo-Century, Morton Grove , IL)

-the Trans-Aid lift (Guardian products , Arleta , CA)

-the Hoyer lift (Ted Hoyer Co., Oshkosh ,WL)

The study shows that after transfer, the subjects rated their perception of exertion / stress on the lower back using a Likert scale of 0 (no stress) to 9 (extreme stress). Manually lifting the patient, not surprisingly, proved the most stressful (rating 6) and yielded the greatest amount of compressive force (4,757 newtons) Of the other manual transfer methods , the walking belt with handles averages the lowest for stress (rating 3) and compressive force (2,044 newtons).

The patient said they felt least comfortable and least secure when lifted manually; they rated the walking belts as most comfortable and secure. Of the hoists, the C3 was rated the most comfortable and secure.

2.2 Body Mechanics

Proper posture is required to limit stress and strain on musculoskeletal structures. When lifting, pushing, or pulling, the stresses and strains upon the musculoskeletal system are increased. Proper posture and body mechanics are based upon alignment and functioning of the musculoskeletal system. Good body mechanics include:

1. Using larger and stronger muscles to perform heavy work;
2. Maintaining the center of gravity of the body close to the center of

the base of support.

3. Keeping the combined center of gravity of the transferor, patient , wheelchair and the bed.

4. Having a base of support that is of the appropriate size and shape.

The initial stance for lifting is with the transferor feet placed in stride and slightly apart. This stance widens the base of support in both the anterior / posterior and lateral directions, negating the effect of small shifts in the center of gravity. In this way a balanced position can be maintained more easily. Lifting should be initiated from a squatting position. The depth of the squat should be deep enough to permit the transferor to reach the patient to be lifted, but not so deep that the leg muscles are at a disadvantage in regaining the upright position. This type of squat is achieved by flexing the hips and knees, rather than by trunk flexion. The trunk should be maintained in good alignment so muscles only have to maintain this alignment, and do not have to work to extend the trunk during the lifting motion. Contracting the muscles of the trunk prior to lifting may reduce the potential for injury. Being as close as possible to the patient to be lifted allows the combined center of gravity to be maintained within the base of support. When the center of gravity is centered within the base of support and near the body's midline, both balance and good postural alignment are easier to maintain.

Transfer requires movements that move the center of gravity away from the center of the base of support. These movements have the potential of causing a loss of balance. Increasing the size of the base of support by setting the feet in stride and slightly apart provides a larger base of support. The transferor's feet should also be unencumbered to move as the situation requires, always allowing the base of support to be re-established under the moving center of gravity. Crossing of the transferor's legs during movement should be avoided because it decreases the size of base support, and constrains freedom of foot movement.

2.3 Who Will Benefit?

From a biomedical point of view, we always provide the benefit to the medical field to make medically available treatment easy for the patient or the caregiver by engineering aspect. This redesigned product can be beneficial to the caregiver and the patient.

The person having a limited range of motion because of the age or some medical problem can transfer themselves with no assistants or minimum supervision. Transferring the patient is the most important issue in medical field among the nursing and the patient. This issue involved both the caregiver and the caretaker.

The limit of a range of motion is achieved when the body segment can not be moved further because of restriction by tissues or patient reports of pain. When the limit of a range of motion is attained, the quality of the restriction felt by the therapist which limits further motion is described as " end feel." End feel varies, depending on the reason for the limitation of further motion. When further motion is limited by bone abutting bone, the end feel is hard, and is called a bony end feel. An example of bony end feel is when complete elbow extension is attained, and the humorous and ulna make contact with each other. When further motion is limited by tightness of muscle, ligament, capsule, or tendon, the end feel is soft, and is called a soft end feel. An example of soft end feel is when complete elbow flexion is attained. When further motion is limited by pain, there is no tissue limitation to motion and the end feel is described as empty. This is called an empty end feel.

In some patients, involuntary muscle contractions may interfere with range of motion. This can occur in patients with upper motor neuron lesions, or when a patient involuntarily contacts muscles to avoid pain. Muscle tone is altered in upper motor neuron lesions, and usually present as spasticity or rigidity.

Spasticity is presented as gradually increasing resistance to movement. A point may be reached where further movement is prevented temporarily, and then followed by sudden reduction of tone if resistance is maintained (clasp knife phenomenon). Following the sudden reduction of tone, movement through the remaining range of motion is possible. Spasticity usually occurs in antigravity muscles.

Rigidity is usually presented as resistance to passive movement in any direction. The resistance of rigidity is the same throughout the range of motion. Rigidity occurs in both antigravity and progravity muscles. Cogwheel rigidity, as observed in Parkinsonian patients, is a pattern of alternating resistance and lack of resistance throughout a range of motion.

In the presence of spasticity or rigidity, slow maintained movement will usually permit movement through the complete range of motion without eliciting interference.

CHAPTER 3

ERGONOMIC EVALUATION

3.1 Ergonomics

The purpose of including an ergonomic evaluation into the initial design phase, has some distinct advantages which are critical to a good and robust design.

Ergonomics is derived from the Greek word erg meaning work and nomos meaning the study of. Ergonomics is a body of knowledge about human abilities, limitations and characteristics relevant to design. The basic objective is to fit the task to the person, by selecting and training the person to do the task. In cases where a high percentage of the population must be capable of doing the task, the task must be redesigned to accommodate the large population. This is done through the field of ergonomics and biomedical engineering.

The issue in this case is to reduce the repetitive strain injuries caused by lifting and transferring patients out of wheelchairs. This not only includes the caregiver, but it also includes the stress or anxiety developed by the patient in the wheelchair. When a patient relies on help from a caregiver to exit a wheelchair, particular stresses are endured by the caregiver. The nature of these stresses will be discussed and compared to national standards to see how they relate to these standards.

In order to design a wheelchair or redesign the task at hand, you must first quantify human variability. This is done through the use of Anthropometry. Anthropometry comes from the Greek meaning to measure man. Anthropometry data usually comes in the form of a chart. This chart usually arranges this data according to percentage of population. Table 3.1 shows some physical dimensions of the nude U.S. adult civilian population. (Kroemer 1994).

TABLE 3.1

Body dimensions (cm) of nude U. S. adult civilians (Kroemer et al., 1994).

	PERCENTILES							
	5th		50th		95th		Standard Deviation	
	Fem.	Male	Fem.	Male	Fem.	Male	Fem.	Male
HEIGHTS (Above Floor)								
Stature (height)	152.78	164.69	162.94	175.58	173.73	186.65	6.36	6.68
Eye height	141.52	152.82	151.61	163.39	162.13	174.29	6.25	6.57
Shoulder (acromial) height	124.09	134.16	133.36	144.25	143.20	154.56	5.79	6.20
Elbow height	92.63	99.52	99.79	107.25	107.40	115.28	4.48	4.81
Wrist height	72.79	77.79	79.03	84.65	85.51	91.52	3.86	4.15
Crotch height	70.02	76.44	77.14	83.72	84.58	91.64	4.41	4.62
HEIGHTS (Above Seat)								
Height (sitting)	79.53	85.45	85.20	91.39	91.02	97.16	2.49	3.56
Eye height (sitting)	68.46	73.50	73.87	79.20	79.43	84.80	3.32	3.42
Shoulder (acromial) height (sitting)	50.91	54.85	55.55	59.78	60.36	64.63	2.86	2.96
Elbow height (sitting)	17.57	18.41	22.05	23.06	26.44	27.37	2.68	2.72
Thigh height (sitting)	14.04	14.86	15.89	16.82	18.02	18.99	1.21	1.26
Knee height (sitting)	47.40	51.44	51.54	55.88	56.02	60.57	2.63	2.79
Popliteal height (sitting)*	35.13	39.46	38.94	43.41	42.94	47.63	2.37	2.49
DEPTHS								
Forward (thumbtip) reach	67.67	73.92	73.46	80.08	79.67	86.70	3.64	3.92
Buttock-knee distance (sitting)	54.21	56.90	58.89	61.64	63.98	66.74	2.96	2.99
Buttock-popliteal distance (sitting)**	44.00	45.81	48.17	50.04	52.77	54.55	2.66	2.66
Elbow-fingertip distance	40.62	44.79	44.29	48.40	48.25	52.42	2.34	2.33
Chest depth	20.86	20.96	23.94	24.32	27.78	28.04	2.11	2.15
BREADTHS								
Forearm-forearm breadth	41.47	47.74	46.85	54.61	52.84	62.06	3.47	4.36
Hip breadth (sitting)	34.25	32.87	38.45	36.68	43.22	41.16	2.72	2.52
HEAD DIMENSIONS								
Head circumference	52.25	54.27	54.62	56.77	57.05	59.35	1.46	1.54
Head breadth	13.66	14.31	14.44	15.17	15.27	16.08	0.49	0.54
Interpupillary breadth	5.66	5.88	6.23	6.47	6.85	7.10	0.36	0.37
FOOT DIMENSIONS								
Foot length	22.44	24.88	24.44	26.97	26.46	29.20	1.22	1.31
Foot breadth	8.16	9.23	8.97	10.06	9.78	10.95	0.49	0.53
Lateral malleolus height	5.23	5.84	6.06	6.71	6.97	7.64	0.53	0.55
HAND DIMENSIONS								
Circumference, metacarpal	17.25	19.85	18.62	21.38	20.03	23.03	0.85	0.97
Hand length	16.50	17.87	18.05	19.38	19.69	21.06	0.97	0.98
Hand breadth, metacarpal	7.34	8.36	7.94	9.04	8.56	9.76	0.38	0.42
Thumb breadth, interphalangeal	1.86	2.19	2.07	2.41	2.29	2.65	0.13	0.14
WEIGHT (Kg)	39.2	57.7	62.01	78.49	84.8	99.3	13.8	12.6

*Underside of the thigh.
**Rear of the calf.

3.2 Factors Effecting Performance of a Human

There are several factors which effect the human performance of a task. These factors depend on three key elements.

Individual: gender, age, back muscle strength, intrabdominal pressure.

Technique: body posture, hand orientation, foot position, and lifting training.

Task: object, weight, ease of handling, initial and final height, angle of rotation, lift symmetry, clothing, thermal environment.

When analyzing this task, these factors must be taken into account. These characteristics show that many things come into effect when a person does a particular task.

3.3 Recent Studies

A recent study conducted by Ulin, Chaffin, Patellos, Blitz, Emerick, Lundy, and Misher (1997) evaluated six transfer methods (three manual and three mechanical). All studied transfers were from a bed to a wheelchair. The patient transfers were done in a rehabilitation unit of a university hospital. Each transfer was video taped using a short nurse and a tall nurse, 150cm and 178 cm respectively. A software program called 3-Dimensional Static Strength Prediction Program (3DSSPP™) was used to analyze each patient transfer and to compute the maximum compressive force on the L5/S1 disc. This program also estimates the percentage of the population capable of transferring patients according to National Institute of Occupational Safety and Health Guidelines (NIOSH).

The conclusions of this study indicate that the risk of low back injuries are considerable when transferring totally dependent patients from a hospital bed to a wheelchair. The average compressive forces at the L5/S1 disc exceeded NIOSH limits when transfers were performed by manual methods. Peak compressive forces of 10,000N were estimated when nurses transferred by manual methods. Peak compressive forces of

1608N were estimated when nurses transferred patients with mechanical lifts. Also the percentage of nurses with the strength capable at the hip and shoulder (1-53%) was below the recommended SDL recommended by NIOSH when using the manual transfer methods.

A laboratory study was conducted by Garg, Banaag, Beller, Owen and (1991) focussing on patient handling tasks of transferring the patient from the bed to wheelchair and from wheelchair to bed. The tasks were studied using five manual techniques and three hoist assisted techniques. Table 3.2 shows a summary of the forces required to transfer patients from a wheelchair to a bed. As shown in the table, a mean of 49% of the females are capable of performing a 2 person manual transfer.

This evaluation showed that pulling techniques as compared to lifting the patient, required lower hand forces and produced lower erector spinal and compressive forces on the L5/S1 disk.

TABLE 3.2

Summary of biomechanical analysis of five different manual methods for transferring patients from wheelchair to bed (mean, s.d.,and range)

Variable	Manual lifting (2 person)	Gait belt (2 person)	Walking belt (2 person)	Walking belt (1 person)	Medesign (1 person)
Trunk Flexion angle(deg)	46+/-11 30-50	40+/-0 40-40	38+/-4 30-40	33+/-4 30-40	36+/-6 30-45
Trunk Lateral Bending(deg)	14+/-6 10-25	10+/-4 5-15	14+/-2 10-15	10+/-3 5-15	0+/-0 0-0
Trunk Rotational angle(deg)	0+/-0 0-0	0+/-0 0-0	0+/-0 0-0	0+/-0 0-0	0+/-0 0-0
Hand Force (N)	312+/-54 263-392	127+/-12 116-138	125+/-18 107-156	277+/-28 254-312	277+/-23 254-313
% Capable Females	49+/-3 45-53	77+/-9 67-90	84+/-11 70-98	59+/-17 36-88	53+/-9 42-64
Trunk Flexion Moment (NM)	168+/-21 143-207	89+/-5 85-97	86+/-5 76-91	118+/-17 102-49	157+/-19 122-172
Lateral bending moment (NM)	109+/-22 85-145	17+/-12 4-35	19+/-12 6-40	27+/-8 16-40	0+/-0 0-0
Rotating moment (NM)	38+/-8 23-45	41+/-6 31-47	38+/-8 28-52	6+/-3 2-10	0+/-0 0-0
Erector spinal force (N)	3363+/-414 2901-4143	1776+/-94 1700-1940	1709+/-100 1517-1811	2353+/-338 2034-2968	3134+/-376 2439-3435
Compressive force (N)	4395+/-339 4027-4979	2027+/-181 1851-2345	1968+/-180 1695-2243	2733+/-359 2385-3315	3339+/-429 2518-3662
Shear force(N)	640+/-75 534-752	570+/-37 507-610	547+/-48 481-627	502+/-46 432-561	448+/-23 445-516

3.4 Description of the Model

A three dimensional biomechanical model was used to simulate the joint angles of a person assuming the task of transferring (lifting) a patient from a wheelchair. This model will take into account anthropometric data , which is used to analyze the results.

The modeling was created using a biomechanical software program called 3-Dimensional Static Strength Prediction Program (3DSSPP™). This program computes the compressive force on the L5/S1 disk as well as estimates the percentage of population of performing the task.

The forces required to perform this task will be calculated by this program. The forces will be compared to NIOSH standards and this will tell us if the task exceeds the recommended weight limit for a particular muscle group.

The model will utilize information conducted from a study by the National Institute of Occupational Safety and Health Administration (NIOSH). Some of the information includes:

Average age and weight of person being transferred are 84.7yrs and 136 pounds respectively.

The average Nurses Assistant (NA) is a female of age 32 with an average weight of 142lbs and a height of five feet- four inches tall.

The task will analyze the forces endured by the NA while attempting to lift a person up from a seated position to a standing position in a wheelchair. (See Figure 3.4).

The caregiver will have a symmetric posture with both knees bent slightly. The elbows will be bent and be as close to the body as possible.

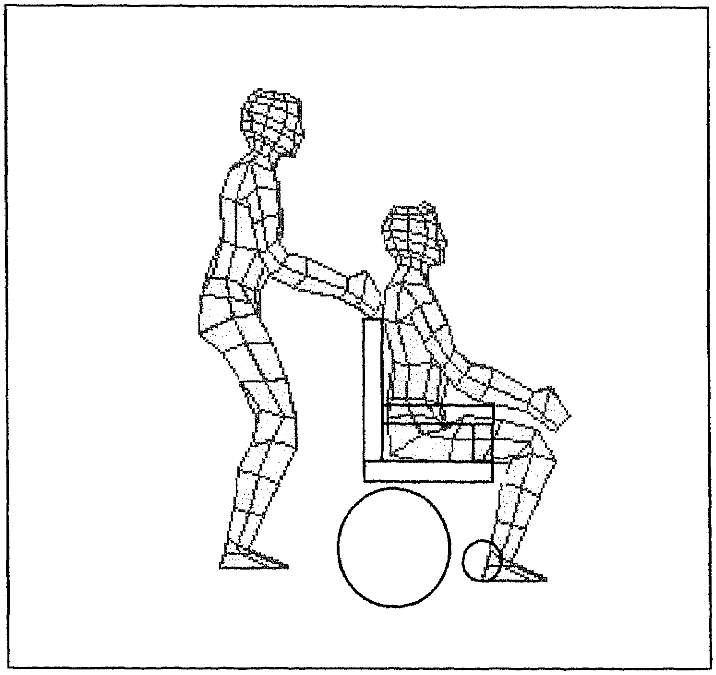


Figure 3.4
NA lifting a person from a seated position

The model will use one person to illustrate the forces in a patient handling task. Most studies that are conducted using manual methods utilize two people to handle a task such as this.

3.5 Interpretation of Data

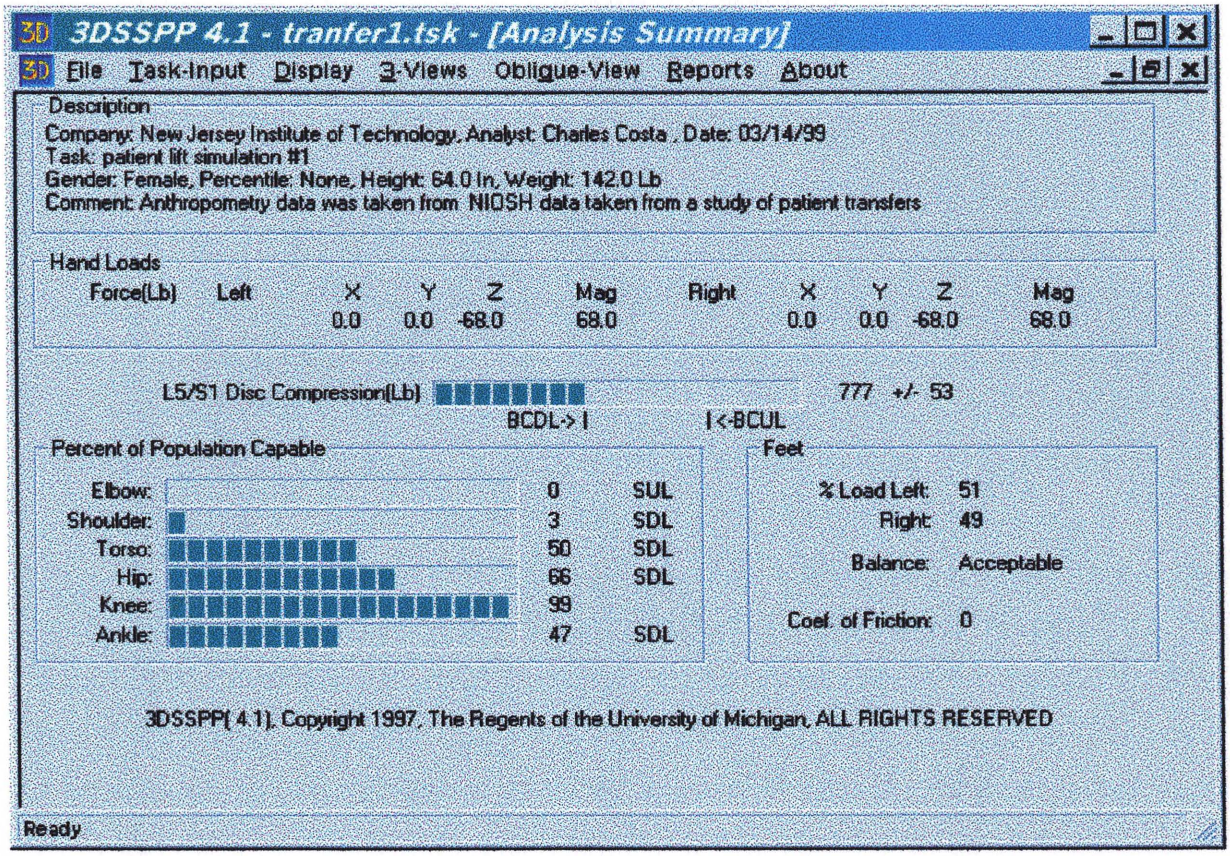
The first graph (Figure 3.5) depicts the percentage of the population capable of completing this task using anthropometry given in a NIOSH patient lifting study. Using a 142lb female at 64" tall trying to lift a 136lb person from a wheelchair. Assuming that the patient does not help the caregiver, we can assume loads of 68lbs per hand. The analysis shows that the compressive forces on the L5/S1 vertebrae are 777lbs. This exceeds the 764lbs compressive force allowable by NIOSH guidelines, and in fact this task would not be suitable for a person of this stature.

The second graph (Figure 3.6) is an analysis done using a 95 percentile male with a weight of 215 lbs. And a height of 74". This person also has the same hand loading as the previous person. This analysis shows that this group of people do not exceed the 746lb compressive forces on the L5/S1 vertebrae, but they are still very close to the limit. Any changes in the lifting posture may lead to potential lower back strain or injury.

The last graph (Figure 3.7), evaluates a 95 percentile female with a weight of 198.5 lbs. and a height of 67.7". The hand loads have been changed to 40lbs per hand. In this case you can see that this person is capable of doing this task without risk to lower back injury. This last case was analyzed to simulate how much the person in the wheelchair must initiate the lift in order for the caregivers not to overexert themselves. Also, lifting conditions are seldom the case in which was analyzed. Uneven stance, heavy load, or the person in the wheelchair unwilling to help the caregiver, can make this task extremely dangerous for the caregiver.

Figure 3.5

Task analysis for a 142 lb. female



3DSSPP 4.1 - tranfer1.tsk - [Analysis Summary]

File Task-Input Display 3-Views Oblique-View Reports About

Description

Company: New Jersey Institute of Technology, Analyst: Charles Costa , Date: 03/14/99
Task: patient lift simulation #1
Gender: Female, Percentile: None, Height: 64.0 In, Weight: 142.0 Lb
Comment: Anthropometry data was taken from NIOSH data taken from a study of patient transfers

Hand Loads

Force(Lb)	Left X	Y	Z	Mag	Right X	Y	Z	Mag
	0.0	0.0	-68.0	68.0	0.0	0.0	-68.0	68.0

L5/S1 Disc Compression(Lb) 777 +/- 53
BCDL-> | |<-BCUL

Percent of Population Capable

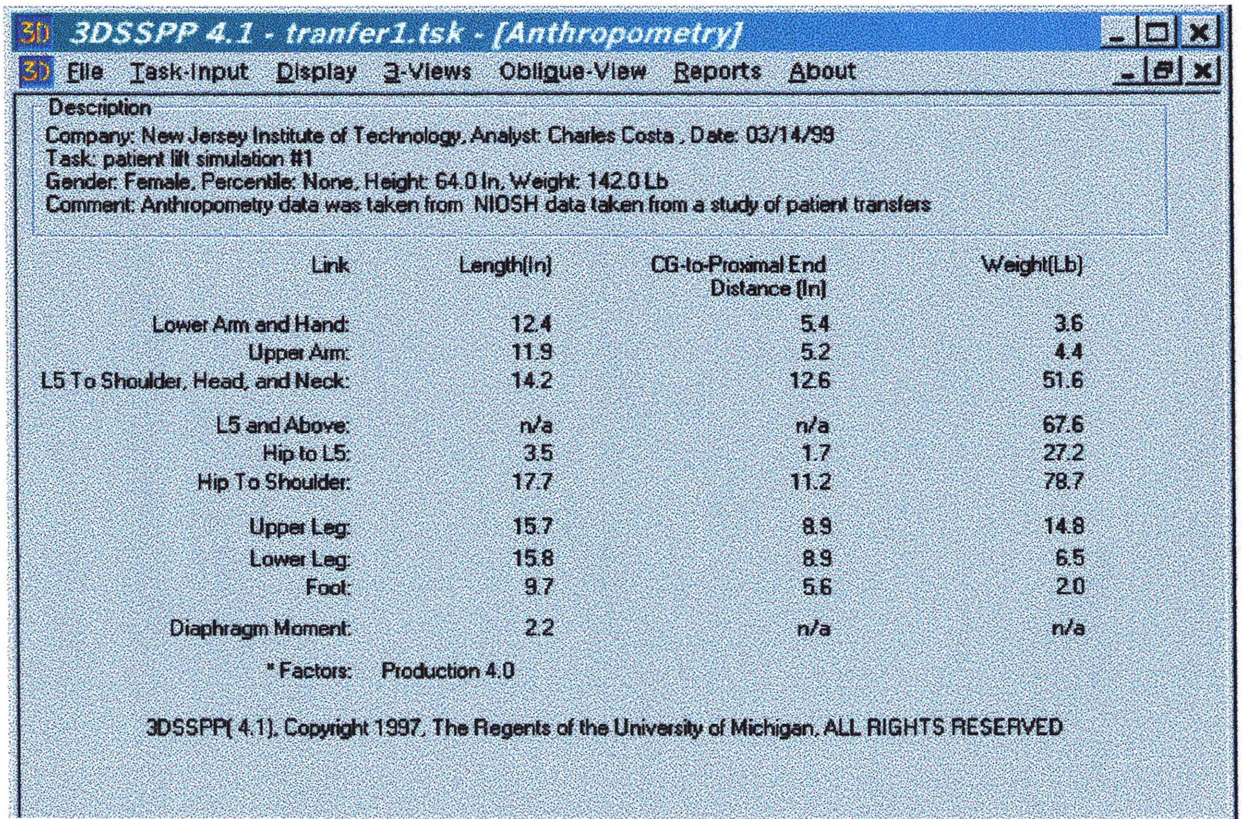
Elbow:	0	SUL
Shoulder:	3	SDL
Torso:	50	SDL
Hip:	66	SDL
Knee:	99	
Ankle:	47	SDL

Feet

% Load Left: 51
Right: 49
Balance: Acceptable
Coef. of Friction: 0

3DSSPP(4.1), Copyright 1997, The Regents of the University of Michigan, ALL RIGHTS RESERVED

Ready



3DSSPP 4.1 - tranfer1.tsk - [Anthropometry]

File Task-Input Display 3-Views Oblique-View Reports About

Description

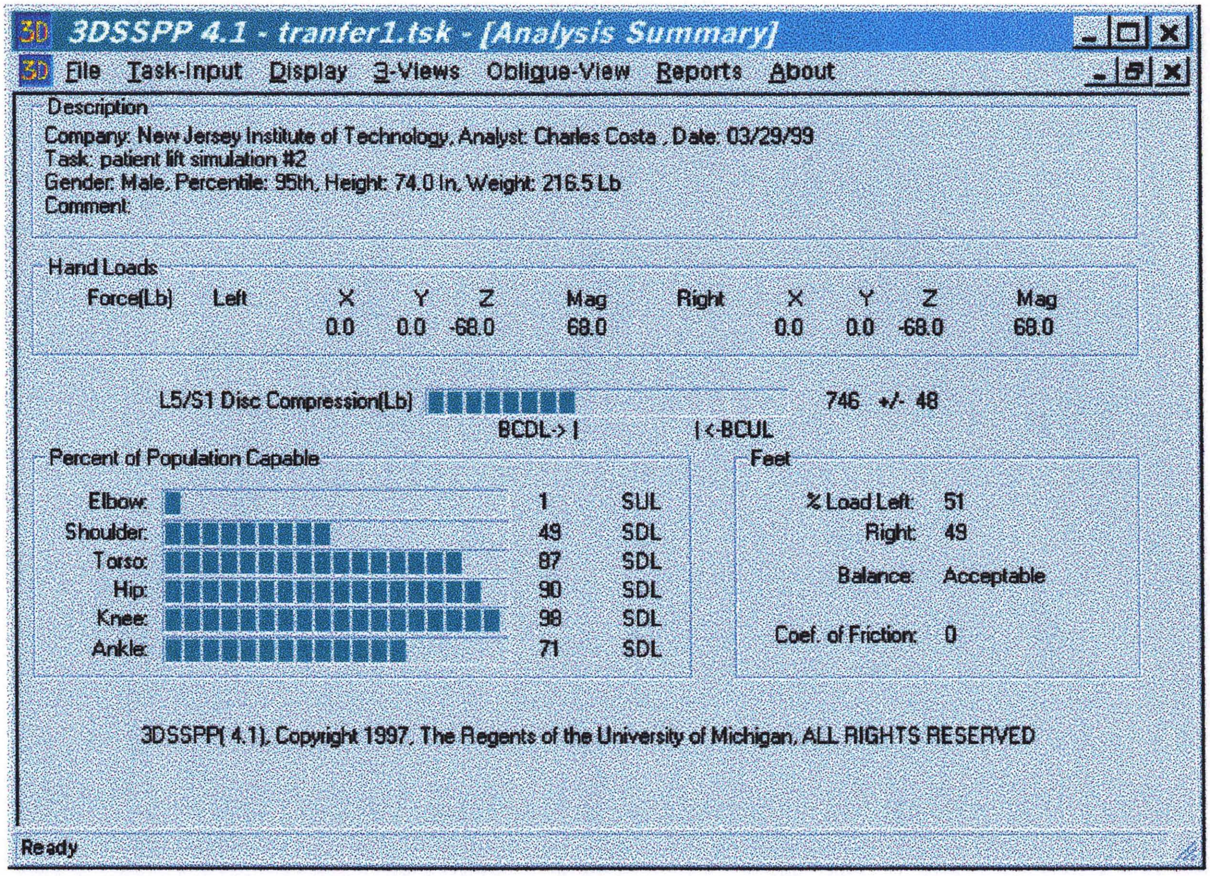
Company: New Jersey Institute of Technology, Analyst: Charles Costa , Date: 03/14/99
Task: patient lift simulation #1
Gender: Female, Percentile: None, Height: 64.0 In, Weight: 142.0 Lb
Comment: Anthropometry data was taken from NIOSH data taken from a study of patient transfers

Link	Length(In)	CG-to-Proximal End Distance (In)	Weight(Lb)
Lower Arm and Hand:	12.4	5.4	3.6
Upper Arm:	11.9	5.2	4.4
L5 To Shoulder, Head, and Neck:	14.2	12.6	51.6
L5 and Above:	n/a	n/a	67.6
Hip to L5:	3.5	1.7	27.2
Hip To Shoulder:	17.7	11.2	78.7
Upper Leg:	15.7	8.9	14.8
Lower Leg:	15.8	8.9	6.5
Foot:	9.7	5.6	2.0
Diaphragm Moment:	2.2	n/a	n/a

* Factors: Production 4.0

3DSSPP(4.1), Copyright 1997, The Regents of the University of Michigan, ALL RIGHTS RESERVED

Figure 3.6
Task analysis for a 95 percentile male



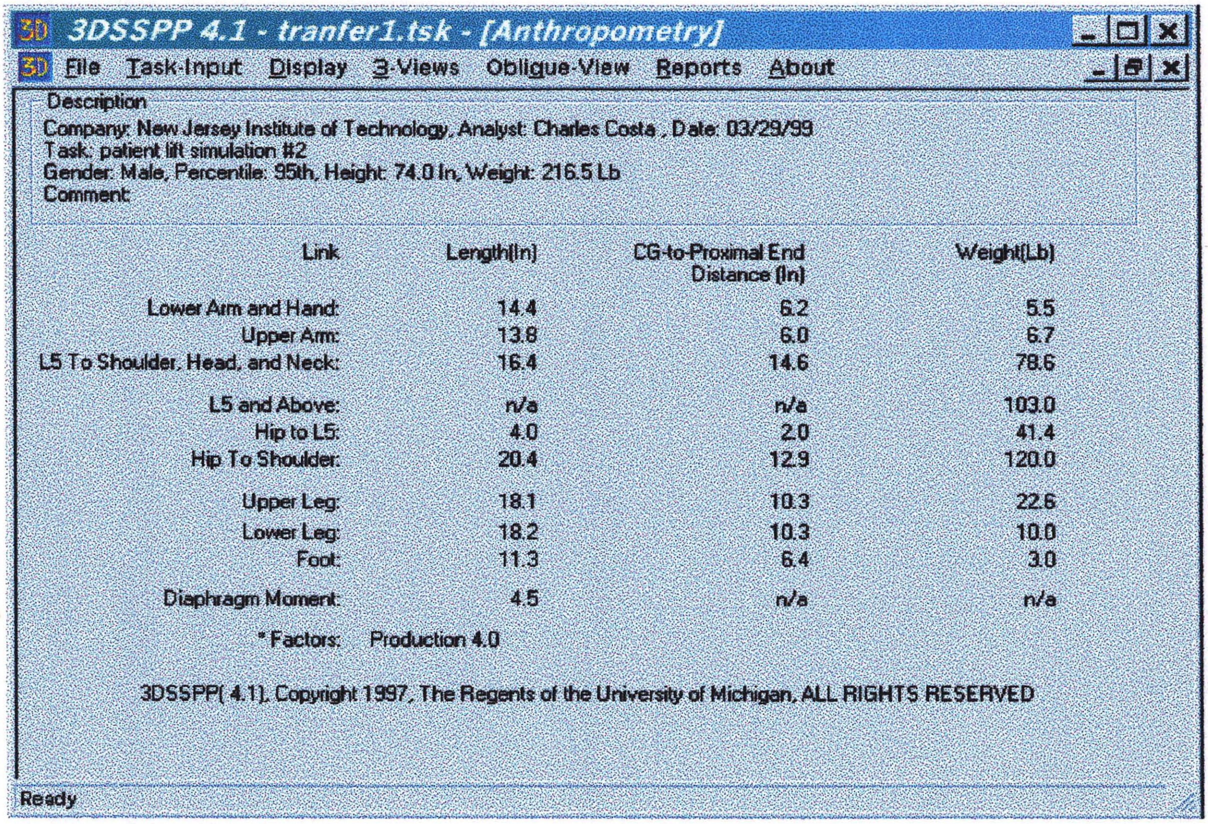
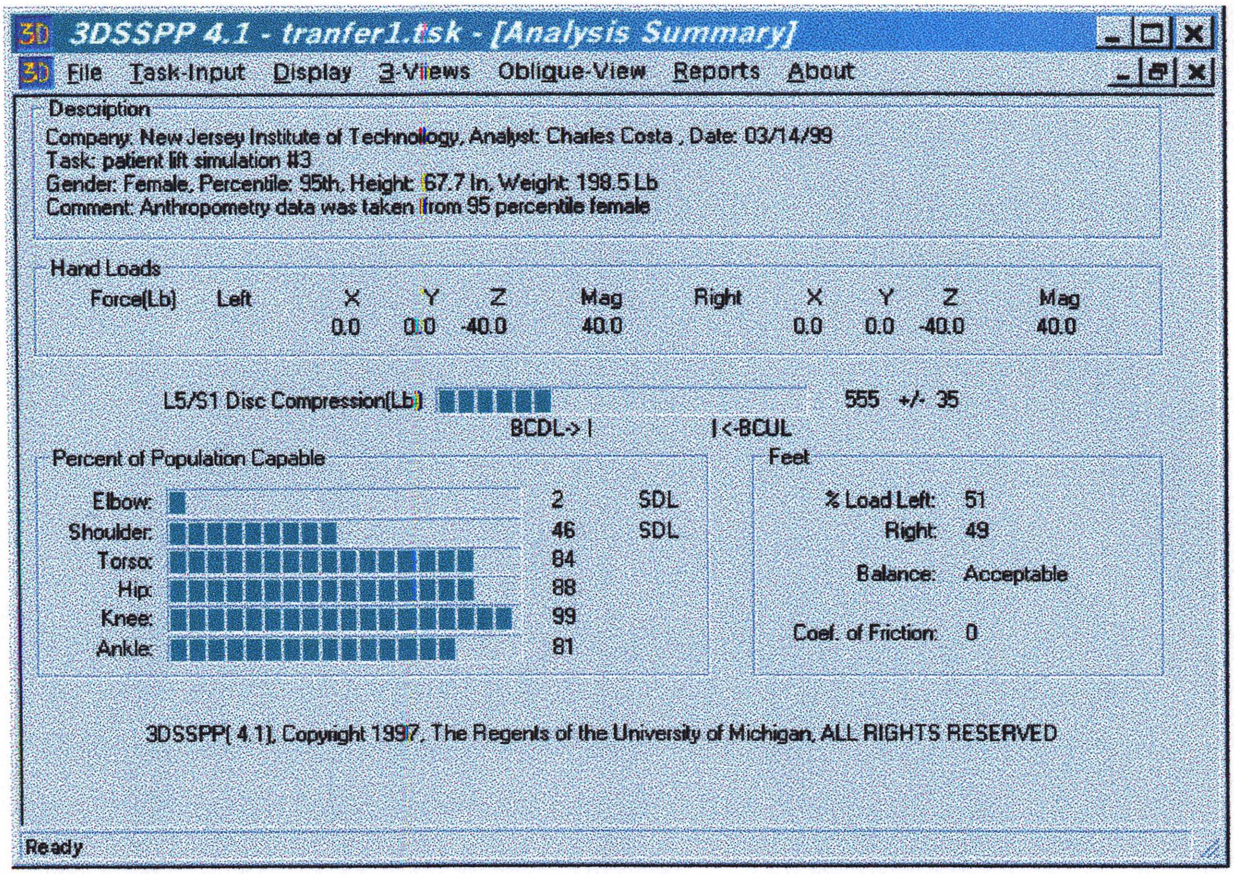


Figure 3.7
Task analysis for a 95 percentile female



3DSSPP 4.1 - tranfer1.tsk - [Analysis Summary]

File Task-Input Display 3-Views Oblique-View Reports About

Description
Company: New Jersey Institute of Technology, Analyst: Charles Costa , Date: 03/14/99
Task: patient lift simulation #3
Gender: Female, Percentile: 95th, Height: 67.7 In, Weight: 198.5 Lb
Comment: Anthropometry data was taken from 95 percentile female

Hand Loads

Force(Lb)	Left	X	Y	Z	Mag	Right	X	Y	Z	Mag
		0.0	0.0	-40.0	40.0		0.0	0.0	-40.0	40.0

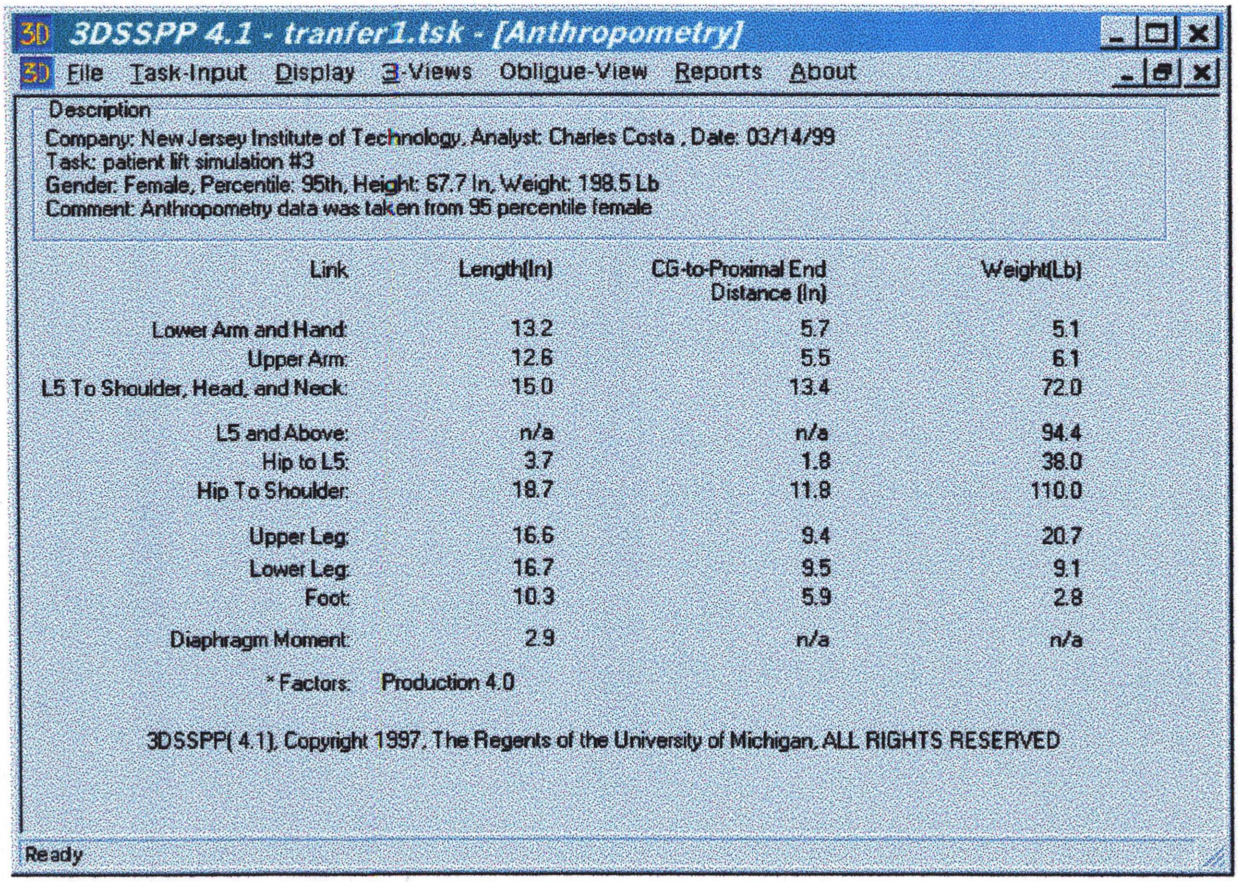
L5/S1 Disc Compression(Lb) 555 +/- 35
BCDL-> | |<-BCUL

Percent of Population Capable

Elbow:	2	SDL
Shoulder:	46	SDL
Torso:	84	
Hip:	88	
Knee:	99	
Ankle:	81	

Feet
% Load Left: 51
Right: 49
Balance: Acceptable
Coef. of Friction: 0

Ready



3DSSPP 4.1 - tranfer1.tsk - [Anthropometry]

File Task-Input Display 3-Views Oblique-View Reports About

Description
Company: New Jersey Institute of Technology, Analyst: Charles Costa , Date: 03/14/99
Task: patient lift simulation #3
Gender: Female, Percentile: 95th, Height: 67.7 In, Weight: 198.5 Lb
Comment: Anthropometry data was taken from 95 percentile female

Link	Length(In)	CG-to-Proximal End Distance (In)	Weight(Lb)
Lower Arm and Hand:	13.2	5.7	5.1
Upper Arm:	12.6	5.5	6.1
L5 To Shoulder, Head, and Neck:	15.0	13.4	72.0
L5 and Above:	n/a	n/a	94.4
Hip to L5:	3.7	1.8	38.0
Hip To Shoulder:	18.7	11.8	110.0
Upper Leg:	16.6	9.4	20.7
Lower Leg:	16.7	9.5	9.1
Foot:	10.3	5.9	2.8
Diaphragm Moment:	2.9	n/a	n/a

*Factors: Production 4.0

Ready

CHAPTER 4

WHEELCHAIR TYPES

This section describes the current types of specialized wheelchairs on the market today. There are many other types lifting apparatus used but my focus will be on wheelchairs.

Figure 4.1 illustrates the model LSPRS unit manufactured by 21st Century Scientific Inc. LSPRS stands for low shear power reclining system. The low shear system is used to increase operator comfort. The low shear system contains a mechanism to lower the chair back as it is being reclined. This prevents the users clothes from being pulled as the chair is being reclined. The seat back will go from nearly vertical to nearly horizontal. This model also shows the optional **(DIPLR)** Duel Independent Power Legrest mechanisms. This allows each legrest to be raised individually. The wheelchair back and legrest are electrically powered through a series of actuators.

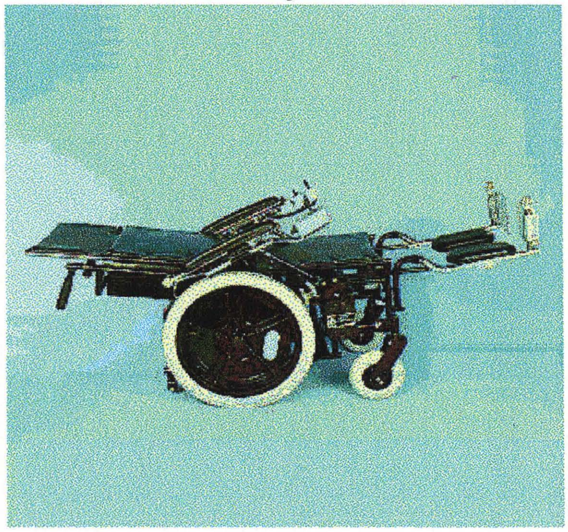


Figure 4.1 LSPRS Wheelchair

These actuators are controlled by the use of a joystick and a series of buttons. Speed and direction are controlled though the joystick. The switches select which mode the joystick is controlling.

The **(PSE)** Power Seat Elevator is another type of wheelchair manufactured by the 21st Century Scientific Corp. Shown in Figure 4.2. In this model the seat and back raise together a total of 6 inches, thereby elevating a standard 21 inch seat height to a height of 27 inches. In this model you also have the ability to add different options.

DIPLR – Dual Independent Power Legrests

LSPRS – Low Shear Power Reclining System

SCBPRS – Shear Compensated Back Power Reclining System

Figure 4.2 illustrates all these options. This company also offers the Recaro® Orthopedically-Correct Power Seating Systems as shown in figure 4.3 and 4.4 This system offers the ultimate in seating comfort and ergonomics. The standard features of the Recaro® system include:

- Airmatic Power Lumbar System
- Power Recliner
- Power Tilt/Seat Height Adjustment
- Manually Adjustable Seat Depth
- Manually Adjustable Headrest
- Manual Side bolster Adjustments
- Swing Away Detachable Footrests
- Back Pocket

Some of the optional equipment includes:

- Power Seat Elevator
- Legrest (manual or power)
- Flip-up Arms
- Seat Heating
- Climate Control Package (seat heating and venting)
- Leather Upholstery

The purpose of providing these pictures is to show that there are many types of wheelchairs on the market that provide comfort and varying degrees of mobility for the user, but none of them focus on the care giver and the stress endured when lifting a person from these units.

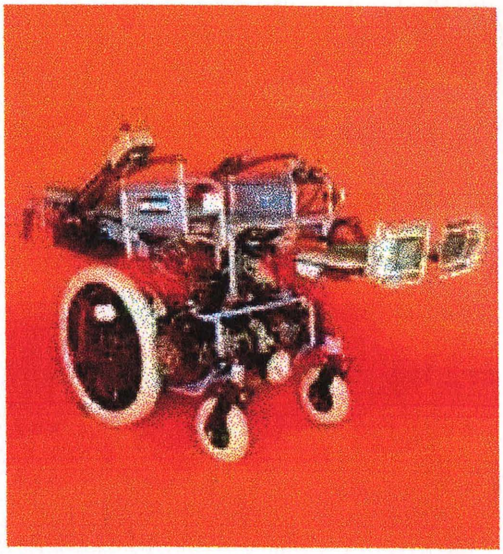


Figure 4.2 PSE Wheelchair

Figure 4.3 Recaro® Wheelchair

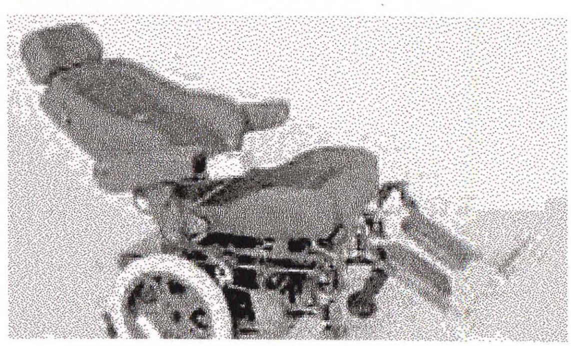


Figure 4.4 Recaro®Wheelchair reclined

CHAPTER 5
MECHANICAL PART

The basic premise of this model is to demonstrate a unique design idea intended for the benefit of healthcare workers and patients alike. The model prototype demonstrates the use of a tilt-back mechanism as well as a tilt-up mechanism. These mechanisms were designed to alleviate the stress the caregiver experiences when transferring a patient from a sitting state (wheelchair) to a supine position . The intended purpose of this model is to illustrate how these mechanisms will perform and how they simplify the task of transferring people with limited mobility, from a wheelchair. For this reason the prototype has been simplified. Major components such as wheels, steering, armrests, footrests, ...et. have been simplified or intentionally left out. These components are taken to be standard and are not needed to demonstrate the unique features of this model.

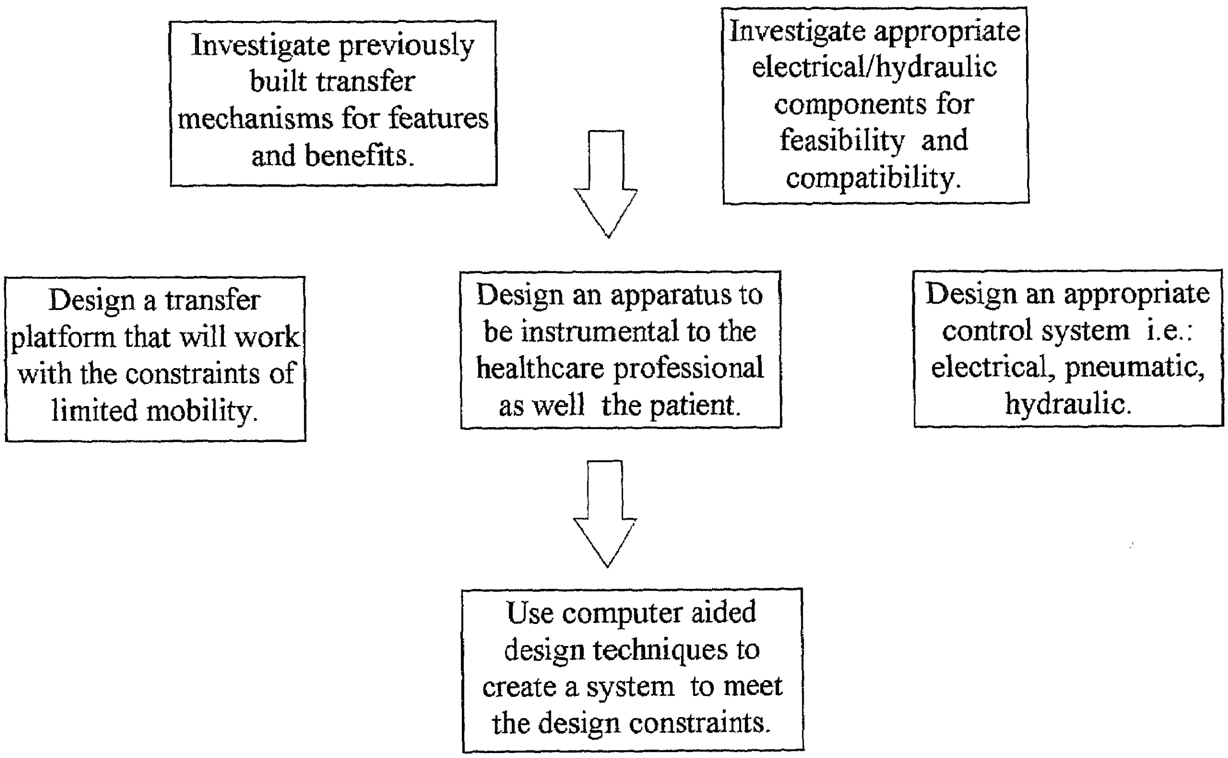
5.1 The Design Process

The basic prototype consists of one specialized component, this is the specially designed wheelchair. The first step in the design process was to sketch the basic feature of this new design(mainly a chair that tilts and reclines). The second step was to obtain information such as brochures, pamphlets and journals relating to wheelchairs. From this information I was able to come up with a drawing in which size, shape, and scale of the model were determined. From these preliminary drawings the model was developed. The purpose of the design was to alleviate the stresses that occur during patient transfers. Assuming that the highest biophysical stresses occur in the L5-S1 area (shown in the ergonomic section) the wheelchair was based around transferring a person from the sitting to standing position. A description of the steps used in the design process is shown in the design protocol Table 5.2.

Table 5.2

Design Protocol

A breakdown of the functions into simultaneous tasks to be combined into the final project.



5.2 Construction of the Model

During the design process some key ingredients were determined to keep the design as practical as possible for the home user to afford. These considerations were;

a) strength and durability

b) robustness for fashioning different shapes

c) weldability

d) cost

The wheelchair was designed using 7/8 diameter carbon steel tubing. This is the same material that is used in standard wheelchairs. There are four basic components to the frame of this unit. The first component is the main support frame or base. This is the section that all the other components are attached, and this component does not move. The seat section is attached to the base frame through the use of two steel pin hinges located at the front bottom of the seat section. The seat section is allowed to rotate from the horizontal position to the vertical position. The back rest is attached to the seat section. The back rest is jointed to the seat with two pin style hinges. It is allowed 90 degrees of motion, and this motion is dependent upon where the seat is at that particular point in time. The footrest is attached to the seat, but its motion is independent of the seat position. This is used to elevate the legs according to the users preference. The leg rest, seat, and back are positioned through the use of hydraulics. The hydraulics are controlled through the use of computer or plc. This system will allow the wheelchairs components to move in a very controlled systematic manner.

5.2.1 Model Drawings

Scaled drawings are provided at the end of this chapter. These drawings demonstrate the use of 3-D parametric solid modeling software. The advantage of using this software is, it enables the designer to see first hand if components will fit correctly, and the design is always drawn to the proper scale.

5.3 Calculation of Forces on Tilt Mechanism

Calculations were done on the mechanism in three positions to determine the maximum load on the hinge pins and actuators. From this information the size and materials of these components were selected. The motion of the chair back is achieved through the use of an hydraulic actuator. This unit is operated by a 12volt DC supply voltage and can attain forces which exceed the forces required to position the components. Figure 5.1 represents a side view of the mechanism linkage in the upright position.

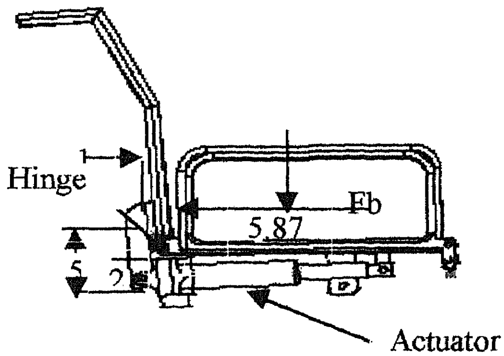


Figure 5.1
Side View of the Backrest Mechanism

Structural members of the wheelchair utilize a .875 diameter carbon steel tubing with .065 wall thickness. This was measured directly off a Tuffcare model 870 wheelchair. Back, seat and height were also taken from this model. The perimeter of the chair back is 69.5 inches or 5.791 ft. The weight is taken from The Ryerson stocks & services catalogue as .5623 lbs/ft. The weight of the back is taken to be 3.25 lbs.

The force on the back of the wheelchair is taken as the component of the force of the torso weight of an average person. The weight of the average person is taken to be 170lbs. The torso weight of the average person is taken to be 2/3 total body weight. In this case the force on the back of the chair is 113.33 lbs. As a factor of safety the back should support at least twice of that which is 226.66lbs.

5.3.1 Back Rest

Using Fig. 5.1 as our free body diagram we get the force required to support the chair back by the actuator: with chair back in the vertical position

$\sum M$ = sum of the moments

$$\sum M \text{ hinge} = 0 = F_{actuator}\ x\ (2) - 113.33\ (5.875) =$$

Factuator x = 332.90 lbs in the x direction is needed to support the back.

With a 2° angle on the actuator, Ø = 2° the actual force the actuator exerts is 500cos 2 = 499.6lbs. So the actuator will support this load.

With the chair back on a 45° angle, the force required by the actuator is;

$$\sum M \text{ hinge} = 0 = F_{actuator} = Fb(5.875) - 3.25\ (4.153) + 2\ Fx$$

Note the actuator is at 10° with x axis

Fx the force of the actuator in the x direction must be at least 339.65 lbs.

With the chair back @ 45° and the actuator @ 10° the actuator exerts a force of 500 cos10= 492lbs.

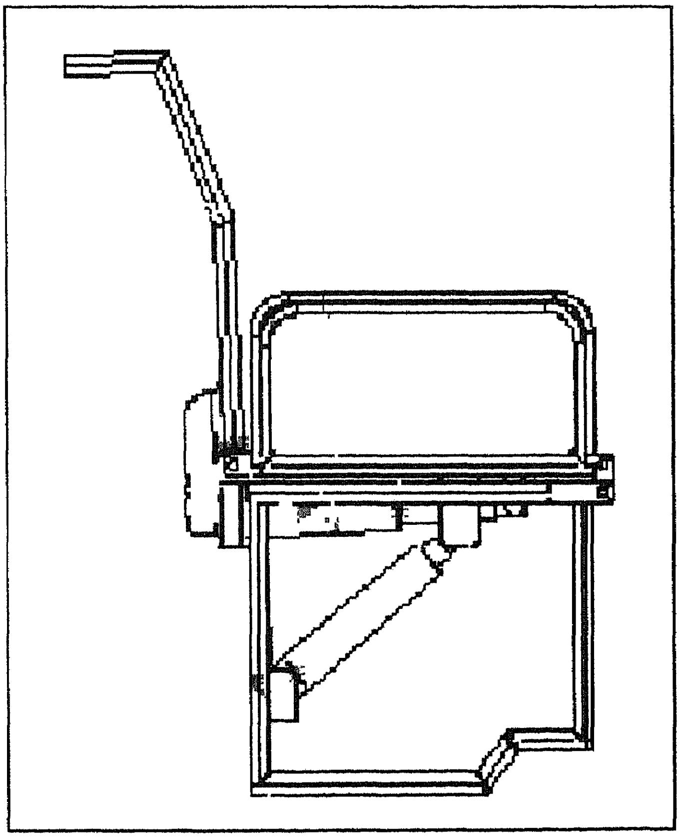


Figure 5.2
Back and Seat in the Down Position

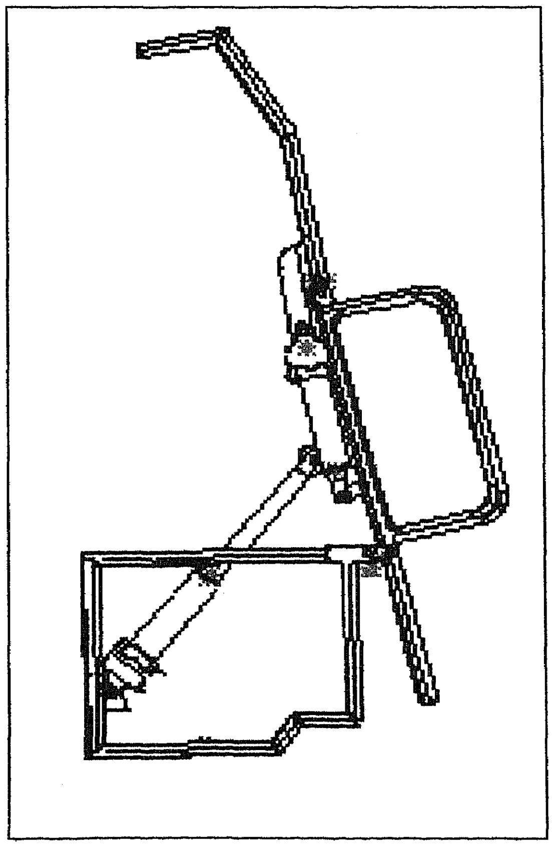


Figure 5.3
Back and Seat in the Upright Position

To calculate the force required to lift the seat from the horizontal position, refer to fig 5.2. Taking an average 170lb person sitting 2/3 back in the seat (12.54") and doubling the weight for safety concerns, if the total force on the seat of the chair is 340 lbs. then the force of the actuators required are:

Note: At the 0 position the actuator is at 35deg with the horizontal.

Factuator = 340lbs (12.54) / (6.5 sin 35)

Factuator = 1143 lbs and since there are 2 actuators it would be 571lbs / actuator.

At the raised position the actuator makes an angle of 40deg with the horizon.

Factuator = 340lbs (12.54) / (6.5 sin 40)

The force on each actuator becomes 1020lbs / 2 = 510lbs.

5.3.3 The Leg Rest

In order to obtain the maximum loading on the actuator, the forces must be observed when the leg rest is in the up and down position. With the leg rest in the down position, the leg rest is 60deg from the horizontal. The actuator exerts a force 25deg into the leg rest. Considering the weight of the average person to be 170lbs and the weight of the leg rest to be 10 lbs. The equation to determine the force required by the actuator is;

ΣM hinge = 0 = Factuator = (170)13.75sin60 + (10)13.75sin60 – Factuator (6)sin 25

Factuator = 845.25 lbs.

If the leg rest is in the up position the results are the following.

ΣM hinge = 0 = Factuator = Factuator (6)sin10 – 10(9) – 170(6.875) =

Factuator = 1210 lbs

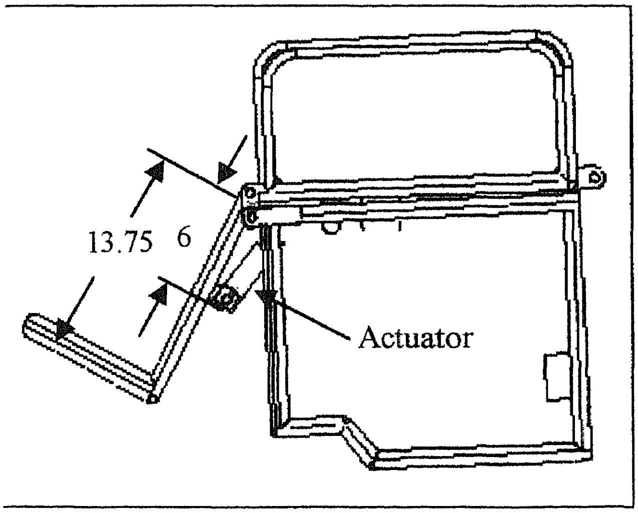
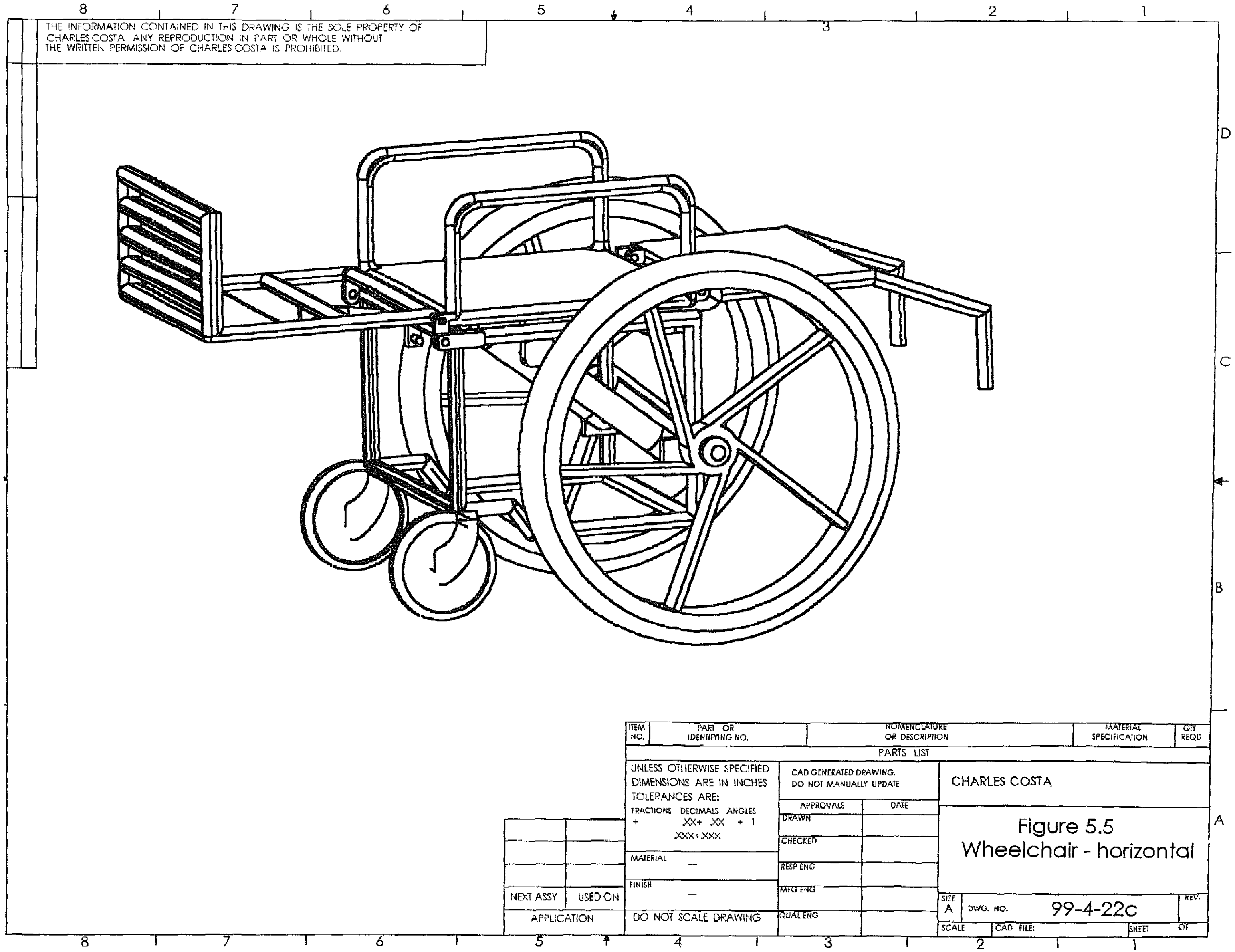


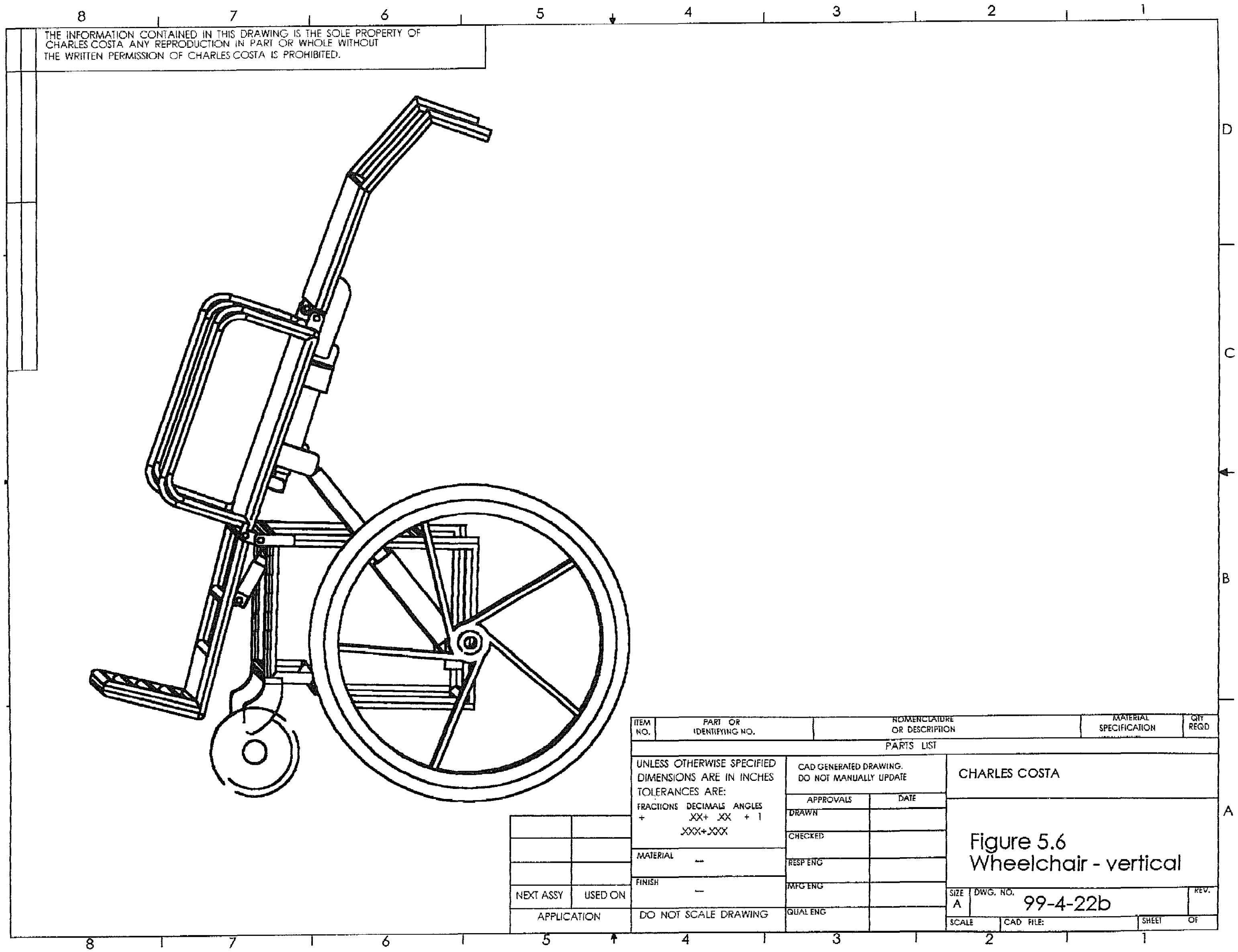
Figure 5.4
Leg Rest

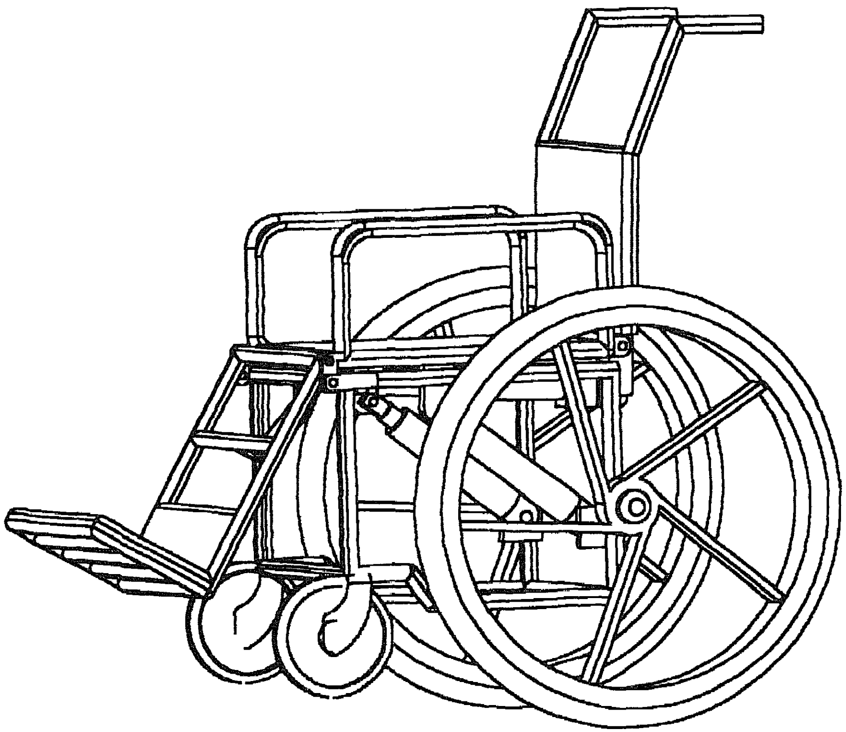
Note: Although the weight of the body will not typically be 170lbs, it was used to see the loading requirements of the actuators under certain circumstances.

5.4 Model Simulation

Simulation of the model was achieved through the use of a computer animation. This animation is driven directly from the parts files of the cad drawings. This is used to test the design in terms of its functionality and its mechanics. During the design stage, simple animations were utilized to check clearances of movable components.


THE INFORMATION CONTAINED IN THIS DRAWING IS THE SOLE PROPERTY OF CHARLES COSTA. ANY REPRODUCTION IN PART OR WHOLE WITHOUT THE WRITTEN PERMISSION OF CHARLES COSTA IS PROHIBITED.
ITEM NO.
PART OR IDENTIFYING NO.
NOMENCLATURE OR DESCRIPTION
MATERIAL SPECIFICATION
QTY REQD
PARTS LIST
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ARE:
FRACTIONS DECIMALS ANGLES
+ .XX+ .XX + 1
.XXX+.XXX
MATERIAL --
FINISH --
CAD GENERATED DRAWING. DO NOT MANUALLY UPDATE
APPROVALS
DATE
DRAWN
CHECKED
RESP ENG
MFG ENG
QUAL ENG
CHARLES COSTA
Figure 5.5
Wheelchair - horizontal
SIZE A
DWG. NO. 99-4-22c
REV.
SCALE
CAD FILE:
SHEET
OF
NEXT ASSY
USED ON
APPLICATION
DO NOT SCALE DRAWING


THE INFORMATION CONTAINED IN THIS DRAWING IS THE SOLE PROPERTY OF CHARLES COSTA ANY REPRODUCTION IN PART OR WHOLE WITHOUT THE WRITTEN PERMISSION OF CHARLES COSTA IS PROHIBITED.
ITEM NO.
PART OR IDENTIFYING NO.
NOMENCLATURE OR DESCRIPTION
MATERIAL SPECIFICATION
QTY REQD
PARTS LIST
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ARE:
FRACTIONS DECIMALS ANGLES
+ .XX+ .XX + 1
.XXX+.XXX
MATERIAL —
FINISH —
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
CAD GENERATED DRAWING. DO NOT MANUALLY UPDATE
APPROVALS
DATE
DRAWN
CHECKED
RESP ENG
MFG ENG
QUAL ENG
CHARLES COSTA
Figure 5.6
Wheelchair - vertical
SIZE A
DWG. NO. 99-4-22b
REV.
SCALE
CAD FILE:
SHEET
OF



ITEM NO.	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	MATERIAL SPECIFICATION	QTY REQD

PARTS LIST

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
TOLERANCES ARE:
FRACTIONS DECIMALS ANGLES
+ .XX+ .XX + 1
.XXX+.XXX

MATERIAL --
FINISH --

CAD GENERATED DRAWING. DO NOT MANUALLY UPDATE

APPROVALS	DATE
DRAWN	
CHECKED	
RESP ENG	
MFG ENG	
QUAL ENG	

NEXT ASSY | USED ON
APPLICATION

DO NOT SCALE DRAWING

Charles Costa

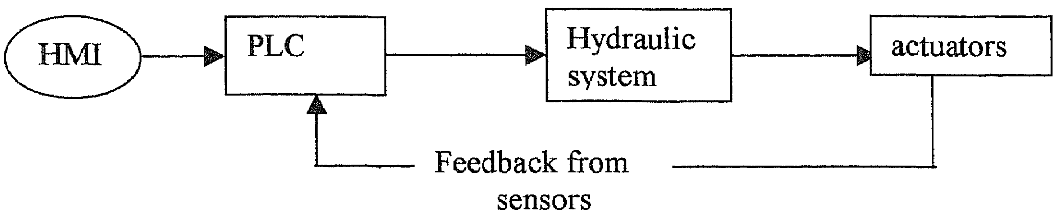
Figure 5.7
Wheelchair - seated

SIZE A | DWG. NO. 99-4-22a | REV.
SCALE | CAD FILE: | SHEET | OF

CHAPTER 6
THE ELECTRICAL CONTROL SYSTEM

The electrical control system is the system responsible for controlling the motion of the wheelchair in a specific manner. It is also the system that links man to the machine through the use of a Human Machine Interface (HMI). This system will also be responsible to provide for built in safety features, and to insure the safety of the operator and the system itself.

The basic system flow chart is as follows:



6.1 Human Machine Interface

The human machine interface is the panel of controls the operator will use to control this piece of equipment. It is also one of the most important parts of the machine as far as the operator is concerned. This interface must be able to perform its desired functions, interact with the controller and also be easy to use. It should take little or no effort to learn the controls so a maximum percentage of the population can use this system.

6.2 The PLC

The PLC or Programmable Logic Controller is the brain of the electrical system. This system is based upon a computer program which is processed via a central processing unit (CPU). See figure 4.1 This processor is the heart of the PLC and the PLC size and requirements are determined from its processor speed and memory limitations. The PLC requirements are also determined through its input and output (I/O) limitations. The program that is stored in the processors memory is nonvolatile. That is, it will not loose the program if the power supply is disconnected or lost. The program is stored in an area of the CPU called the EEPROM. The EEPROM or Erasable Programmable Read Only Memory has its own internal battery as a power supply. This is a separate supply from the main power which drives the PLC.

The software for the PLC is generally purchased separately from the PLC and each PLC manufacturer has its own unique language, which supports its various lines of PLC's. This program to drive the PLC is written using this software. It is generally done using a personal computer. Once the program is written and debugged, it is downloaded to the PLC.

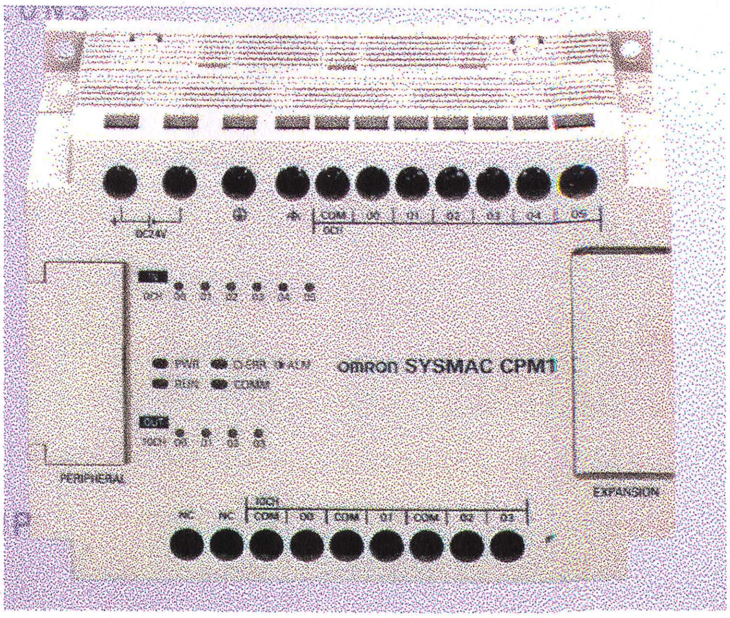


Figure 6.1

Figure 6.1 shows an Omron Micro-PLC model number CPM1. These units are offered with various features, such as different operating voltages and input / output configurations.

6.3 Feedback

Feedback is the process of sending information back to the controller or PLC to give an accurate representation of what is happening in the system. Based upon this information the PLC's program tells it to react in either a positive or negative way. Thus positive or negative feedback. In this case the feedback would be in the form of displacement from the hydraulic actuators. The method of getting this feedback would be by the use of the Hall Effect Principle.

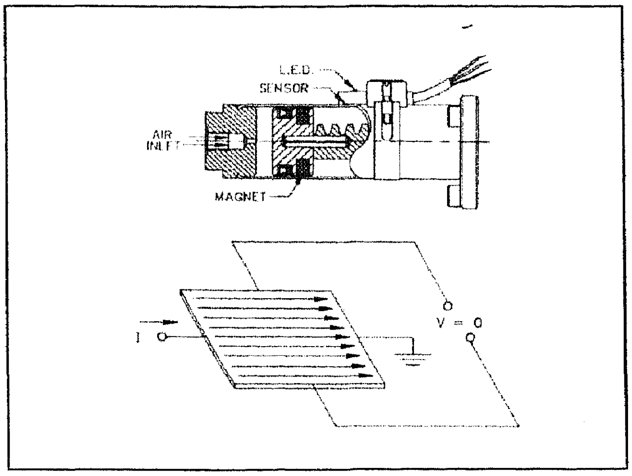


Fig. 6.2
Hall Effect Sensor V=0

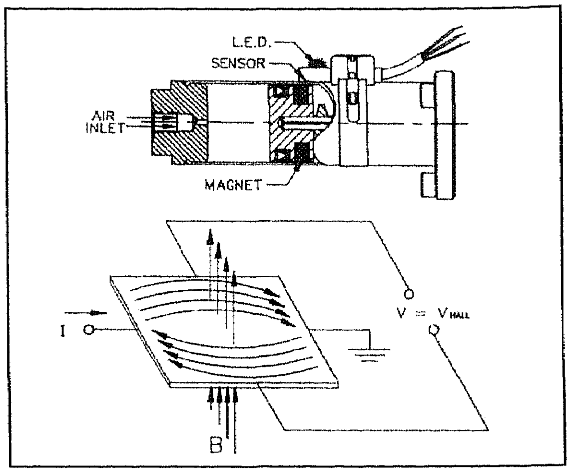


Fig. 6.3
Hall Effect Sensor V≠0

In operation a constant current is passed through the Hall sensor. When the magnet is not directly below the sensor, the current distribution will be uniform and no potential difference will exist across the output. V=0, see Figure 6.2. When the magnet is directly below the Hall sensor, it disturbs the current distribution. This produces a potential difference across the output, see fig. 5.3. The hall effect sensors are rigidly mounted to each cylinder or actuator. These sensors act like switches, in this case, they tell the PLC when the cylinders reach specific positions i.e. fully extended or fully contracted. This could also be done with simple, single pole microswitches, but the advantage to using these sensors are there are no moving parts. These sensors will never wear out do to mechanical reasons.

CHAPTER 7

THE HYDRAULIC SYSTEM

The hydraulic system is the power plant of the system. As the electrical system controls how and when the wheelchair moves, the hydraulic system provides the forces necessary to displace the wheelchair components in the desired position. This is a ideal application for a hydraulic system. Some of the main advantages to using hydraulics are as follows.

1) Hydraulics provide the high forces necessary to counteract the loads.
2) Hydraulics provide a smooth and stable operation, as compared to pneumatics in which the air is compressible.
3) Hydraulics are cost effective.

The main components of this hydraulic system will consist of hydraulic actuators, a pump and valving.

7.1 Hydraulic Actuators

Hydraulic actuators convert hydraulic working energy into mechanical working energy. They are the points where all the visible activity takes place and one of the first things to consider in the design of a machine. The specific type of actuators used in this design are called cylinders. Hydraulic cylinders transform hydraulic working energy into a linear mechanical energy. A symbolic representation a cylinder is shown in figure 7.1. The cylinder shown is a double acting cylinder. This means that the working force of the cylinder can be applied in both directions a and b. The force exerted by the cylinder is given by the

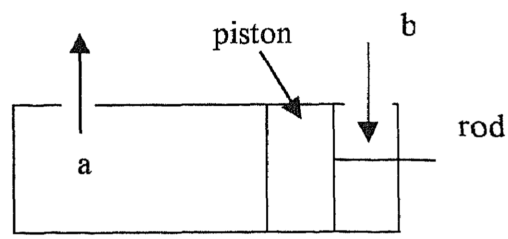


Figure 7.1
Hydraulic Cylinder

equation F = P x A. Where P is the pressure given by the hydraulic pump and A is the area of the piston. In the case where the piston is pulling the area is given as Area of the piston - Area of the piston rod , Parker-Hannifin (1980).

7.1.1 Calculations of Piston Diameter and Pump Size

As a result of the calculations done in section 3.0 we know that the forces required for the actuators are as follows.

The back rest actuator must apply forces of 492 lbs.

The seat (2 actuators) must apply forces of at least 571 lbs.

The leg rest must apply forces of at least 1210 lbs.

Using the largest force for the extreme value, 1210 lbs., we can conclude that if all the pistons exert forces of at least 1210 lbs. that will satisfy the constraints of the system.

If the piston diameter is taken to be 2" and the piston rod is taken to be 5/8 of an inch, then the pressure required by the pump is as follows.

P = F / A , where F = and A is taken to be piston diameter -rod diameter.

$A = 2.84\ in^2$ so, force/ area = pressure = 426.05 psi.

The pump must supply at least 426.05 psi to operate these actuators under these loading conditions. This is not an unrealistic pressure for a hydraulic pump, typically these pumps generate pressures of 1000 - 1500 psi.

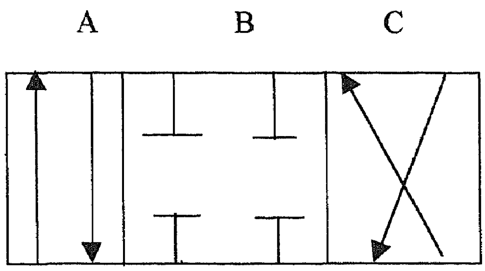
7.2 The Pump

The pump chosen for this type of application is a gear pump, more specifically a gerotor pump. This pump was chosen because there are no minimum speed requirements for the motor to drive this pump. A gerotor pump is an internal gear pump with an inner drive gear and an outer driven gear. The inner gear has one less tooth than the outer gear. As the inner gear is turned by the motor, it rotates the larger outer gear. On one side of the pumping mechanism an increasing volume is formed as the gear teeth unmesh. On the other side of the pump a decreasing volume is formed. A gerotor pump is an unbalanced design.

7.3 Directional Control Valves

The valve that must be used in this hydraulic circuit is a 4 - way directional valve. It is called a 4 - way valve because it has 4 distinct passages within its body. The function of a 4 - way directional valve is to cause the forward and reverse action of a double acting cylinder. The valve is activated through the use of an electric solenoid. This solenoid is powered through the control system. The control system also determines when the solenoid should be activated. This 4 - way valve is also described by its spool center position. In this valve the center position of the spool maintains a closed center condition. This means that when the valve is in the neutral or center position, it maintains pressure in the actuator as well as allowing each individual actuator to operate independently from the same pump. Fig 7.3 shows the symbol for a 4-way closed center directional valve. The valve is divided into 3 separate boxes. Each box represents what the valve flow would be, under each of its spool positions. Position A is where the actuator will extend to its outward position. Position B is where the actuators are locked in their present positions, and position C is where the actuators are in their return position.

Figure 7.3
Directional 4-Way Valve



7.4 The Complete System

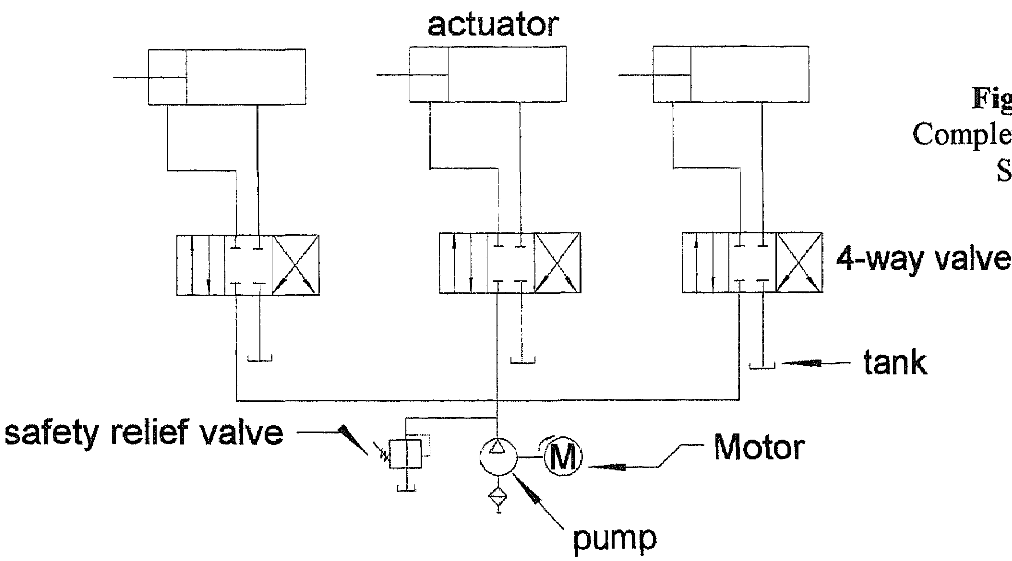


Figure 7.4
Complete Hydraulic System

The drawing of the complete hydraulic system (Figure 7.4) shows how the actuators, valves and pump are arranged in the circuit. Each actuator and valve represents one assembly of the wheelchair that moves. The first actuator and valve is for the motion of the leg rest. The second is for the seat and the third is for the back rest. The valves and the motor are coupled with the electrical system and this is what controls the motion of the system. The operator interface creates the signals, the plc processes the signals and sends the appropriate signals to the individual actuators as required. The feedback from the actuators is sent back to the plc. This feedback is used as an interlock feature. The purpose of this feature is to ensure that the actuators are in their right full positions before the next operation or movement occurs.

CHAPTER 8
CONCLUSION

The finding of this study indicated that nursing staff did indeed encounter high levels of stress during the process of transferring patients. This stress was shown to be higher than acceptable levels for a task as per given by the National Institute of Safety and Health Administration. Other factors to be considered in addition to the weight of the patient and the distance in carrying the patient are other frequently occurring patient variables such as frailty, combativeness, pain, fractures, and unpredictability. All of these can have an impact on the safety of nursing personnel as well as the safety and comfort of the patient.

The prototype demonstrates a way of reducing the stressful job of nursing staff as well as safety of caregiver and the patient. This design eliminates the caregiver from over exertion by allowing the wheelchair to provide the forces needed to lift the patient. It also will reduce the amount of mental stress on the patient and caregiver. Because this devise physically looks like a standard wheelchair, the patient and caregiver would not have a reluctance to use it. This prototype can also be used as a standard wheelchair so no other external devises are needed when a transfer is required. One important aspect of this design is that it does not look intimidating and frail. When a patient sees a sling or a manual lifting devise, they get nervous because the lifting mechanism does not look safe, or it looks uncomfortable, with this wheelchair you will not have that problem.

The chair was designed to keep in tact the original design parameters i.e. seat height, wheel diameter, overall width and length . The frame sizes of members were not changed. The electrical system was designed with the safety of the user in mind. This is why a computer processor with feedback is used to control the motion. Components will not move until the previous component is in the desired position as checked by the processor. The hydraulics were utilized to ensure a safe, reliable and smooth transition of motion.

REFERENCES

Garg, A., B.D.,Beller, D.,Banaag, J., 1991. A biomechanical and ergonomic evaluation of patient transferring tasks: bed to wheelchair and wheelchair to bed. Ergonomics 34, pp. 289-312.

Garg,A., Owen,B., 1992, Reducing back stress to nursing personnel: an ergonomic intervention in a nursing home. Ergonomics vol. 35, no 11, pp. 1353-1375.

Klein, B.P., Jensen, R.C., Sanderson, L.M., 1984. Assessment of workers compensation claims for back strains / sprains. J. Occup. Med. 26, pp.443-448.

Kroemer, K., kroemer, H.,and Kroemer-Elbert, K. "Ergonomics". Englewood Cliffs, N.J. Prentice-Hall, 1994, p. 111.

Lindbeck,L., Engkvist,I.L., 1992, Biomechanical analysis of two patient handling tasks. 1993, International Journal of Industrial Ergonomics. 12, pp. 117-125.

Macllwain C, "Robotic stretcher takes the strain off nurses' backs" Journal -The Engineer, Feb. 1993, Vol 276, pp. 36.

Oberg E, Jones D. F and Holbrook L Horton, "Machinery's Hand Book, 23rd edition", published by Industrial Press Inc, New York.

Owen, B. D. and Garg, A., 1989 ,Patient handling tasks perceived to be the most stressful by nursing assistants, Advances in Industrial Ergonomics and Safety 1, pp. 775-781.

Owen B.D., Ph.D., R.N., Arun Garg, Ph.D., 1994, "Reducing back stress through an ergonomic approach: weighing a patient." International journal of nurses student ; vol. 31, no. 6 , pp. 511-519.

Owen B.D., Ph.D., R.N., Arun Garg, Ph.D., "Back stress isn't part of the job", American journal of nursing, Feb. 1993 pp. 48-51.

Pamphlets:

(i) Action storm series , Arrow and Torque
899, Cleveland street , Elyria, Ohio 44035

(ii) Stryker Medical
6300, Sprinkle Road, Kalamazzo, Michigan 49001-9799

REFERENCES
(Continued)

(iii) Amedco health care, inc. An Everest and Jennings Co.
401, S. Outer Service Road, Wright City , MO 63390

(iv) Hausted Inc.
927, Lake Road, P.O. Box 710, Medina, OH 44258-0710

Parker-Hannifin, Bulletin 0221-B1, "Industrial Hydraulic Technology" 1980

Parker-Hannifin, Bulletin 0224-B1, "Design Engineers Handbook" 1980