THE UNIVERSITY OF ALBERTA

TO DETERMINE THE CHANGES IN UPPER BODY MUSCULAR STRENGTH OF SPINAL CORD INJURED INDIVIDUALS AS A RESULT OF A SIX WEEK TREATMENT SESSION USING NAUTILUS EQUIPMENT

by

© HENRIETTE JANINE GROENEVELD

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled TO DETERMINE THE CHANGES IN UPPER BODY MUSCULAR STRENGTH OF SPINAL CORD INJURED INDIVIDUALS AS A RESULT OF A SIX WEEK TREATMENT SESSION USING NAUTILUS EQUIPMENT submitted by HENRIETTE JANINE GROENEVELD in partial fulfilment of the requirements for the degree of MASTER OF SCIENCE.

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Supervisor

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Date...April 10, 1986.......

DEDICATION

To my parents

Hans Groeneveld

and

Jeannette Groeneveld - van Baak

with love

ABSTRACT

The purpose of this study was to determine the changes in upper body muscular strength of spinal cord injured individuals as a result of a six week treatment session using Nautilus.

Five male individuals were involved with complete lesions in the thoracic region. The individuals were between 27 - 47 years of age. The individuals were tested on shoulder and elbow strength and endurance using Cybex II. Two training programs were used. Subjects C and E completed a ten week program while subjects A, B, and D were involved in a twelve week program. After the initial test on the Cybex II, subjects C and E were tested on the Cybex II again after the 1st and 2nd week. The treatment on the Nautilus started in the 3rd week. The Nautilus sessions were done three times a week for six weeks. On the 2nd, 3rd, 4th, 6th, and 8th week after the initial test, Cybex and Nautilus sessions fell on the same day, a fifteen minute rest period was implemented between the two. After the six week treatment period, the treatment was stoppped and after two weeks of rest another testing session on the Cybex II was completed.

Subjects A, B, D were tested the 1st, 2nd, and 4th week after the initial test. This group started their training on the Nautilus after the 4th week, they also performed on the Nautilus three times a week. Testing sessions during the treatment period were held on the 5th, 6th, 8th, and 10th week after the initial test. Same procedures were followed as subjects C and E, if the testing and treatment fell on the same day. Also after the six week treatment period the treatment was stopped and subjects A, B, and D followed again the same procedures as subjects C and E.

The data on the Cybex II yielded measures of strength and endurance of major muscle groups while performing the shoulder and elbow movements over time. In addition the data on the Nautilus weight training equipment gave accurate readings of the weight lifted on each

machine at each training session. Both sets of data were presented graphically and subjected to visual analysis. The experimental design on the Nautilus weight training equipment was a changing criterion to increase systematically and gradually the subjects performances over the six week treatment period. The graphs representing the Cybex II results were assessed according to trend, level, and variability of performance between and within the three phases.

It was expected that performances on the Cybex II would show a stable baseline throughout the pre-treatment period followed by an increased trend over the six week Nautilus treatment period. An interruption of training would then result in a decrease in trend. The results indicated significant increases in performance by all subjects on the Nautilus weight training equipment from a three percent increase to a 221 percent increase. The Cybex II testing equipment data showed relative stable pre-treatment performances on the shoulder and elbow flexio/extension variables. The initiation of the treatment program did not result in positive changes in performance

It seemed that the specificity factor of training and motivation played an important role in this type of study. The conclusion of this study appeared that the Cybex II isokinetic testing device and the Nautilus isotonic exercise device might not have been the appropriate criterions for testing and training of muscular strength of spinal cord injured individuals.

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INTRODUCTION

Until World War II the attitude of society toward the physically disabled was so negative that they were often kept hidden from the public (Guttmann,1976). Following World War II the number of disabled individuals increased dramatically. In response to the needs of many seriously injured combatants, Sir Ludwig Guttmann, a noted neurosurgeon, pioneered a comprehensive care system for victims of spinal cord trauma. Due to his treatment innovations in the late fifties and early sixties, the death rate decreased effectively from ninety percent to twelve percent (Gains,1982). These advances in medicine and rehabilitative treatment have been largely responsible for increasing the life span of the physically disabled so that it now approaches that of the general population (Guttmann,1976).

Better treatment, rehabilitation methods and increased longevity have necessitated greater public awareness and have encouraged the start of recreation and competitive sport programming for the physically disabled. Efforts were first made to develop sports competition for the physically disabled by Guttmann in 1946. He introduced sports to traumatic paraplegics as part of their medical treatment (Gains,1982) and since that time interest in health promotion of the physically disabled through participation in sports, fitness, and lifestyle programs has visibly increased. In 1948 the First Stoke Mandeville Games were held with only sixteen competitors. At the First Olympic Games for the Physically Disabled held in Rome, Italy in 1960, there were 400 participants and by 1980, participation had mushroomed to over 2500 athletes at the Sixth Olympic Games in Arnhem, the Netherlands.

Not only has participation increased but the quality of sport performances has also improved. A comparison of the track and field results of the 1976 and 1980 Olympic Games for the Disabled with the 1984 World Wheelchair Games indicates that previous records have been surpassed. World records are still being broken on a regular basis (Appendix A). In addition, wheelchair athletes are competing in longer track distances, for example 5000 meters, 10000 meters, and marathons. These events were introduced for the first time at the Seventh World Wheelchair Games in England in 1984. Wheelchair track events were held for the first time at the 1984 Los Angeles Olympic Summer Games on a demonstration basis. The best female wheelchair athletes participated in the 800 meters and the best male wheelchair athletes participated in the 1500 meters. Sharon Hedrick of the United States won the 800 meters in 2:15:73 minutes. Paul van Winkle of Belgium won the 1500 meters in 3:58:50 minutes (McBee,1984). The age of wheelchair athletics has arrived. Accessibility, public awareness, legislation and renewed determination to be involved have fueled the fire for wheelchair athletes (Dawson,1980). Because the growth in sports participation and quality of sport performances have been so rapid, serious problems have arisen with inappropriate training programs, poor conditioning, and inadequate coaching (Dawson,1980). The unique needs of these athletes dictate that detailed assessments and prescriptive training programs be provided. An adequate assessment and training program should include:

1. an assessment of physically disabled individuals' performance and fitness levels.
2. the design of an appropriate training programs specific to the individual's needs, capabilities, and sport.
3. a record of the progress of the individual.
4. monitoring of the individual's program.
5. establishment of training necessary to elicit optimal improvement in performance.
6. provision of up-to-date information on training programs of the physically disabled athlete (Steadward,1980).

At present there are only three major centres in Canada that provide any assessment and prescriptive services for the disabled. These centres are: the Research and Training Centre for the Physically Disabled, University of Alberta, Edmonton, directed by Dr. R. D. Steadward; Variety Village, Scarborough, Ontario, directed by Dr. G. Ward; and the Research Laboratory, University of British Columbia, Vancouver, directed by Dr. K. Coutts.

Due to the rapid growth of wheelchair sports, serious questions have arisen concerning the physiological aspect of exercise training after spinal cord trauma. In the past, most of the training and coaching information was compiled from data collected on able bodied athletes (Dawson,1980). Little research was conducted to scientifically determine the chronic effects of wheelchair athletics on the physically disabled participants. Also, the main focus of physiological research for the physically disabled has been on the cardio-vascular system, whereas, little attention has been given to the training of muscular strength (Davis,1981; Dawson,1980). According to Frey (1975) and Davis (1980), muscular strength is one of the most important factors in wheelchair sports, and yet the assessment of strength of physically disabled individuals is still in its infancy. Currently, muscular strength has been studied utilizing four different techniques: hand dynamometer (Zwiren,1975), repetitive weight lifting (Nilsson,1975), static upper arm cable tensiometry (Gersten,1963; Kofsky,1986),and isokinetic upper body strength (Grimby,1980; Davis,1986).

In response to the recent growth in sport participation by the physically disabled, the corresponding increase in athletic performances, and the need for muscular strength research, the present study evolved. It was designed to focus on the assessment of muscular strength and the evaluation of resistant training programs. The specific purpose of this study was to determine the changes in upper body muscular strength of spinal cord injured individuals as a result of a six week treatment session using Nautilus equipment.

A. Delimitations

1. The study was restricted to five individuals with spinal cord injuries involving complete lesions in the thoracic region.
2. The age of the subjects was between twenty-seven and forty-seven years.
3. The Cybex II isokinetic dynamometer was used on the following movements during testing:

   a) Shoulder flexion and extension

b) Elbow flexion and extension.

4. The Nautilus was employed for all treatment sessions on the following exercises:

   a) Behind Neck

   b) Double Shoulder (Lateral Raise)

   c) Double Chest (Arm Cross and Decline Press)

   d) Biceps Curl

   e) Triceps Extension.

5. The subjects volunteered for this study.

6. The subjects' motivation level during the testing and treatment sessions could not be controlled.

7. There was no control on activity outside the training sessions.

8. The physical condition of the individuals prior to program varied.

9. The physical condition of the individuals prior to trauma varied .

B. Definitions of Terms

Paraplegia: refers to paralysis of the lower legs and trunk resulting in impaired function and sensation.

Complete spinal cord injury: indicates no "sacral sparing" as evidenced by perineal sensation.

Strength: is the maximal force that can be exerted against an immovable resistance by a single contraction.

Isokinetic exercise: involves maximal force production of a muscle or group of muscles throughout the entire range of motion at a controlled speed of contraction.

Cybex: is an isokinetic device that provides accommodating resistance against a lever moving at a set angular velocity. The resistance supplied by the machine is exactly the same as the input arm of the device.

Nautilus: provides a variable form of resistance through the use of a cam. Typically, at the start of the movement the available force is low, so the radius of the cam is small and therefore the resistance is low. As the individual moves further into the range of motion, the force increases and consequently the radius of the cam becomes larger and thus the resistance is increased to match the higher force level.

Chapter II

SELECTED REVIEW OF LITERATURE

A. Individuals with Spinal Cord Injuries

The many causes of traumatic paraplegia range from complications at birth and falls, through bullet wounds and sport injuries to industrial and road accidents. According to Guttmann (1976), the most frequent cause of traumatic paraplegia is road accidents, while sports injuries represent the second highest number. In the most recent statistics available from the Canadian Paraplegic Association (1985) 44.5% of new spinal cord injuries which occurred between April 1,1984 and March 31,1985 were related to motor vehicle accidents.

Injuries from road accidents are frequently associated with fractures of the bones of the spinal column. The spinal cord can also be damaged by dislocation of one bone upon the other without any signs of fracture. The paralysis is caused by interruption of the nerve pathways going from the brain to the involved limbs. The function of these pathways may be disturbed because of pressure on the spinal cord from bony fragments or from soft tissue from the discs.

If the pressure can be removed quickly enough and the blood supply to the area restored, then the nerves may begin to function again. When this occurs, it is referred to as an incomplete lesion. A complete spinal cord injury which exists for a twenty-four hour period will usually not have significant functional recovery. The cord injury is complete if there is no "sacral sparing" as evidenced by perineal sensation (Cull,1977; Hardy,1975).

B. Cybex II - Isokinetic Dynamometer

An isokinetic exercise unit such as the Cybex II has been in use since the early 1970's. Cybex II is a mechanical device which assesses muscle strength isokinetically (Elliot,1978).

Cybex II makes it possible to control a constant speed at which a body segment moves through a full range of motion. Once the isokinetic device is set at a specific operating speed, the internal mechanism will prevent the lever arm from surpassing it's predetermined speed. Any increased muscular output applied to the lever arm will produce increased resistance rather than increased acceleration (Moffroid, 1969; Thistle,1967; Hislop,1967; Perrine,1968). The isokinetic device also allows resistance to be applied in two opposing directions. Because of this feature it is possible to concentrically exercise opposing muscle groups simultaneously (Coplin,1971).

The Cybex II isokinetic system consists of three components: the first component is a dynamometer which measures torque input up to 360 foot/pounds or 488 Newton Meters (Nm). The resistance supplied via the input attachment varies automatically to accommodate the fluctuating force applied by the subject. Any force applied against the input attachment is measured as torque on the input shaft and displayed on the dynamometer. The second component is a speed selector which can be set to obtain a constant speed of rotation from 0 to 35 rpm (.175 to 4.716 radians per second). Once a speed is selected, the input shaft can not be accelerated beyond that speed regardless of the input torque applied below 360 foot/pounds or 488 Nm. The third component is a dual channel recorder. It has input to the dynamometer and an electrogoniometer and thus can simultaneously produce and display a permanent written record of the applied torque and the range of joint angles across the entire range of motion of the limb being tested (Lumex Corporation,1975; Thistle,1967; Elliot,1978).

Moffroid and colleagues (1969) reported a 0.999 co-efficient of validity of predicted to obtained torque measurements and a 0.995 co-efficient of reliability for torque output. A correlation of 0.985 was found for 34 points on generated torque curves to ensure a constant velocity of the input arm throughout the full range of motion.

C. Nautilus Weight Training Equipment

Nautilus exercise machines are a relatively new commercial training system which Arthur Jones introduced in 1970 after experimenting for twenty years (Darden,1980). Nautilus manufacturers saw the need to redirect gravity employing rotary resistance in order to provide each muscle with "overload" throughout the entire range of motion. Nautilus is not isokinetic, for it maintains no control over movement speed, but Nautilus theoretically provides variable resistances which suggests that it effectively matches the shapes of typical human strength curves throughout specified ranges of movement (Heusner,1980; Nautilus Sport/Medical Industries,1982; Hobson,1983). The resistance is varied by the use of carefully designed cams and spiral pulleys. That is, the resistance automatically is increased at those points where the muscles are strongest and is decreased where the muscles are weakest (Heusner,1980; Nautilus Sports/Medical Industries,1974 and 1979). Each machine employs a different cam because each movement has its own distinct strength curve (Fleck,1979). The Nautilus is claimed to be scientifically designed to produce optimal increase in muscular strength, muscular hypertrophy, and flexibility with minimal discomfort (muscle soreness) in a relatively brief period of time (Coleman,1977; Darden,1974; Fox & Mathews,1981).

D. Strength training programs

There have been numerous strength training programs devised for able-bodied individuals. For the purpose of this study isotonic strength training programs performed on the upper body will be emphasized.

Isotonic exercise can be defined as the action of moving weights through a range of motion. The resistance to the body segment (skeletal lever) remains constant during the full range of motion. However, the resistance to the muscle is not constant because of the modifying effects of the lever system through which it must pass (Hislop,1967; Perrine,1968).

The first individuals who attempted to outline specific procedures for isotonic training were DeLorme and Watkins (1948). They presented a protocol for load resisting exercise which is referred to as progressive resistive exercises (PRE). DeLorme's (1952) application of PRE to adolescent boys in both elbow flexion and knee extension for a four month period resulted in an average increase in strength of 59% and 49% respectively as measured by one repetition maximum (RM).

Houltz (1946) applied PRE to female subjects, exercising quadriceps and muscles involved in handcurls. He found that in four weeks of training strength increased by more than double the initial amount.

Berger (1962) looked at the effect of nine different weight training programs to determine which were more effective in improving strength. The weight training program took twelve weeks and training was performed three times a week. The program varied from 1, 2, or 3 sets and from 2, 6, or 10 repetitions per set. Berger found that three sets of six repetitions was the best for improving strength.

Sanders (1980) compared the responses of twenty-two college age males to training using traditional barbell equipment and nautilus equipment. He took a pre- and post test on two-minute bouts of rhythmic isometric exercises involving forearm extensors and shoulder flexors. Weight training was performed three times a week for five weeks. Each workout consisted of different exercises each performed for three sets of six repetitions. Sanders found a significant improvement as a result of training in both groups. He concluded that training with the traditional barbell method or nautilus dynamic equipment three times a week for a period of five weeks using the PRE method was sufficient to produce significant gains in muscular strength. Stull and Clarke (1970) looked at twenty male university students who participated in a six week training program three times a week. They performed three sets of ten repetitions of arm curls against a resistance of one-half 10 RM, three-quarters 10 RM and 10 RM. Pre- and post test consisted of a series of 150 maximum contractions performed every other second over a five minute period. The results of the PRE training program employed in this study elicited parameters of initial strength, final strength, and total work.

In summary there are very few research studies which address the development of muscular strength of the upper body. Those cited concluded that as little as four weeks of a PRE program will significantly increase muscular stength and that anywhere from three sets of six to ten repetitions will also improve strength.

E. Specificity of Training

Pipes and Wilmore (1975) performed a study on isotonic versus isokinetic strength training. They divided the subjects into four groups - isotonic, isokinetic (low), isokinetic (high), and control. The subjects trained three times a week for eight weeks on different isotonic exercises. The four groups were tested on static strength and dynamic strenght. The dynamic strength was measured isotonically with determining an one repetition maximum on leg press, elbow flexion, and bent rowing and isokinetically with Cybex II isokinetic device at 24 deg/sec and 136 deg/sec on elbow flexion, triceps extension, shoulder extension, and simulated bench press and on the device used for the training program which is leg press isokinetic press device and bench press isokinetic training device. Isotonic measurement of dynamic strength indicated a significant increase in the isotonic group. However, no significant difference for the isotonic group was recorded on either isokinetic measurement.

Also Moffroid and colleagues (1969) performed a study in which sixty subjects completed four weeks of isometric, isotonic, or isokinetic exercise training. Each group was tested on the isokinetic device once weekly. The results indicated that the isotonic group when tested on the isokinetic device showed no significant difference between pre and post tests. The researchers concluded that muscular response to a given exercise system was relatively specific with regard to the effects on the torque curve. In addition, other neuromuscular influences and the degree of motivation in delivering a maximal effort had to be considered.

A study by MacDougall et al (1977, 1979, 1980), who had subjects training their triceps brachii muscle on several weight training exercises involving elbow extension made similar conclusions. Although there were substantial increases in weight ifted, elbow extension strength measured on the isokinetic dynamometer showed no significant increase. In a second experiment where the subjects performed the same weight training program but also practiced on the isokinetic dynamometer three times a week, significant improvements were noted in both weight lifted and dynamometer scores. It was concluded that the physiological basis for this aspect of specificity was the fact that neural adaptations plays an important role in response to strength training.

The above researchers found that when training individuals on isotonic exercises there were no significant differences between the pre- and post scores when tested on the isokinetic testing devices.

F. Factors related to Muscular Strength Increase

In addition to the role of specificity of training which was previously illustrated, there are a number of other factors which frequently interact to produce changes in strength measures.

Increases in muscular strength are often attributed to muscular hypertrophy, specifically the increases in the cross sectional area of individual muscle fibers (Lesmes,1978; Fox & Mathews,1980; Schmidtbleicher,1985). In studies where strength gains were not accompanied by muscle hypertrophy (Lesmes,1978), it was suggested that the increases in torque outputs were due to other muscular or possible neuromuscular adaptations.

Heusner (1980) has stated that physiological, morphological, and neurotrophic alterations play an important role in the response to muscular training which occur in the synapses, peripheral nerves, and motor end plates of the neuromuscular junctions. Although the specific implications of these training effects are not clear it is known that specific proteins synthesized in a given muscle fiber, the contractile speed of that muscle fiber, and the predominant type of energy metabolism in the muscle fiber are all under neural control. Besides complicated functions in the mechanical, biochemical, neural, and endocrine areas that contribute to increases in muscular strength, the learning of a motor skill also plays an important role in this integrated system.

According to Schmidtbleicher (1985) and Heusner (1980) short term increases in performance can be based on a coordinative learning effect. The subjects can coordinate the timing of the musculature involved in the training movement. As a skill is learned, effective, ineffective, and antagonistic motor units may be recruited. By a gradual process of neuromuscular trial and error in conjunction with feedback from various internal and external sources fewer and fewer noneffective motor units are dropped and more efficient motor units are activated by the Central Nervous System. Gradually during the training period the retained motor units are organized until a highly effective pattern of motor unit activity is established and there is a comparable decrease in energy expenditure.

G. Strength training programs for paraplegics

It is difficult to evaluate the effectiveness of different training programs on spinal cord injured individuals because of their heterogeneous nature. Each subject presents a different picture with respect to age, site of lesion, degree of activity prior to injury, duration of disability, and motivation. The research data on muscular strength in spinal cord injured individuals has been collected by to the following techniques eg. hand dynamometer (Zwiren,1975), repetitive weight lifting (Nilsson, 1975), static upper arm cable tensiometry (Gersten,1963; Kofsky,1983), and lately, isokinetic upper body strength (Grimby,1980; Davis, 1983).

Zwiren (1975) looked at four groups, namely able-bodied athletes, able-bodied sedentary individuals, wheelchair athletes, and wheelchair sedentary individuals. One of the test items was grip strength. He took duplicated measurements from each hand using a Smedley hand dynamometer. Zwiren found that grip strength (highest value of the dominant side) was not significantly different among the four groups.

Nilsson (1975) examined twelve paraplegics for aerobic work capacity and muscular strength. Only seven subjects completed the training program three times a week, for seven weeks. Muscular stength testing consisted of:

1) maximal dynamic stength (the heaviest load the subject could lift with their arms while lying on their back), and

2) dynamic endurance (the maximal number of times the subjects could lift approximately 85% of that weight).

The weight training included triceps training in both sitting and supine position, biceps training, abdominal training, and medicine ball throwing. After the training period, the muscular strength tests were repeated. Nilsson found that testing results before and after training showed significant improvement in maximal dynamic strength and dynamic endurance. The mean dynamic strength increased from 64 to 76 kg ($p<0.005$) and the mean dynamic endurance increased from 10 to 18 repetitions ($p<0.01$) . He concluded that a seven week training period, three times a week using weight lifting and armcranking resulted in a significant improvement in both muscular strength and maximal aerobic capacity.

Gersten (1963) took ten paraplegics and applied a standard progressive resistance exercise program (PRE) two to four and a half months after injury to the spinal cord. Testing of isometric tension and the ten repetition maximum (10 RM) were completed on the biceps and triceps while in the supine position on the Elgin table with the arm adducted. Isometric tension for the biceps was determined at an angle of 90 degrees while for the triceps the elbow angle was 110 degrees.

Isometric tension was recorded with the cable tensiometer with a pull from the hand and a cable forearm angle of 90 degrees and the 10 RM was determined with standard techniques. PRE was performed on both triceps and biceps once daily, five times a week, with testing once weekly for five weeks. Few subjects continued for ten weeks. Gersten's results showed that improvement in both isometric tension and in 10 RM was markedly and significantly ($p<0.001$) greater in the biceps than in the triceps.

Kofsky (1986) studied 207 wheelchair bound individuals on upper body strength. The individuals were classified into four disability groups from class 2 to class 5, using the International Stoke Mandeville Games Federation classification. Subjects were then ranked for activity levels A,B, or C from national calibre to sedentary. A Clark cable tensiometer was used to determine maximal force of elbow extension, elbow flexion and shoulder extension with the arm at a 90 degree angle. She looked at sex specific variations of strength with age.

The results indicated that males had greater upper body muscular strength than females. No significant differences of upper body strength between the four disability classes in either sex were observed. The data were then used to test for differences between the three activity groups. Significant differences of upper body strength were observed in both sexes. Group A,B (active group) achieved higher scores than group C (sedentary group). Age was apparently not a significant factor influencing upper body strength.

Kofsky also devised four sex-specific classification tables which included norms for upper body strength for active and sedentary wheelchair bound individuals - since 80% of the individuals tested were between 20-40 years of age.

Grimby (1980) studied five paraplegics with varying degrees of physical training. He determined that static and dynamic muscle strength, measured isokinetically with the arm abducted, was on the average 20 to 30% higher than that of normal moderately trained men (mean age 28 years).

Davis (1986) compared differences in upper body isokinetic strength (Cybex II) of fifteen highly active disabled males (HA) who performed four exercise periods a week with that of 15 disabled males with a low level of physical activity (LA) who performed two exercise periods per week. All measurements were taken on the dominant limb at 60, 120, 180, 240, and 300 degrees per second of shoulder and elbow flexion/extension and shoulder abduction/adduction.

Peak moment(M), peak power (PP), average power (AP), and work (W) were analyzed on each movement using computer digitization of force-time curves. Also drop-off indices were calculated on each movement during 50 repeated biphasic contractions at 180 degrees per second.

The results showed no difference in drop-off indices between HA and LA groups. Both decreased performances by 47-56% over 50 repeated contractions. Throughout the speed range 60 - 300 degrees per second, the HA group displayed an advantage relative to the LA group of M (27% - 50%), TP (22% - 43%), AP (21% - 36%), and W (21% - 46%). The differences in the joint movements (37 - 50%) were greatest in shoulder abduction. This result appears to be a direct effect of specific shoulder conditioning in the HA individuals. AP was the best "discriminator" between HA and LA individuals which was indicated by regression analysis. Davis created power velocity curves for shoulder flexion and elbow extension.

He concluded that the velocity x group interaction strongly suggests that fast twitch muscle strength is specifically enhanced by physical activity in disabled adults.

In summary, the results of studies evaluating the effects of exercise on muscular strength of persons with spinal cord injuries have been equivocal. The majority of the studies did not involve a training period (Zwiren,1975; Grimby,1980; Kofsky,1983). When training programs were used, often the results were evaluated against able bodied criterion groups. Davis (1983) compared high active spinal cord injured individuals to low active spinal cord injured individuals. While Gersten (1963) compared biceps strength to triceps strength overtime and Nilsson (1975) used a training program which included weight training and cardio-vascular training. This study was designed to evaluate the strength changes overtime within each individual while performing a six week weight training program, and provide a good source of information for further, productive research.

H. Single Subject Descriptive Research Design

Descriptive research is often criticized because it fails to use a strictly scientific method and therefore can seldom produce conclusive results. Despite this shortcoming, few areas of research have developed without the benefit of descriptive studies. Descriptive research entails collecting data in an attempt to describe as accurately as possible the nature and degree of existing conditions (Lehmann & Mehrens,1979; Moore,1983). The goal of descriptive research is not to predict or establish cause-and-effect relationships between variables but to provide valuable information concerning the problem or phenomenon to be studied. The results of the study often provide the guidance necessary to adequately plan and implement subsequent experimental research (Moore,1983).

In this study, single subject design was chosen to investigate whether muscular strength could be increased during a weight training program and whether it would decrease when the program was discontinued. Single subject design was used as it gives an individual's representation to the response of the treatment variable. An advantage of single subject design is that it minimizes one of the stongest confounding factors in behavioural science - variability due to individual subject differences. A comparison is made between an individual's own behaviour under one condition and under others.

Single subject designs are subject to internal and external validity threats. Internal validity refers to the degree of certainty that manipulation of the independent variable is responsible for observed changes in the dependent variable. External validity refers to the extent to which results of an experiment can be generalized to different populations, settings, experimentors, etc. Several possible threats to internal validity are history, maturation, testing instrumentation, multiple intervention interference, instability, change in unit composition, reactive intervention and interaction (Campbell,1963; Kratochwill,1978; Tawney,1984).

Research in the area of muscular strength training of spinal cord injured individuals is relatively new. Indeed, good descriptive research is hard to find. Although a number of studies have looked at muscular strength in spinal cord injured individuals, the design has usually involved measurement at one site and comparison to an inappropriate able-bodied criterion group. No one has written detailed documentation of the changes in muscular strength of spinal cord injured individuals as a function of their participation in a controlled weight training program. A study of this kind is necessary before one can fully understand the nature of muscular stength and muscular stength training in spinal cord injuries. Therefore, a descriptive single subject design approach to the problem seems to be most appropriate at this time.

Chapter III

METHODOLOGY

A. Subjects

Five spinal cord injured males between the ages of twenty-seven and forty-seven served as subjects (Table 1). All subjects possessed a permanent, physical disability involving the lower limbs and/or trunk in the thoracic region between thoracic four (T4) and thoracic ten (T10) levels.

Local hospitals were visited to recruite subjects for this study but due to a lack of response, the Canadian Paraplegic Association was approached to provide a list of individuals who would be interested in participating in the study.

Table 1

Subject Description

Subject	Age	Level of Injury	Date of Injury	Cause of Injury	Recreation and Sports Activities Pre	Recreation and Sports Activities Post Study
A	47	T 10	1983	Construction	--	--
B	27	T 4	1982	Motor Vehicle	--	--
C	29	T 10	1958	Motor Vehicle	--	Weights
D	35	T 4	1983	Snow Mobile	--	Baseball
E	34	T 9	1969	Porch Collapse	--	--

B. Cybex II - Isokinetic Dynamometer

The Cybex II is an isokinetic device that is capable of measuring muscular torque outputs in foot/pounds (ft/lbs) or Newton Meters (Nm) at a wide range of velocities in degrees per second (deg/s) or radians per second (r/s). Once an angular velocity was selected, the input shaft could not be accelerated beyond that speed, regardless of the input torque applied below 360 ft/lbs or 488 Nm. The torque output of the muscles was reflected by the dynamometer and recorded on the dual channel recorder with a heated stylus. This recording system provided the researcher with a permanent written record of the individual's performance through the entire range of motion.

1. General positioning and stabilization guidelines

Figures 1 and 2 illustrate subject and apparatus positioning for shoulder flexion/extension and elbow flexion/extension using the Cybex II.

Figure 1: Shoulder Flexion/Extension

The subject was in a supine position on the Upper Body Exercise and Testing Table (UBXT) and was stabilized with a strap at the hips, chest and knees. The input arm length and rotational-axes alignment through the range of motion were checked. For shoulder flexion/extension (figure 1) the UBXT was positioned so that the end of the shoulder testing accessary just cleared the side of the UBXT upholstery and the individual's body. For elbow flexion/extension (figure 2) the UBXT and hand grip were set so that subject's shoulder was in 90 degrees abduction with the limb parallel to the input arm. The upper arm was strapped so that the shoulder was prevented from moving away from the 90 degrees abduction.

Figure 2: Elbow Flexion/Extension

2. Procedures

On the first visit, each subject was given an outline of the scope of the study and was shown the testing and treatment procedures. Each subject completed a personal information form (see Appendix B), a consent form (see Appendix C), and provided a medical form signed by their physician (see Appendix D). The subject's second visit involved the testing of muscular strength and endurance with the Cybex II, which was calibrated prior to every testing session using the method suggested by the manufacturer (Appendix E). During the second visit the following movements were performed: shoulder flexion/extension and elbow flexion/extension (Table 2).

Table 2

Testing Timeline on Cybex II

Time	
0:00	Arrival in Lab
0:05	Stretching
0:15	Cybex testing on right shoulder flexion/extension
0:20	Cybex testing on left shoulder flexion/extension
0:25	Cybex testing on right elbow flexion/extension
0:30	Cybex testing on left elbow flexion/extension

These measurements were recorded on a data sheet each time the individual completed a Cybex II test (Appendix F).

Procedures, as outlined in the Cybex procedures manual, were used for the above mentioned movements when the individual was tested on the Cybex II for shoulder and elbow movements (Cybex,1975).

C. Nautilus - Weight Training Equipment

The Nautilus weight training equipment was used for training the muscle groups of the subjects. The major muscle groups being used during shoulder and elbow flexion/extension on the Cybex II were: Pectoralis Major, Deltoid, Latissimus Dorsi, Triceps Brachii, and Biceps Brachii. The following six Nautilus machines were selected, as they involved the same major muscle groups: Behind Neck, Double Shoulder (Lateral Raise), Double Chest (Arm Cross, Decline Press), Triceps Extension, and Biceps Curl. Table 3 shows the procedures used during a treatment session on the Nautilus machines.

Table 3

Treatment on Nautilus Training Equipment

Time	
0:00	Arrival at Lab
0:05	Stretching
0:15	Behind Neck
0:20	Double Shoulder: Lateral Raise
0:25	Double Chest: Arm Cross and Decline Press
0:35	Triceps Extension
0:40	Biceps Curl

1. General positioning and stabilization guidelines

Figures 3 to 8 illustrate subject and apparatus positioning for the six selected exercises performed on the Nautilus.

On the Behind Neck (figure 3), the seat was adjusted, or extra pads were provided, so the shoulder joints were in line with the axes of cams; a seat belt was fastened at the hips, and the subject's chest was strapped to the machine.

Prior to the Lateral Raise exercise (figure 4), the seat was lowered so the individual could transfer easily onto the machine. The seat was then moved upwards and extra pads were provided when needed so that the shoulder joints were in line with the axes of cams. Again, a seat belt was fastened at the hips and the legs were strapped together at the knees. At the end of the exercise, the seat was lowered to allow for easy transfer back into the wheelchair.

The seat was also lowered for transfering onto the Double Chest machine (figure 5 and 6). The subjects legs were placed on the footpedal and held by the researcher so the individual could transfer himself onto the seat of the machine. The seat was moved upwards and extra pads were used, when necessary, so the shoulders were directly under the axes of the overhead cams. The waist belt was fastened during both exercises. Due to paralysis of the lower limbs, the researcher placed the decline press into the starting position by pushing the footpedal and handles. After the last repetition on the decline press the seat was lowered and the researcher held the individual's legs to facilitate the transfer.

Prior to the Triceps Extension exercise (figure 7), the bar was placed in full extension by using a strap which allowed the subject to transfer easily onto the machine. The researcher would help the subject, by placing the legs, while the subject was transfering onto the seat. Extra pads were provided so the shoulders were on the same level as the elbows. A waist belt was fastened. The same procedures were used when transfering from the machine.

Again, assistance was provided by the researcher, when needed while transfering onto the seat of the Biceps Curl machine (figure 8). Extra pads were provided so the elbows were in line with the axis of the cam. One pad was put at the chest so the individual would be in an upright position and would not be able to use his back while lifting the bar.

All the extra pads were strapped down to prevent them from shifting while transfering on and off the machines.

2. Procedures

The total duration of training on the Nautilus was six weeks (figure 9) for subjects A, B, and D from week 2 to week 8 and six weeks for subjects C and E from week 4 to week 10. The starting weight was dependent on the subject's strength and execution of the proper technique on the Nautilus. Each subject attempted to perform three sets of six repetitions with a one minute interval between the sets on all six machines. After completing two consecutive sessions of three sets of six repetitions the weight was increased. This weight increase was dependent upon the number of repetitions performed on the last set of the previous two sessions. When the subject performed one or two extra repetitions in the third set, the weight was increased by two and a half pounds (2 1/2 lbs). If it was more than two repetitions the weight was increased by five pounds (5 lbs). The results were recorded on a data sheet each time the individual came to the lab for a training session (Appendix G). After the participants were in position and stabilized on the Nautilus machines, the following procedures were used:

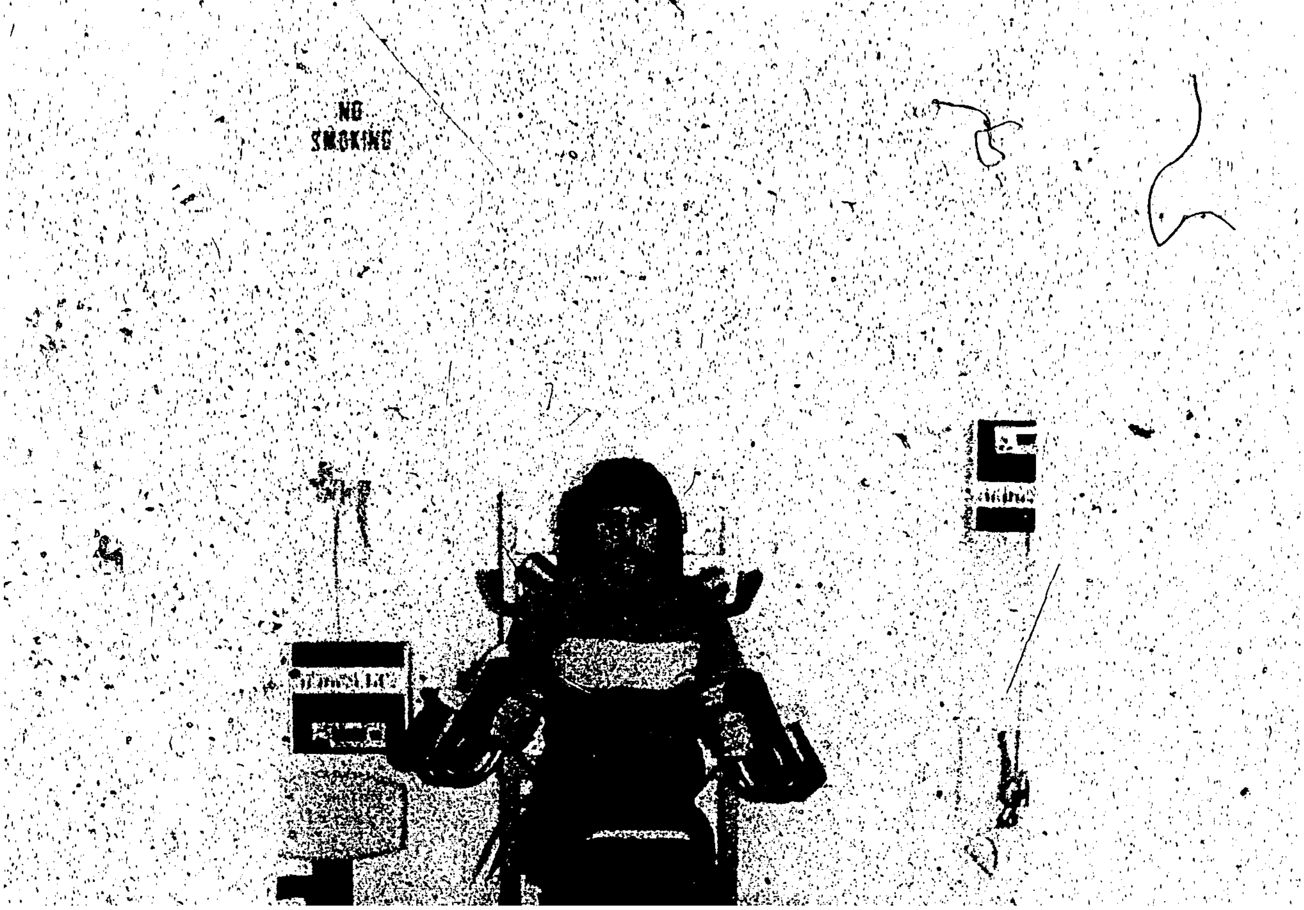
Behind Neck

1. the backs of the upper arms (triceps area) were placed between the padded movement arms;
2. the forearms were crossed behind the neck;
3. both arms were moved downward until perpendicular to the floor (2 counts);
4. the head was kept against the back of the seat;
5. pause;
6. the arms were slowly returned (4 counts) to the cross arm position behind the neck and the entire sequence was repeated (Darden,1980).

Figure 3: Behind Neck

Double Shoulder (Lateral Raise)

1. the handles were pulled back until the knuckles touched the pads;
2. with elbows leading, both arms were raised until parallel with the floor (2 counts);
3. pause;
4. slowly the arms were moved back to their original position (4 counts) and this sequence was repeated;
5. throughout this motion the head was kept back against the seat (Darden,1980).



Double Chest (Arm Cross)

1. the forearms were placed behind and firmly against the movement arm pads;
2. the handles were grasped lightly (thumb around the handle) and the head was against the back of the seat;
3. the subject pushed the forearms and tried to touch the elbows together in front of the chest (2 counts);
4. slowly the resistance was lowered (4 counts);
5. this procedure was repeated (Darden,1980).

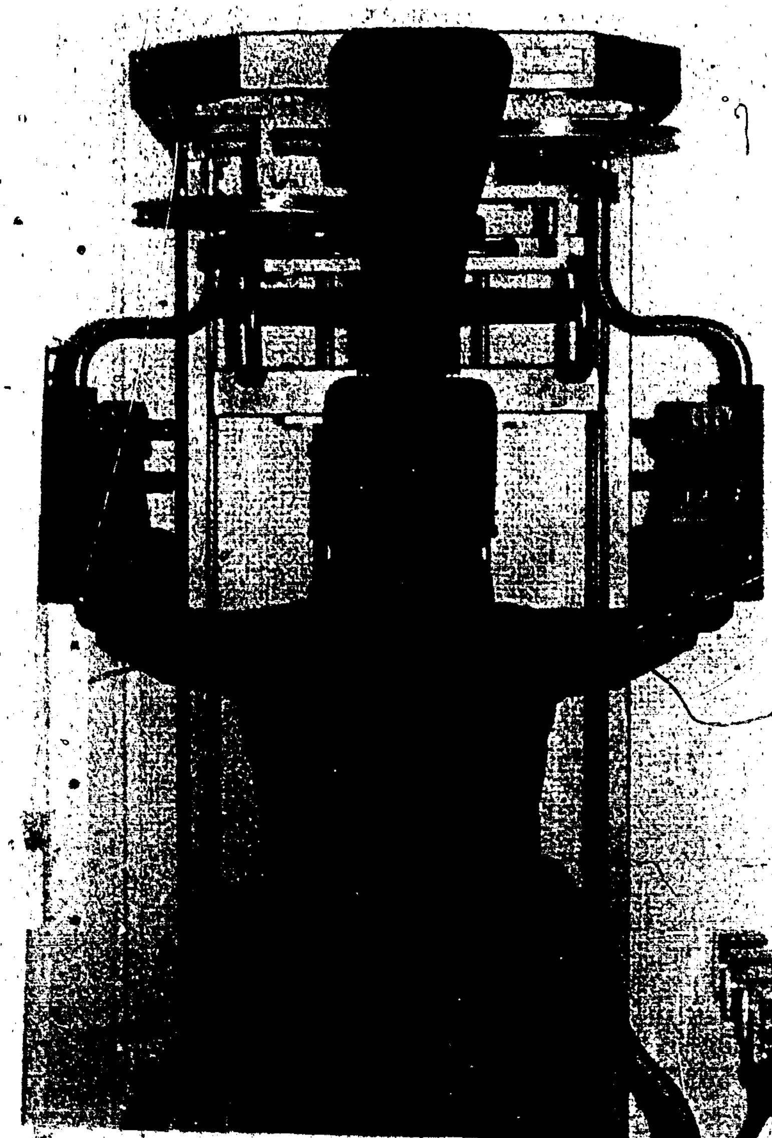


Figure 5: Double Chest (Arm Cross)

Double Chest (Decline Press)

1. the handles were gripped and the bars were pressed forward in a controlled fashion (2 counts);
2. the torso was kept erect and the head was back;
3. the resistance was slowly lowered keeping the elbows wide (4 counts);
4. this pressing movement was repeated (Darden,1980).

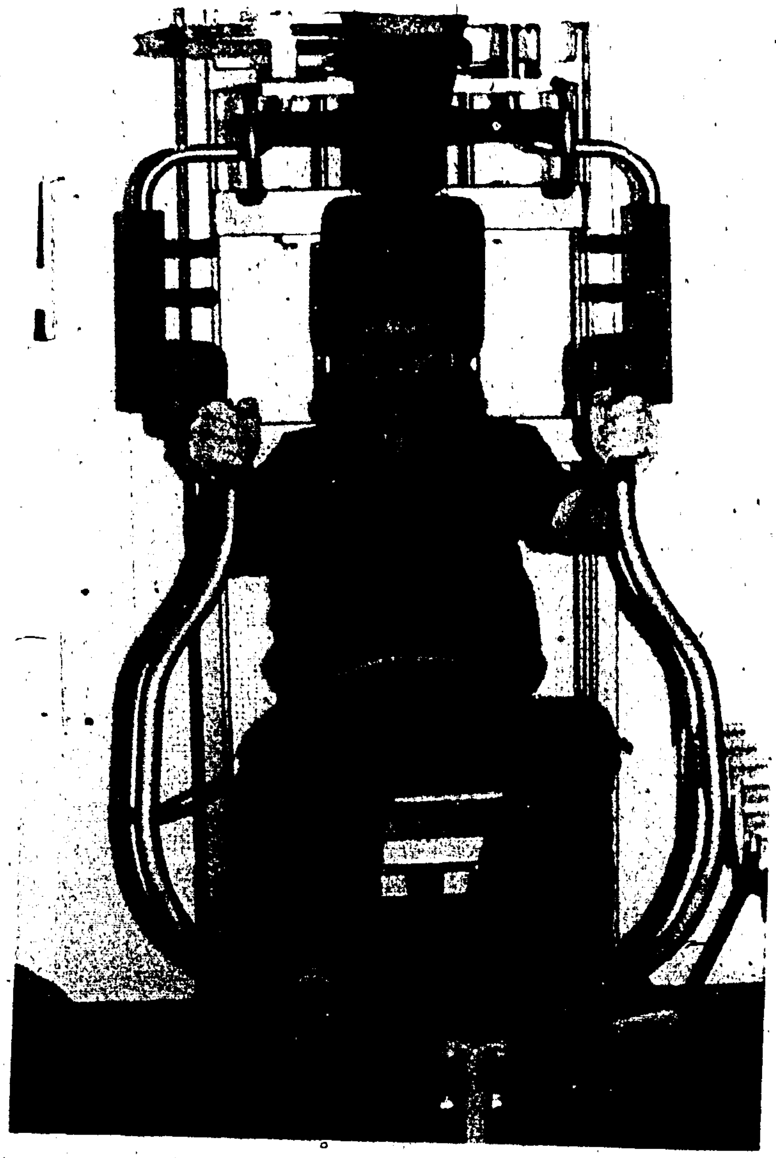


Figure 6: Double Chest (Decline Press)

Triceps Extension

1. the hands were on the pads with the thumbs up;
2. the arms were slowly straightened (2 counts);
3. pause;
4. slowly the arms were returned to the stretched position (4 counts);
5. the head was kept back and the entire action was repeated (Darden,1980).

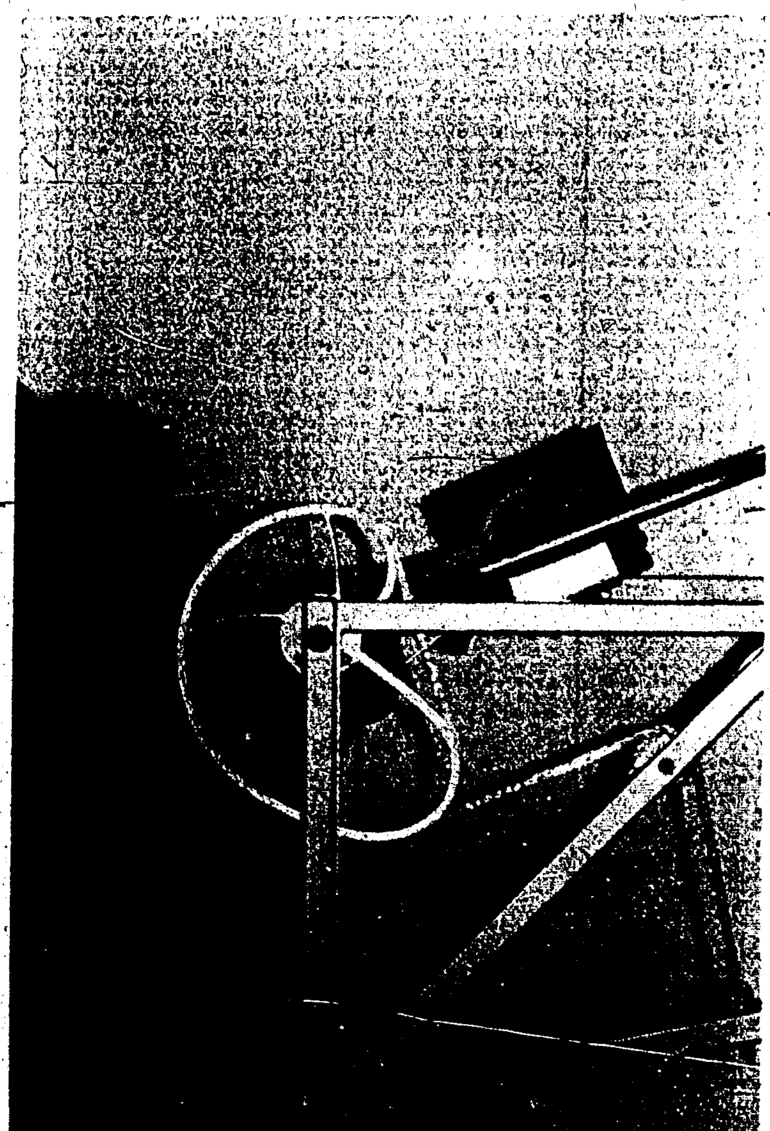


Figure 7: Triceps Extension

Biceps Curl

1. the bar was grasped with the hands together and palms up;
2. the bar was curled smoothly until it reached the neck (2 counts);
3. pause;
4. the bar was returned slowly to the stretched position (4 counts). The action was repeated (Darden,1980).

Figure 8: Biceps Curl

D. Training Programs

Week	Cybex Testing (TE) and Nautilus Treatment (TR)	
	Subjects A,B,D	Subjects C,E
0	TE	TE
1	TE	TE
2	*TE/TR	TE
3	TE/TR	
4	TE/TR	*TE/TR
5		TE/TR
6	TE/TR	TE/TR
7		
8	**TE/TR	TE/TR
9		
10	TE	**TE/TR
11		
12		TE

* Start of Training Program
** Conclusion of Training Program

Figure 9: Training Programs

Subjects A, B, and D completed a ten week program of training. After the initial test on the Cybex II, subjects A, B, and D were tested on the Cybex II again after the first and second week. During these two weeks the subjects were not involved in any other training activity.

activity. They maintained their normal daily routine. The treatment on the Nautilus started in the third week. The subjects were involved in treatment sessions three times a week, Monday, Wednesday, and Friday, for six weeks. When a testing and treatment session fell on the same day, which happened on the second, third, fourth, sixth, and eighth week after the initial test, there was a fifteen minute rest period between the two (see Table 4). After the six week treatment period, the treatment was stopped and the subjects were asked to keep a regular routine for the next two weeks. After the two week interval, another testing session was completed on the Cybex II.

Subjects C and E, while completing a twelve week training program were tested the first, second, and fourth week after the initial test and prior to the treatment period. These subjects started the treatment on the Nautilus during the fourth week. The treatment was identical to that of subjects A, B, and D, a six week duration of exercises on Monday, Wednesday, Friday. The testing sessions during the treatment period were held on the fifth, sixth, eighth, and tenth week after the initial test. The procedures were identical to these for subjects A,B, and D, if the testing and treatment fell on the same day.

E. Treatment of the Data

A detailed description of the measurements taken on the Cybex II and Nautilus Weight Training Equipment were provided in the procedures section of this chapter.

The data recorded on the Cybex II for shoulder flexion/extension and elbow flexion/extension yielded measurements of change in strength and endurance of major muscle groups. In addition, the Nautilus Weight Training Equipment provided accurate readings of the weight lifted on each machine at each training session. Both sets of data were presented graphically and subjected to visual analysis.

The experimental design on the Nautilus weight training equipment was a changing criterion design. The changing criterion design was organized by Sidman (1960) and named by

Table 4

Testing Procedures on Cybex II and Nautilus Equipment

Time	
0:00	Arrival at Lab
0:05	Stetching
0:15	Cybex testing on right shoulder flexion/extension
0:20	Cybex testing on left shoulder flexion/extension
0:25	Cybex testing on right elbow flexion/extension
0:30	Cybex testing on left elbow flexion/extension
0:35	Rest
0:50	Behind Neck
0:55	Double Shoulder: Lateral Raise
1:00	Double Chest; Arm Cross and Decline Press
1:10	Triceps Extension
1:15	Biceps Curl

Hall (1971). The design is excellent for evaluating progressive changes in learning or training programs. The essential feature of the design is the stepwise change of a criterion level for learning or training on a given target behaviour. Thus, the criterion serves as a baseline along with the subjects performance in relation to the criterion within each phase of the program. Hartman and Hall (1976) argue that "when the rate of target behaviour changes with each stepwise change in the criterion, experimental control is demonstrated".

Internal validity is enhanced when a stable level is reached within each phase; and then a subsequent change occurs in relation to the increasing of the criterion level. Thus, control is demonstrated when performance changes follow the expected pattern of increased demand set by each new criterion.

A changing criterion design was used to increase systematically and gradually the subjects' performances over the six week treatment period on the Nautilus equipment. The criterion for each session was set by multiplying the three sets by the six repetitions. This was multiplied by the starting weight. Eg. Three sets x six repetitions x twenty pounds. When the criterion was surpassed and performed properly, the criterion was increased by multiplying the sets and repetitions by the new weight. The graphs representing the Cybex II results were assessed according to trend, level, and variability of performance between and within the three phases (Kratochwill,1978).

The trend direction refers to the steepness of the data path across time. The direction of the trend slope can show acceleration, deceleration, and zero celeration of a time period. There are two methods used to estimate trend: Freehand method entails visually inspecting the data of a condition and drawing a straight line that bisects the data points (Parsonson & Bear,1978); though, this method is fast, it is not that reliable. The Split Middle method, described by White & Haring (1980), will yield a more reliable and accurate estimatation of trend. The split middle method relies on median or middle dates and ordinate values to estimate trend.

There are two basic aspects of level of importance when inspecting data; that is, level of stability and level of change. The data is said to be stable when the range of data point values are small. The change in level is determined by comparing the last point of one phase with the first point of the next phase.

Chapter IV

RESULTS AND DISCUSSION

The purpose of this study was to document in detail, the changes in muscular strength of spinal cord injured individuals as they participated in a six week weight training program. The presentation of the results is divided into two major parts:

a. measurements obtained from Cybex II testing are displayed in histogram Figures 10 to 24, and

b. data gathered on the changing criterion Nautilus Weight Training Program are presented in Figures 25 to 54.

The two major parts are subdivided, presenting the results of each individual subject separately, starting with subject A and finishing with subject E. Tables on the exact performance scores of the five subjects on the Cybex II are presented in Appendix H. The Nautilus training results appear in Appendix I.

The previous chapter (chapter 3) described the process of setting the criteria for the Nautilus exercises. Each criterion varied from individual to individual and from exercise to exercise (figures 25 to 54). As a factor of the varing starting weight, the weight increase from session to session (eg. 2 1/2 or 5 lbs), and the time of onset were implemented, for instance, after the second, third, fourth, or fifth session. The exact values of the criterion, on each Nautilus exercise, for every subject, appear in Appendix J.

A. Cybex II Testing Discussion

Subject A:

As shown in Figure 10, subject A maintained relatively stable performance on shoulder flexion, elbow flexion and elbow extension measures during the pre-treatment phase. As the figure shows, the treatment did not result in observable changes of level or trend for these

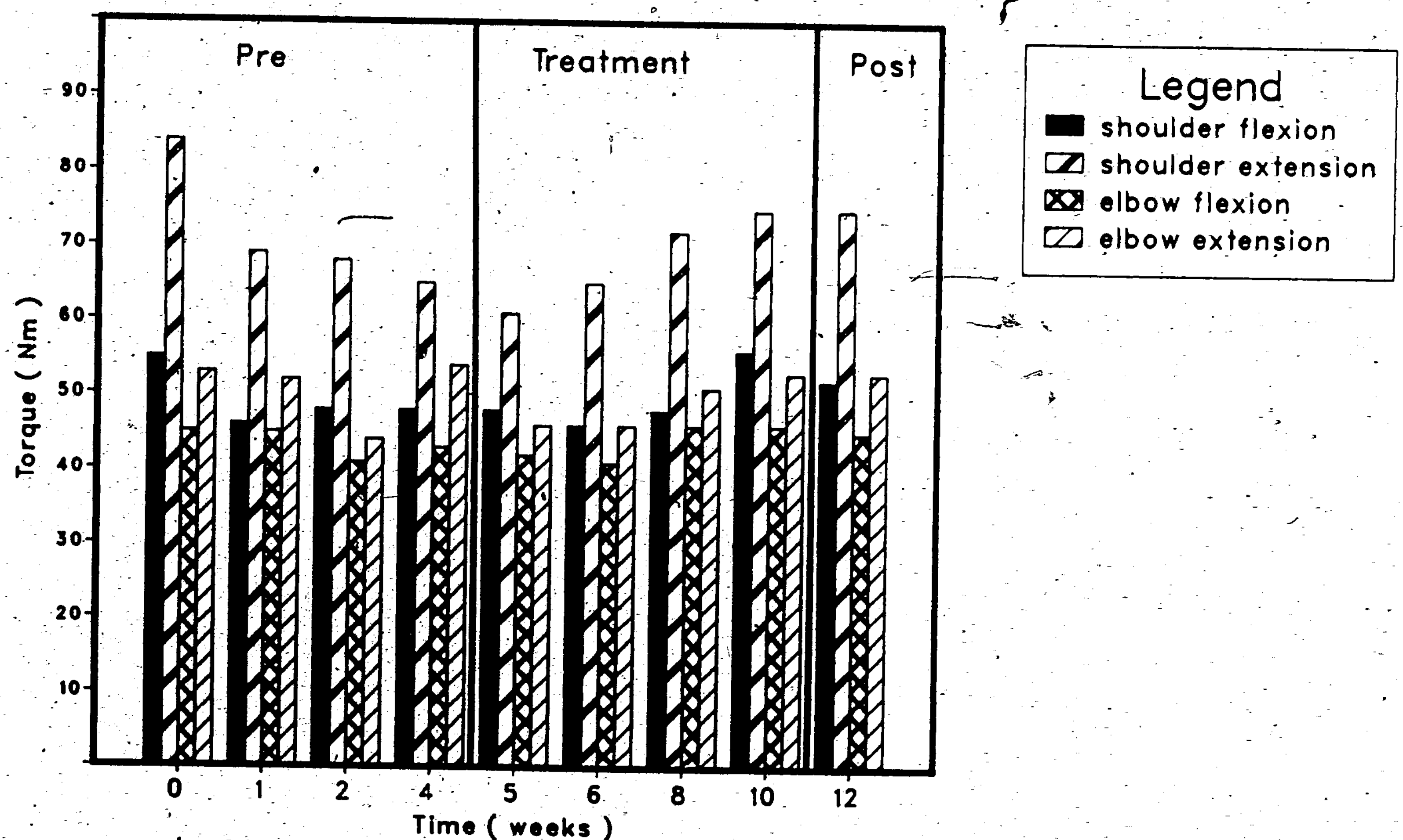


Figure 10: Subject A – Cybex II

Shoulder and Elbow Flexion/Extension at .524 r/s

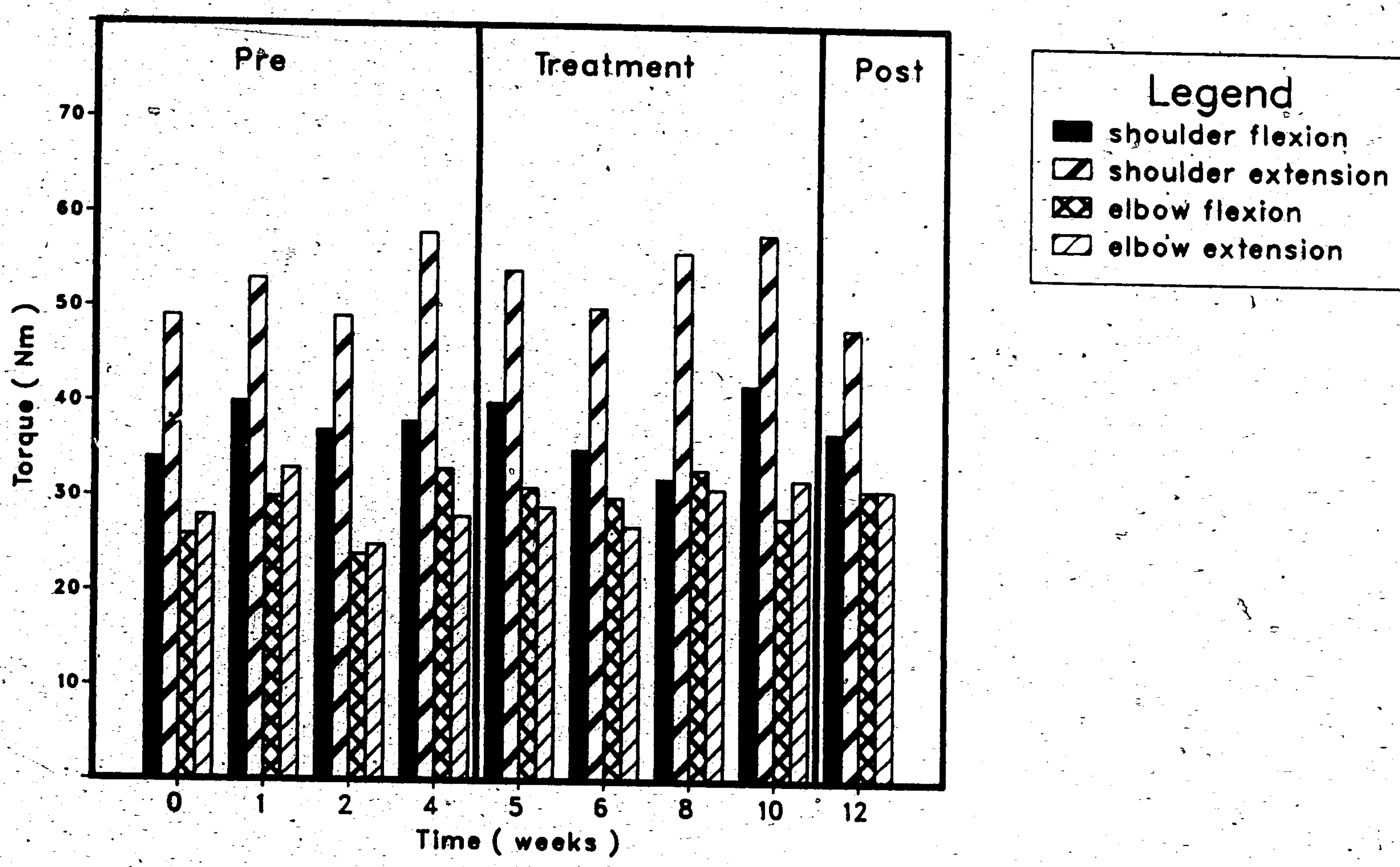


Figure 11: Subject A – Cybex II

Shoulder and Elbow Flexion/Extension at 3.144 r/s

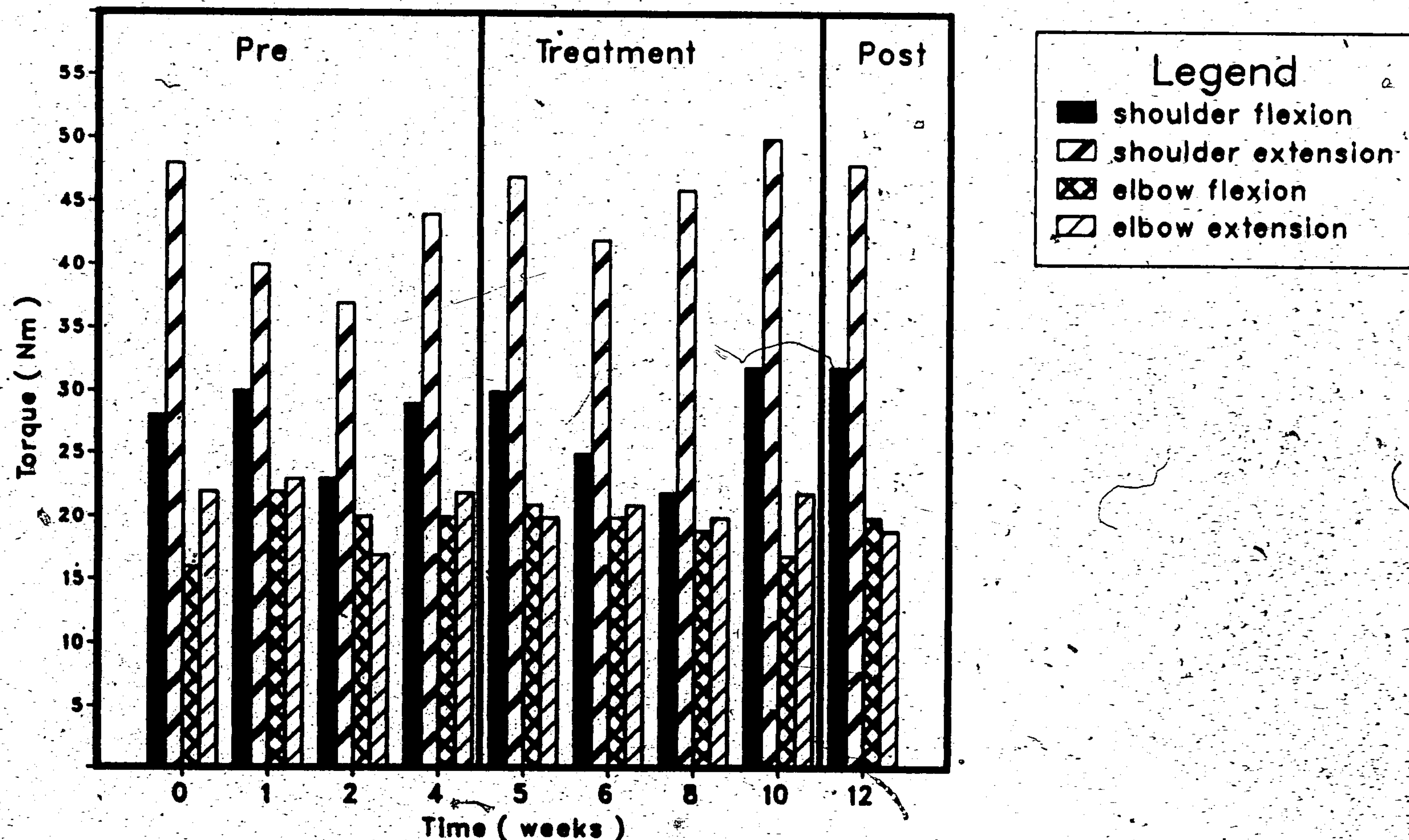


Figure 12: Subject A – Cybex II

Shoulder and Elbow Flexion/Extension at 3.144 r/s at 30 sec

variables during the treatment or post-treatment phases of the program.

Subject A's performance on the shoulder extension variable reached stability after the second session of the pre-treatment phase. However, there was a positive improvement during the eighth and tenth week of the program, which was maintained until the twelfth week of the post-treatment.

Figure 11 presents subject A's results on the Cybex at a speed of 3.144 r/s. Examination of the figure indicates that subject A had relatively stable pre-treatment performance on all four dependent variables. Initiation of the treatment program did not result in positive changes in performance.

Subject A's performance on the shoulder and elbow flexion/extension at a speed of 3.144 r/s at 30 sec is presented in Figure 12. The results show some variability of performance during the pre-treatment phase and minimal change during the treatment and post-treatment phases.

Subject B:

Figure 13 presents subject B's performance at .524 r/s. Again, fairly stable performances were found for the shoulder flexion, elbow flexion, and elbow extension; however, the shoulder extension results were somewhat variable as they were for subject A. Subjects B's performance on all four dependent variables did not result in positive changes in level or trend.

Subject B's performance on the shoulder and elbow flexion/extension at a speed of 3.144 r/s is presented in Figure 14. Baseline results for the four dependent variables are somewhat variable and the treatment did not result in positive changes in level or trend.

Figure 15 presents subject B's performances at 3.144 r/s at 30 sec. Examination of the figure indicates that subject B had relatively stable performance on the shoulder flexion, elbow flexion, and elbow extension movements. However, shoulder extension results are somewhat variable as they were for subject A. Again, no treatment effects were noted.

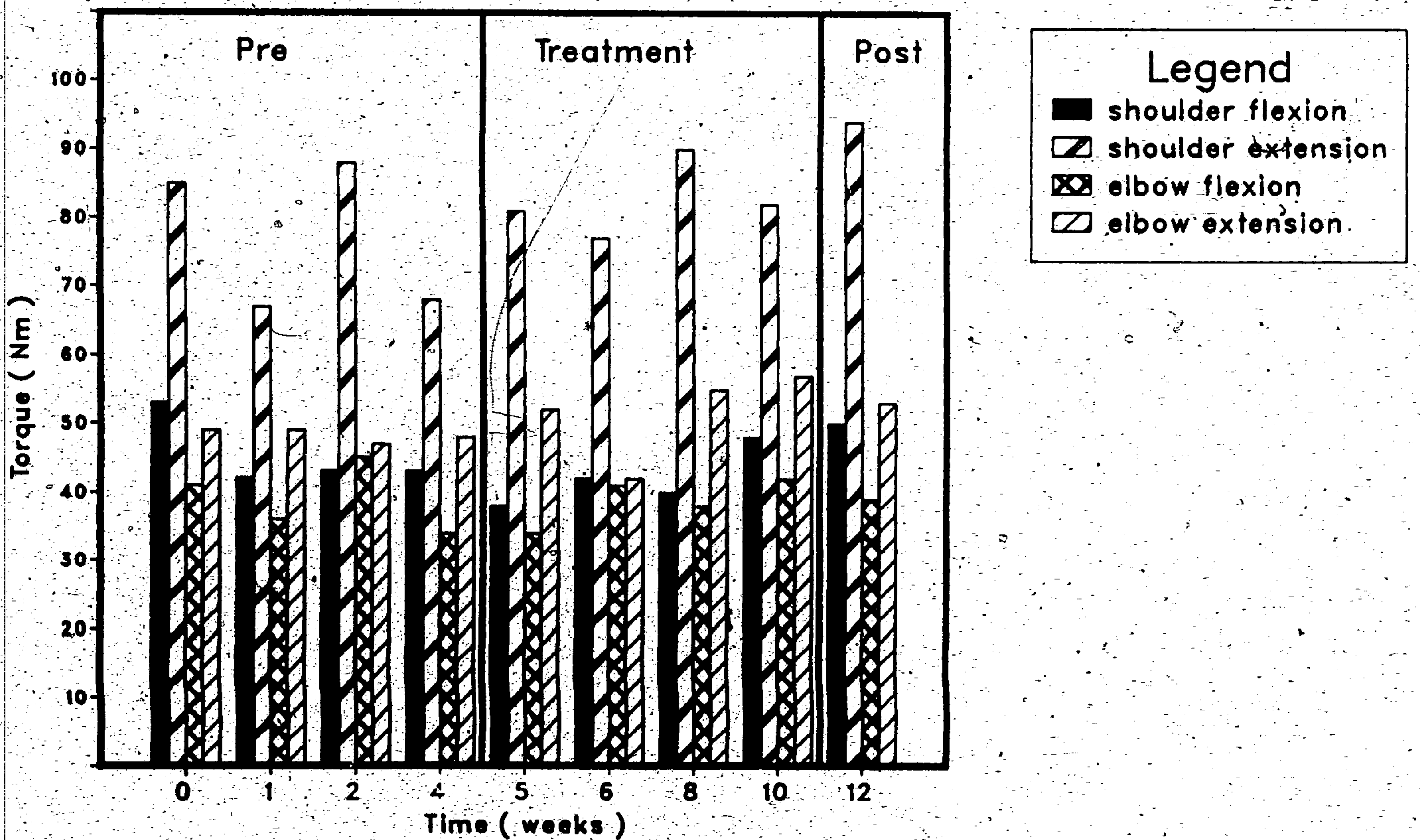


Figure 13: Subject B – Cybex II

Shoulder and Elbow Flexion/Extension at .524 r/s

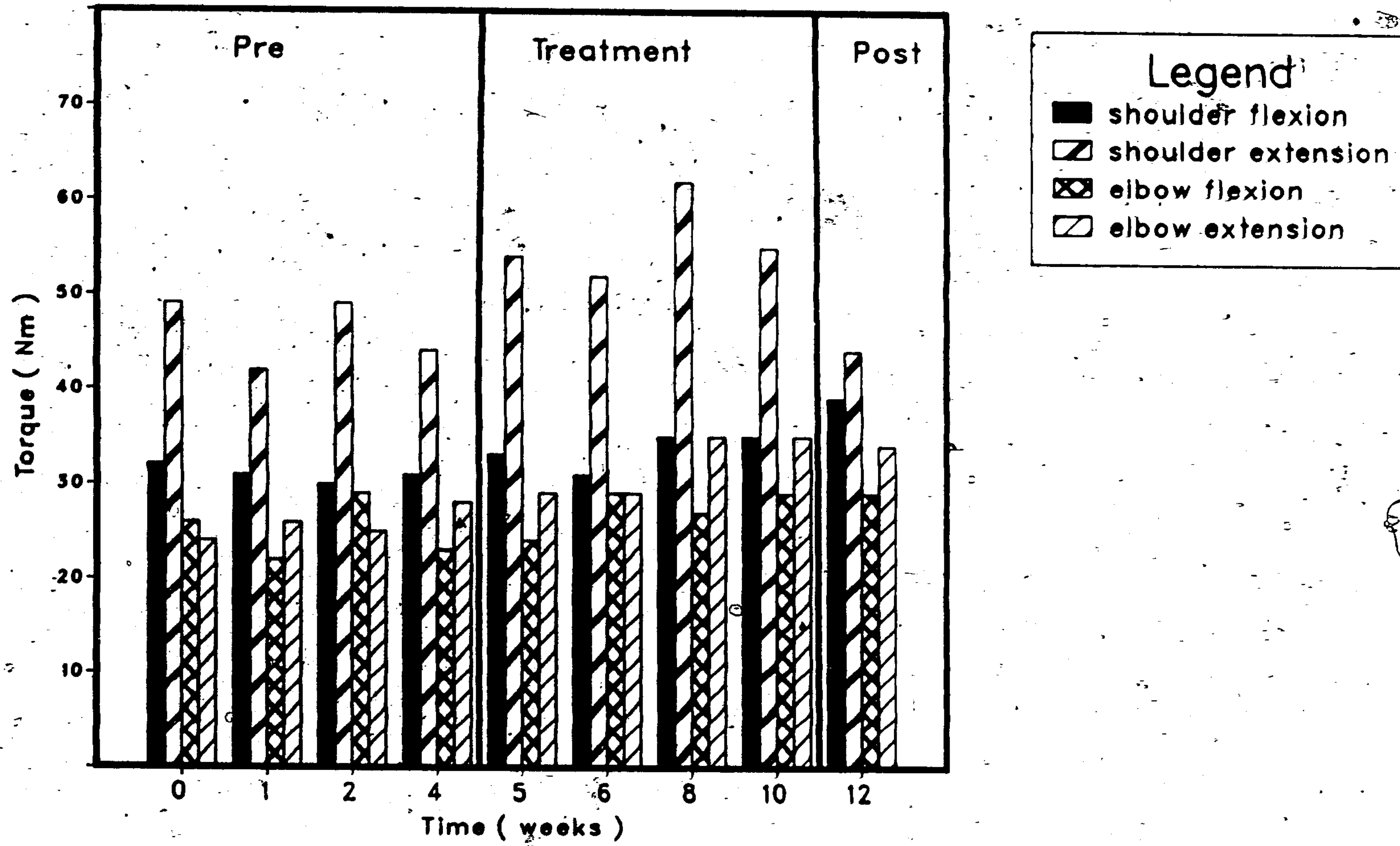


Figure 14: Subject B – Cybex II

Shoulder and Elbow Flexion/Extension at 3.144 r/s

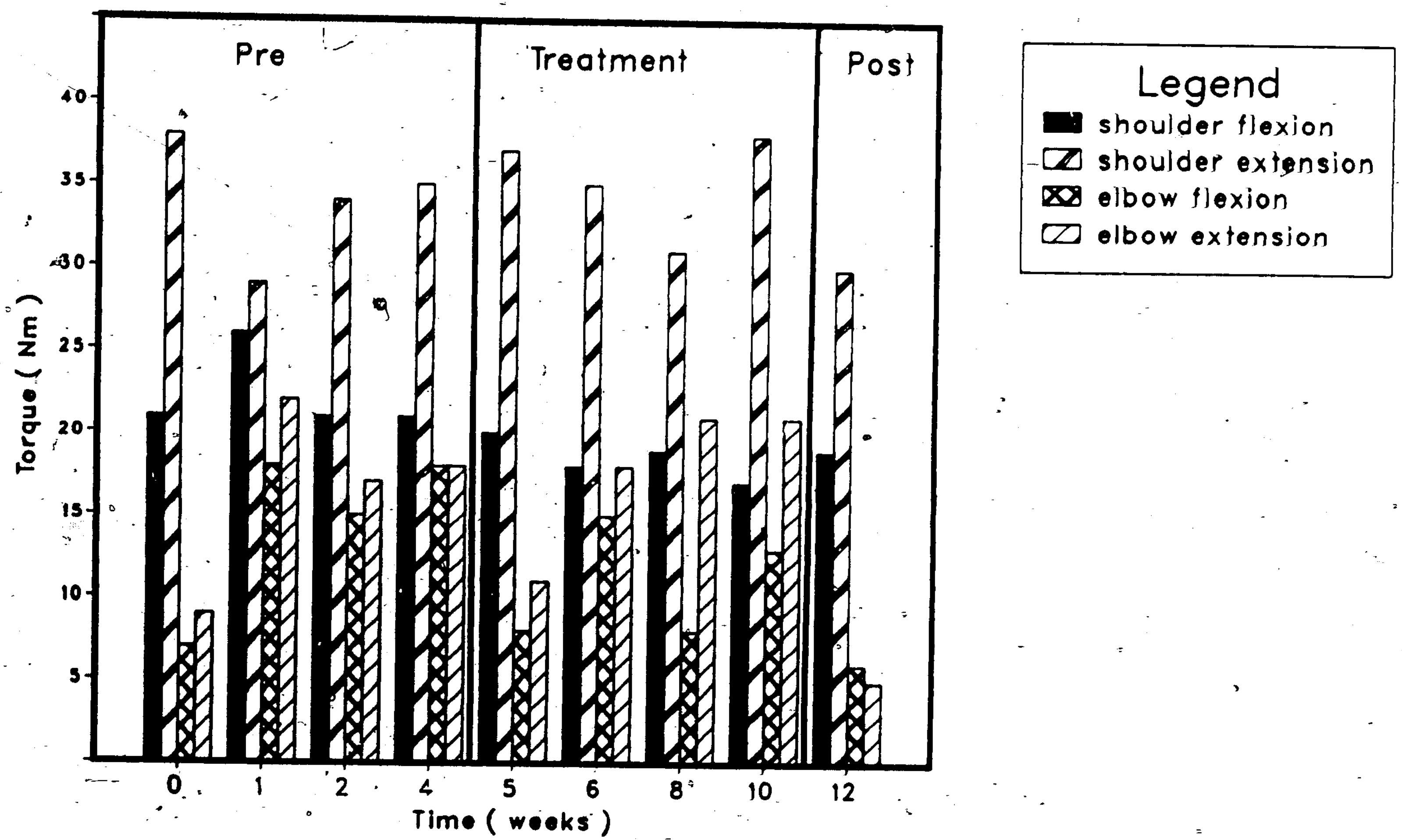


Figure 15: Subject B – Cybex II

Shoulder and Elbow Flexion/Extension at 3.144 r/s at 30 sec

Subject C:

As shown in Figure 16, subject C maintained a stable performance on all four dependent variables throughout the entire study. Clearly, subject C showed no positive changes in level or trend following the initiation of the treatment phase.

Subject C's performance on shoulder and elbow flexion/extension at a speed of 3.144 r/s is presented in Figure 17. The results show relatively stable performances thoughout the study on elbow extension and elbow flexion; however, shoulder extension results were somewhat variable. Subject C's performance on the shoulder flexion movement showed some positive trend during the treatment phase after a fairly stable pre-treatment phase.

Figure 18 presents subject C's performance at 3.144 r/s at 30 sec. Examination of the figure indicates that subject C had a relatively stable pre-treatment performance and minimal change during the treatment and post-treatment phases. Subject C's performance on all four dependent variables did not result in positive changes in level or trend following the initiation of the training program.

Subject D:

Figure 19 presents subject D's performance at .524 r/s. Fairly stable performances were found for the shoulder flexion, elbow flexion, and elbow extension; however, after a somewhat variable pre-treatment phase, shoulder extension showed a somewhat positive trend in the treatment phase.

Subject D's performance on the shoulder and elbow flexion/extension at a speed of 3.144 r/s is presented in Figure 20. As the figure illustrates, shoulder flexion, elbow flexion, and elbow extension variables were very stable performances throughout the study; however, subject D's shoulder extension performance was fairly stable during pre-treatment and yet a somewhat positive trend during the treatment phase.

Subject D's performance on the shoulder and elbow flexion/extension at a speed of 3.144 r/s at 30 sec is presented in Figure 21. The results show relatively stable performances on

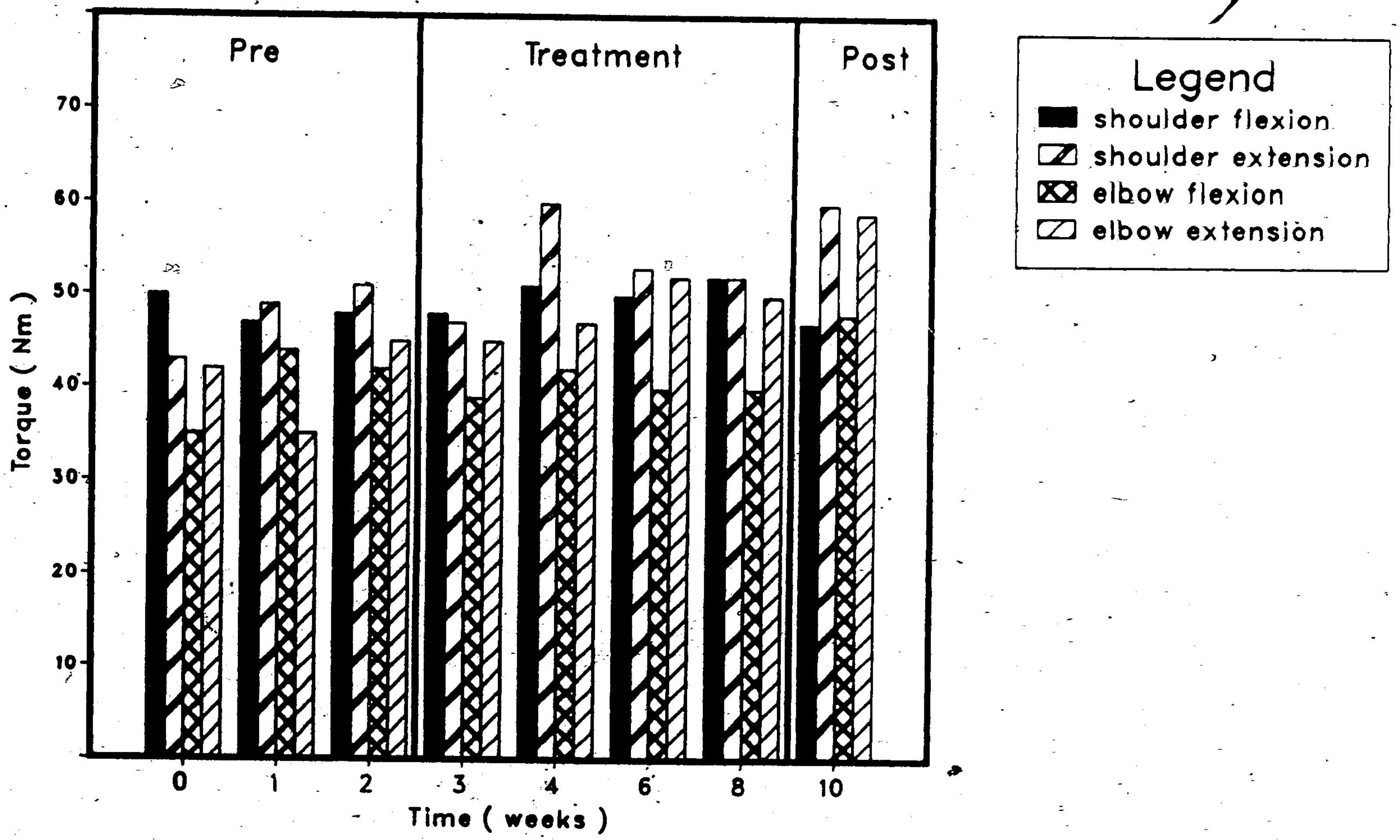


Figure 16: Subject C – Cybex II

Shoulder and Elbow Flexion/Extension at .524 r/s

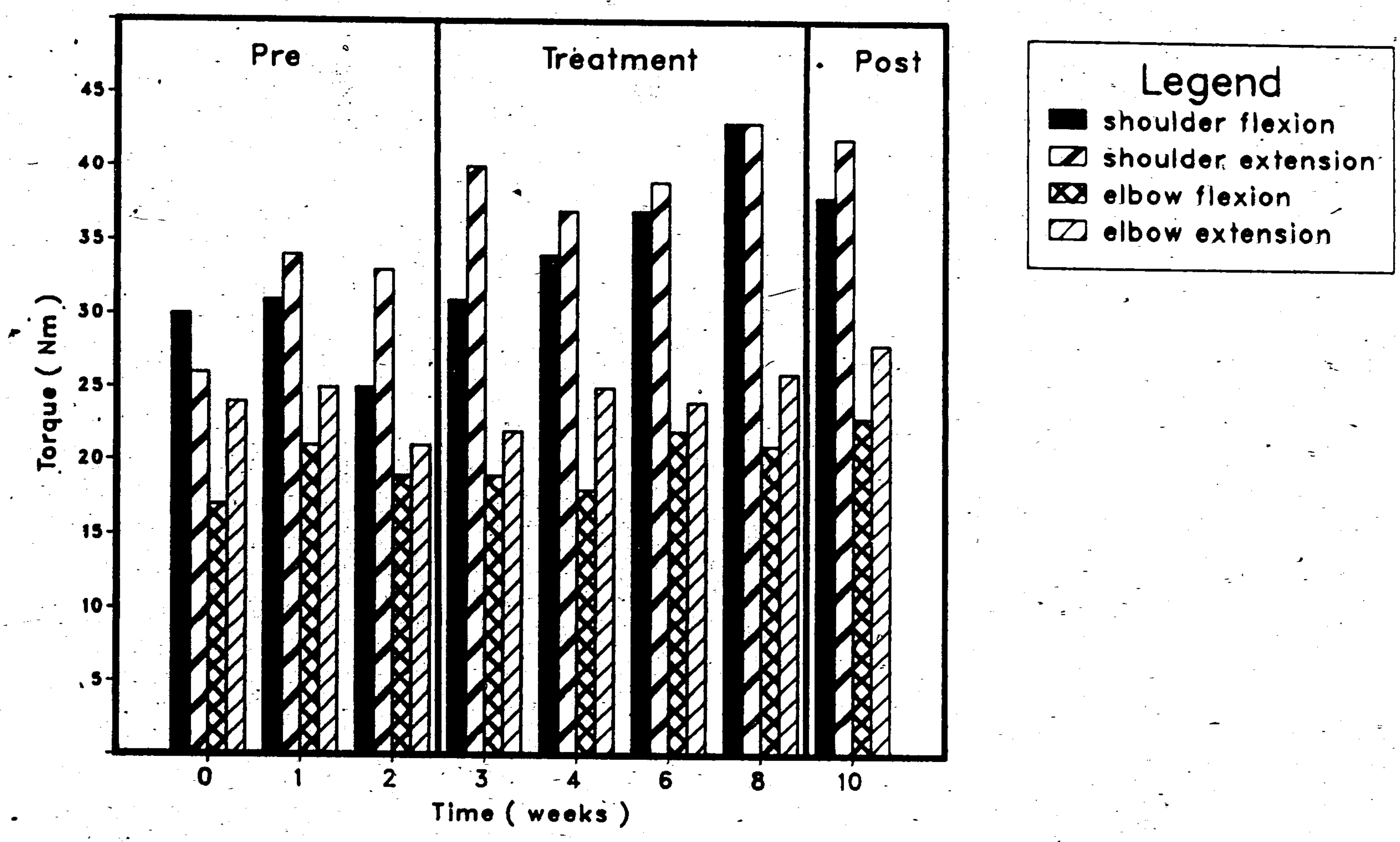


Figure 17: Subject C – Cybex II

Shoulder and Elbow Flexion/Extension at 3.144 r/s

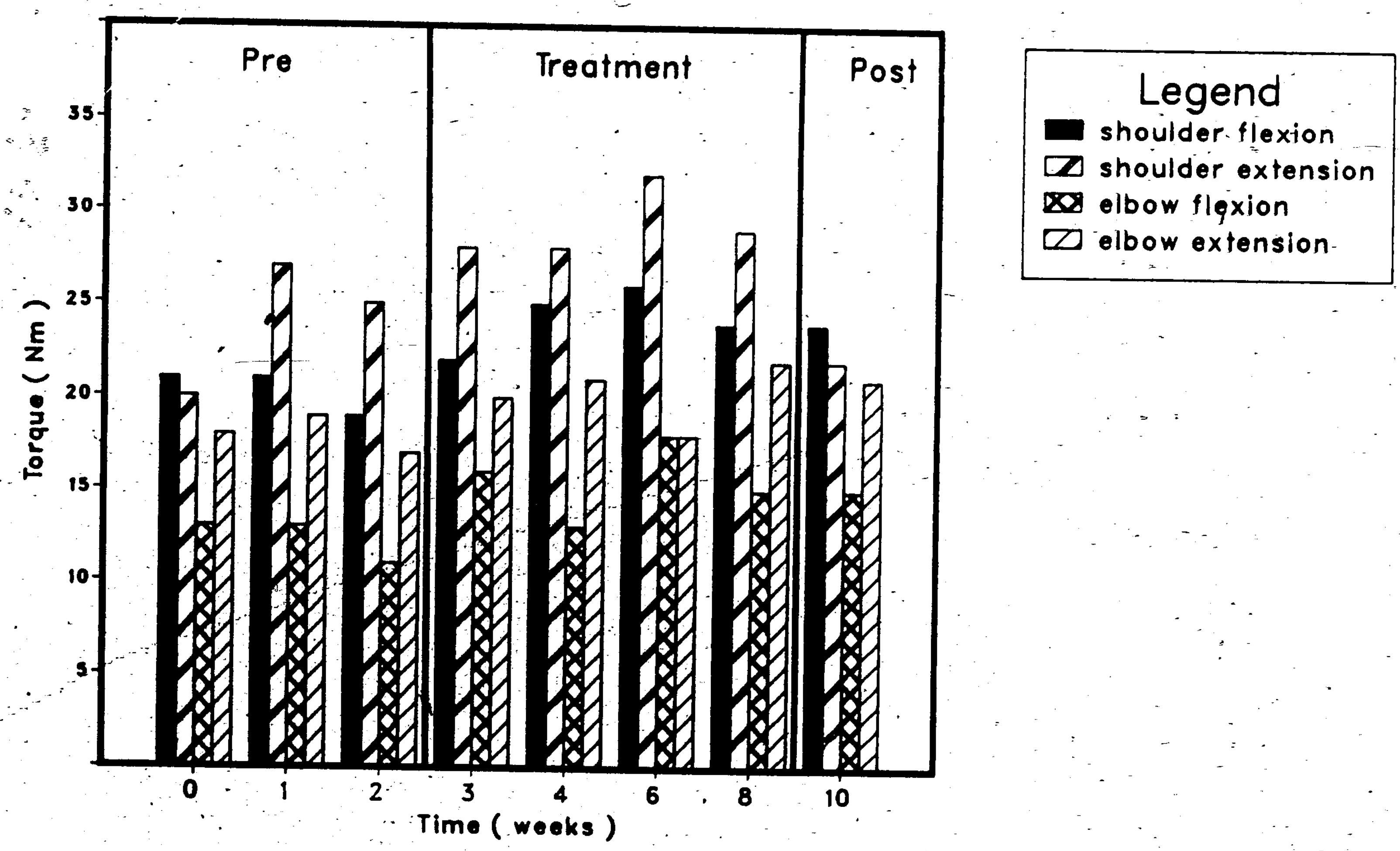


Figure 18: Subject C – Cybex II

Shoulder and Elbow Flexion/Extension at 3.144 r/s at 30 sec

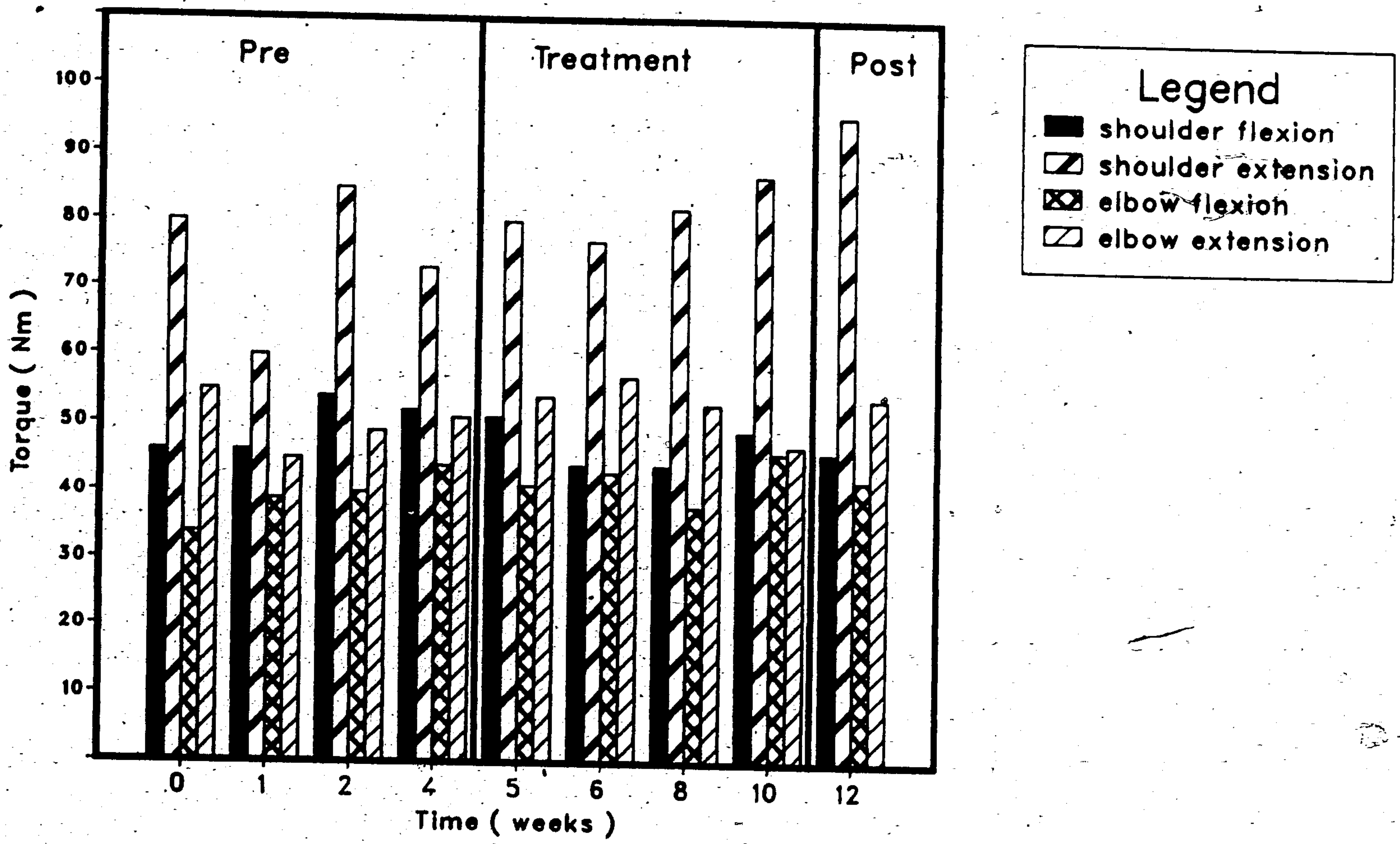


Figure 19: Subject D – Cybex II

Shoulder and Elbow Flexion/Extension at .524 r/s

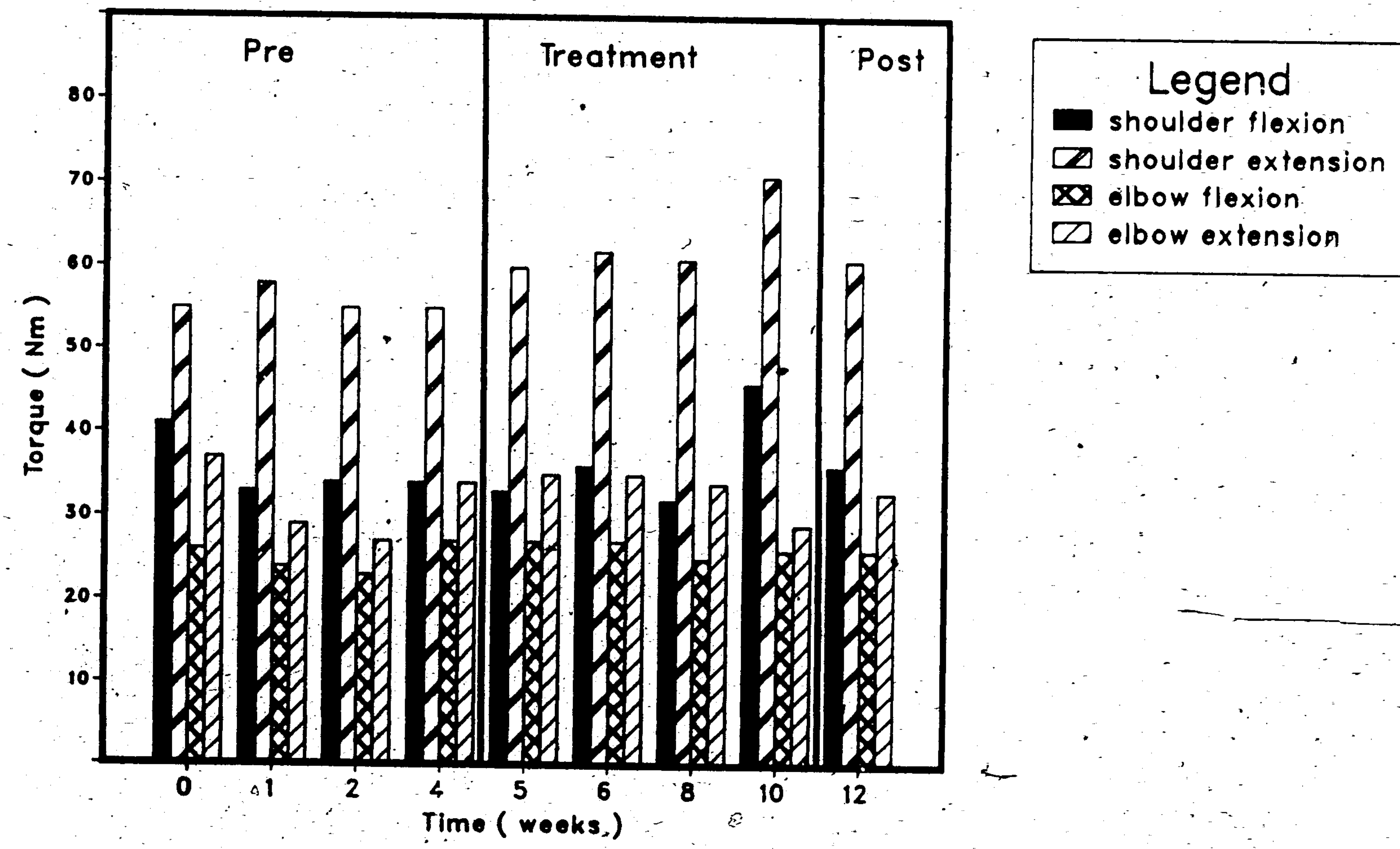


Figure 20: Subject D – Cybex II

Shoulder and Elbow Flexion/Extension at 3.144 r/s

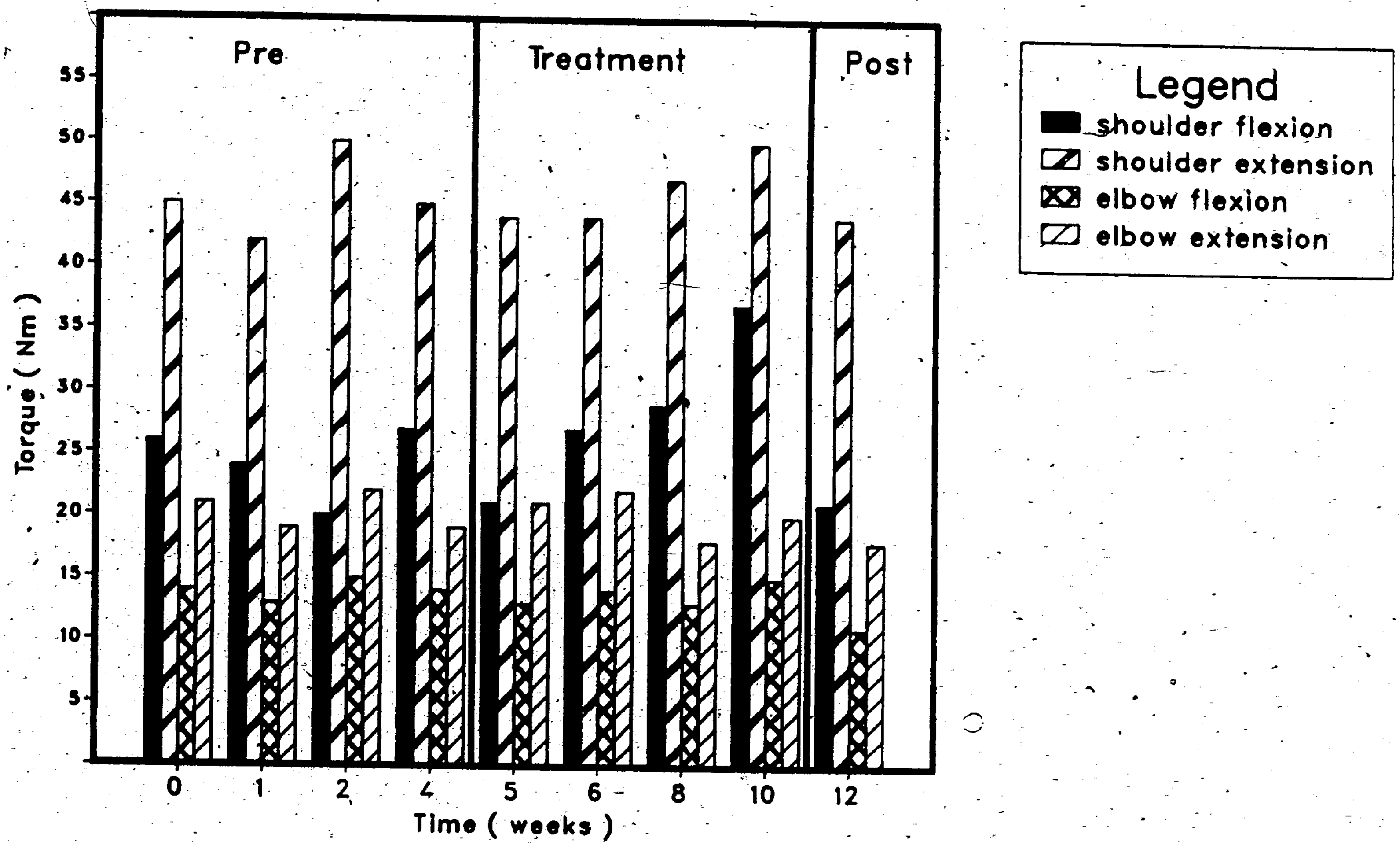


Figure 21: Subject D – Cybex II

Shoulder and Elbow Flexion/Extension at 3.144 r/s at 30 sec

the shoulder extension, elbow flexion, and elbow extension; however, only the shoulder flexion results show a positive trend during the treatment phase after a fairly stable pre-treatment phase.

Subject E:

Figure 22 presents subject E's results on the Cybex at a speed of .524 r/s. Examination of the figure indicates that subject E's results were somewhat variable for all four dependent variables; however, the initiation of training did not result in positive changes in level or trend.

As Figure 23 demonstrates, the treatment did not result in observable changes in level and trend for any variable during the treatment phase. Subject E's performance on all four dependent variables was fairly stable during the entire study.

As Figure 24 demonstrates, subject E, on the shoulder and elbow flexion/extension, at a speed of 3.144 r/s at 30 sec displayed very stable performance on the elbow flexion movement. However, the shoulder extension, shoulder flexion, and elbow extension results showed negative trends in the pre-treatment phase with a somewhat stable performance for shoulder flexion and elbow extension during the treatment phase. Only the shoulder extension results showed a positive trend in the treatment phase.

B. Nautilus Training Program Discussion

Subject A:

Figure 25 presents subject A's strength changes over the eighteen training sessions. As the graph clearly shows, he made very impressive strength gains during the program. In fact, he had an increase of 221%; from an initial weight of 420 lbs to 1350 lbs at the end of the program. It should also be noted that his performance during each phase always exceeded the criterion level that was set for him.

Figure 26 presents the strength changes for subject A on the Lateral Raise dependent variable. Again, very positive strength changes were found. His performance exceeded the

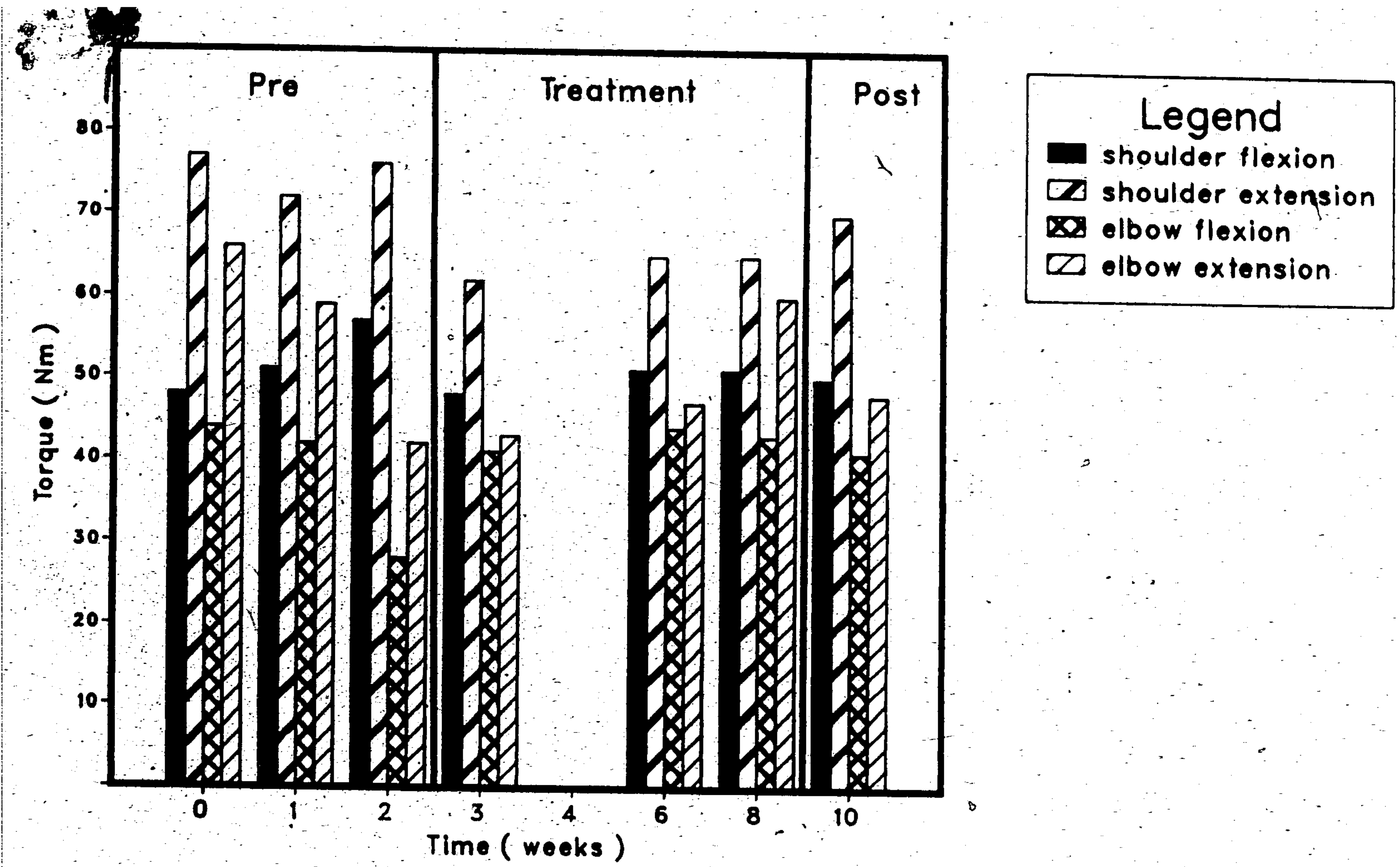


Figure 22: Subject E – Cybex II

Shoulder and Elbow Flexion/Extension at .524 r/s

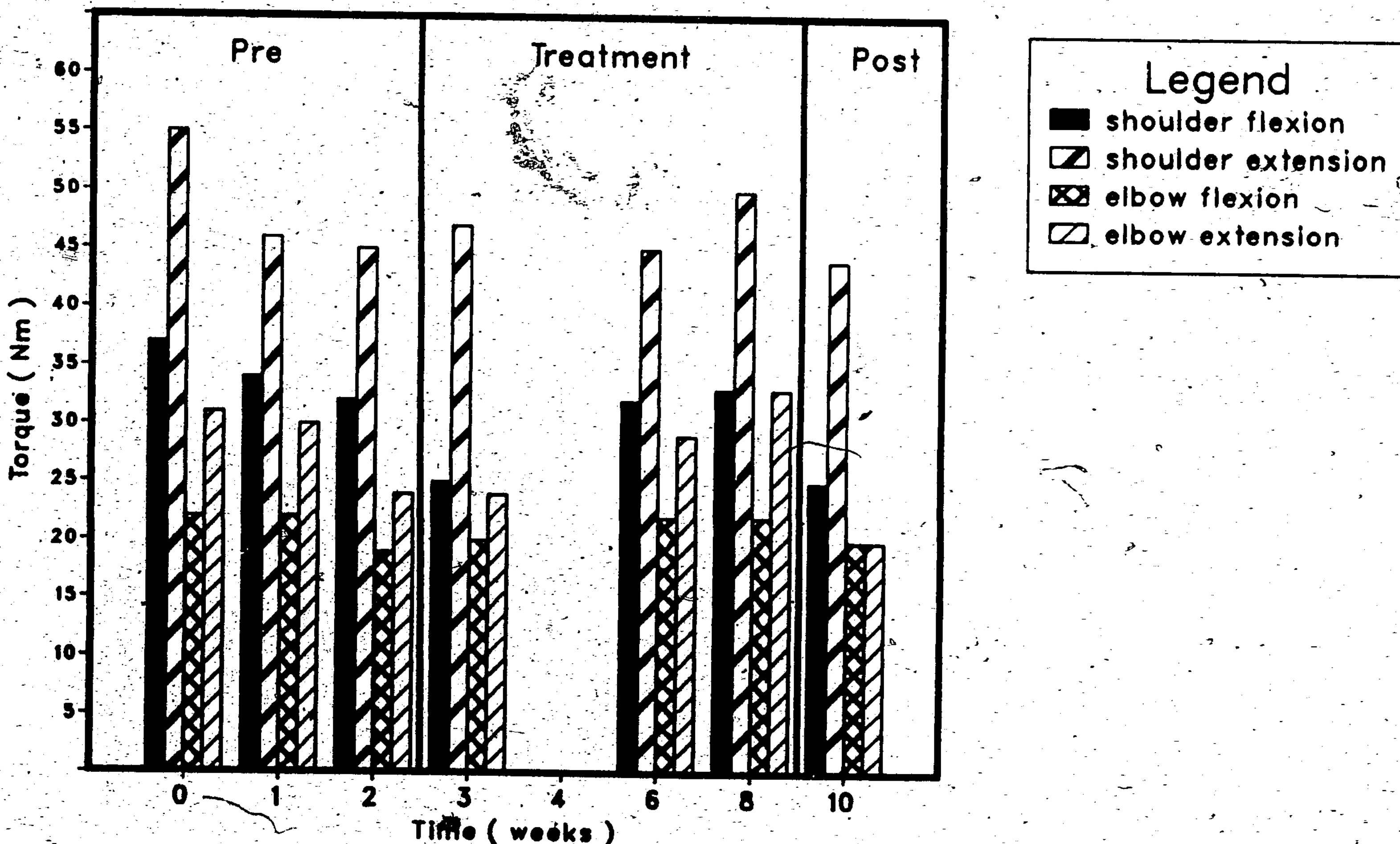


Figure 23: Subject E – Cybex II

Shoulder and Elbow Flexion/Extension at 3.144 r/s

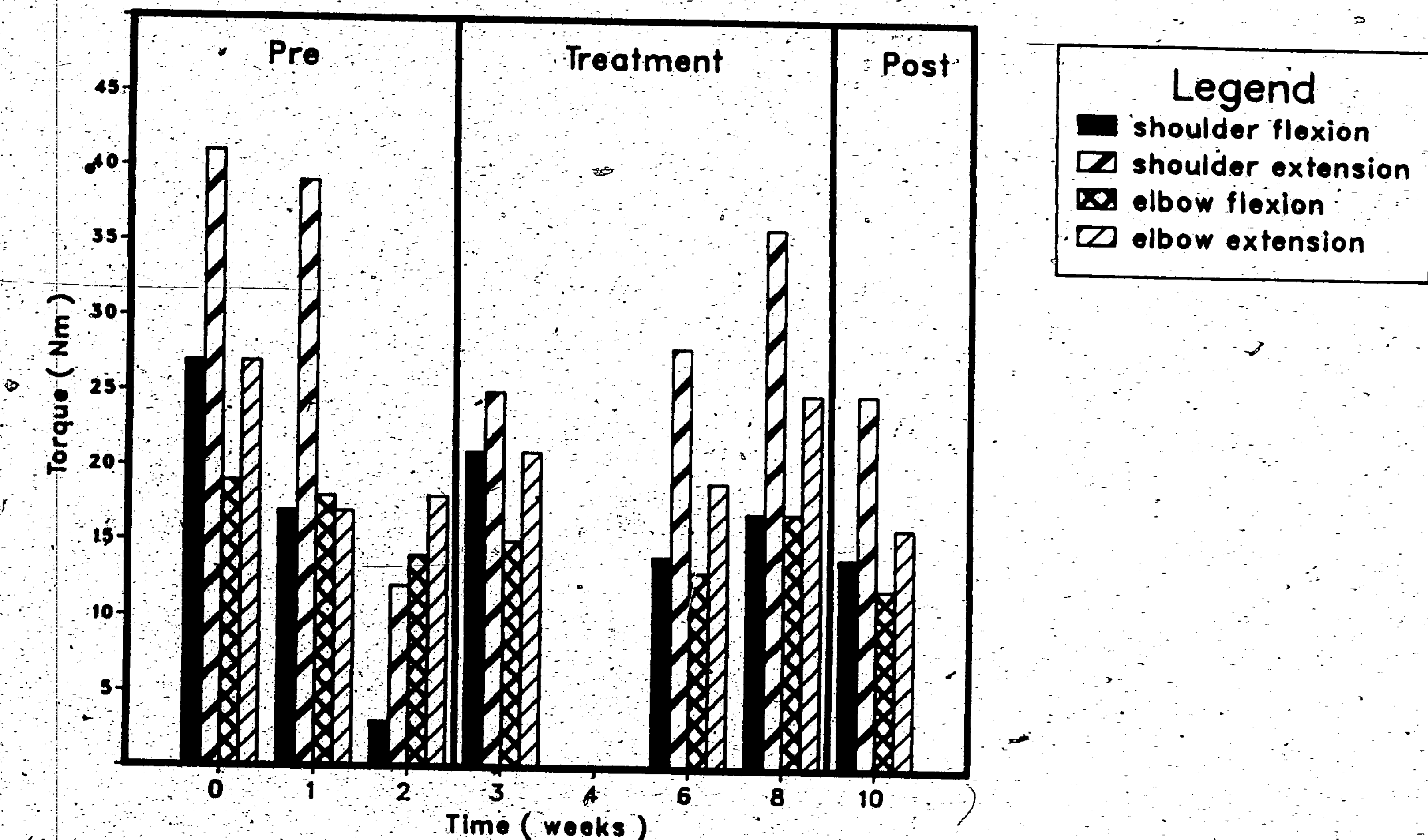


Figure 24: Subject E – Cybex II

Shoulder and Elbow Flexion/Extension at 3.144 r/s at 30 sec

criterion set for him at each phase except during phase eight where his performance was somewhat variable, Performance was increased by 170% from 450 lbs to 1215 lbs.

Figure 27 presents the strength changes for subject A on the Arm Cross dependent variable. Again, very positive strength changes were found. His performance exceeded the criterion set for him at each phase except during phase seven where his performance was somewhat variable. He started at 720 lbs and increased to 1575 lbs which is a 119% increase over the entire training program.

Subject A's performance on the Decline Press is presented in Figure 28. Again, very positive strength changes were found as was shown in the Behind Neck, Lateral Raise, and Arm Cross. In fact, he had an increase of 139% from 660 lbs to 1575 lbs. His performance was somewhat variable in the last two phases which might indicate that he was close to his training maximum.

Figure 29 reports the performance of subject A on the Biceps Curl. The striking feature of the graph is the stability of his performance during phase three of the treatment program. In contrast to his results in the Behind Neck, the Lateral Raise, the Arm Cross, and the Decline Press, he showed very minimal changes in strength on this variable until the fifteenth session of the program where his performance increased. His performance showed an increase from 360 lbs to 560 lbs an increase of 56%.

Subject A's performance on the Triceps Extension variable is presented in Figure 30. Again, his performance showed similar results as those of the Biceps Curl; that is, a stable third phase with somewhat variable performance in the last two phases. His performance shows an increase of 91%; from an initial weight of 420 lbs to a finishing weight of 800 lbs.

Subject B:

Figure 31 presents the strength changes on the Behind Neck variable by subject B. Dramatic changes occurred during the first few phases; however, his performance leveled off during the rest of the program after peak performances during sessions ten and eleven.

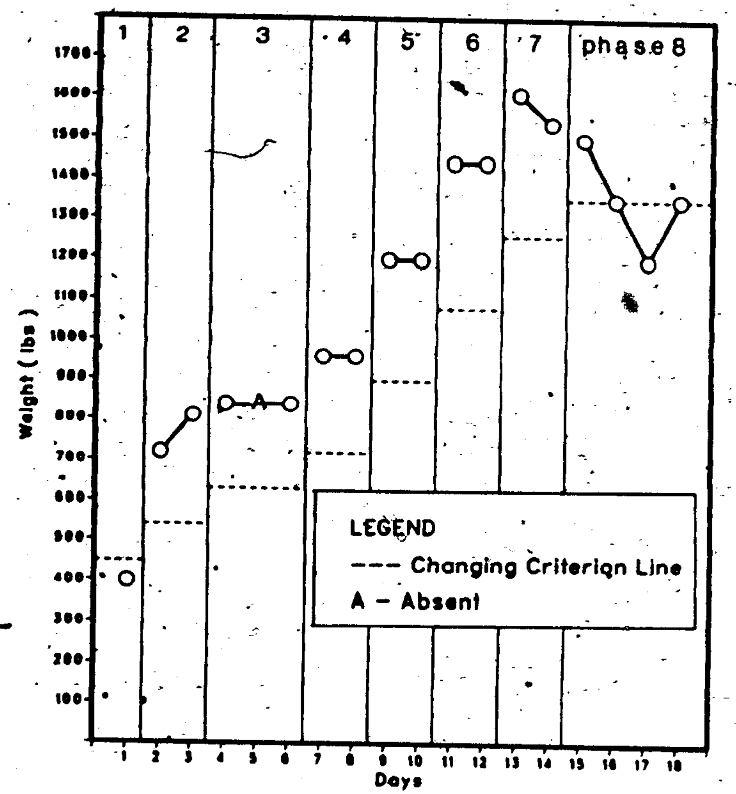


Figure 25: Strength Changes on the Behind Neck Nautilus Machine for Subject A

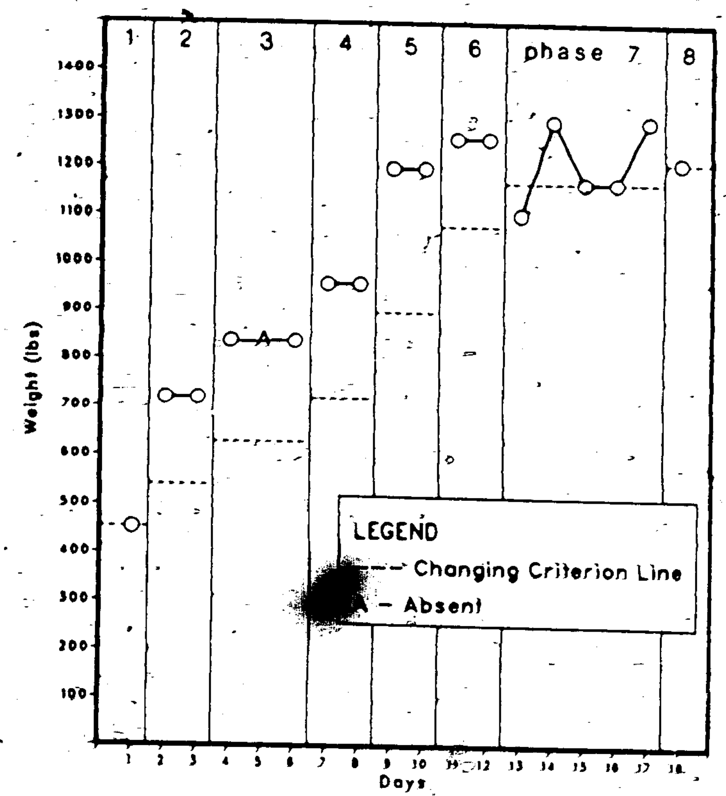


Figure 26: Strength Changes on the Lateral Raise Nautilus Machine for Subject A

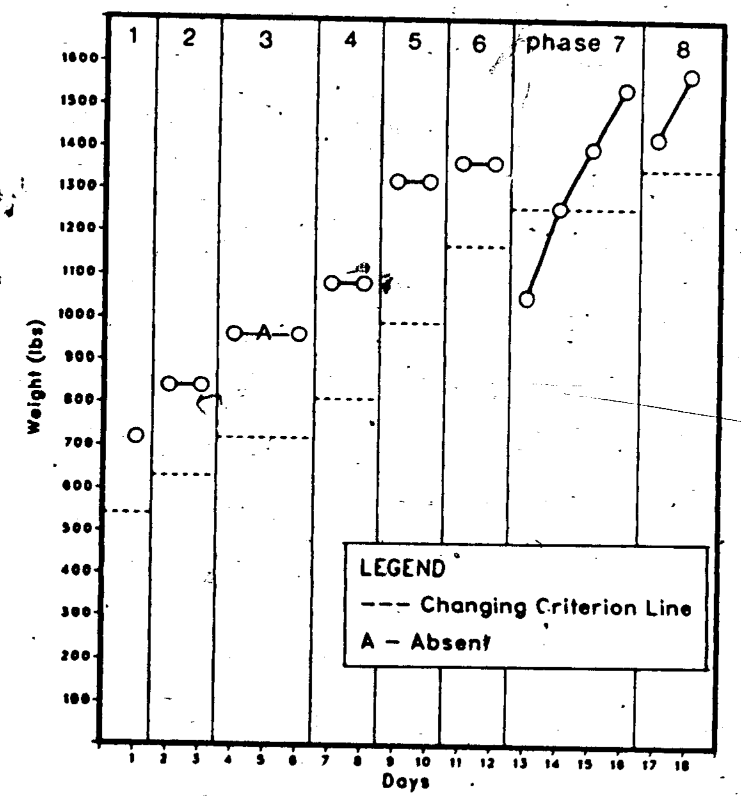


Figure 27: Strength Changes on the Arm Cross Nautilus Machine for Subject A

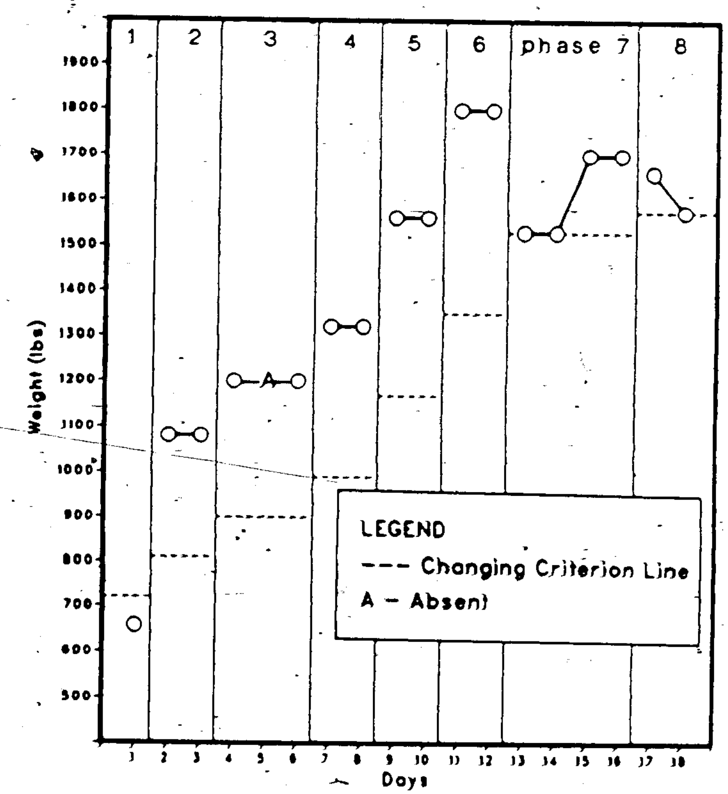


Figure 28: Strength Changes on the Decline Press Nautilus Machine for Subject A

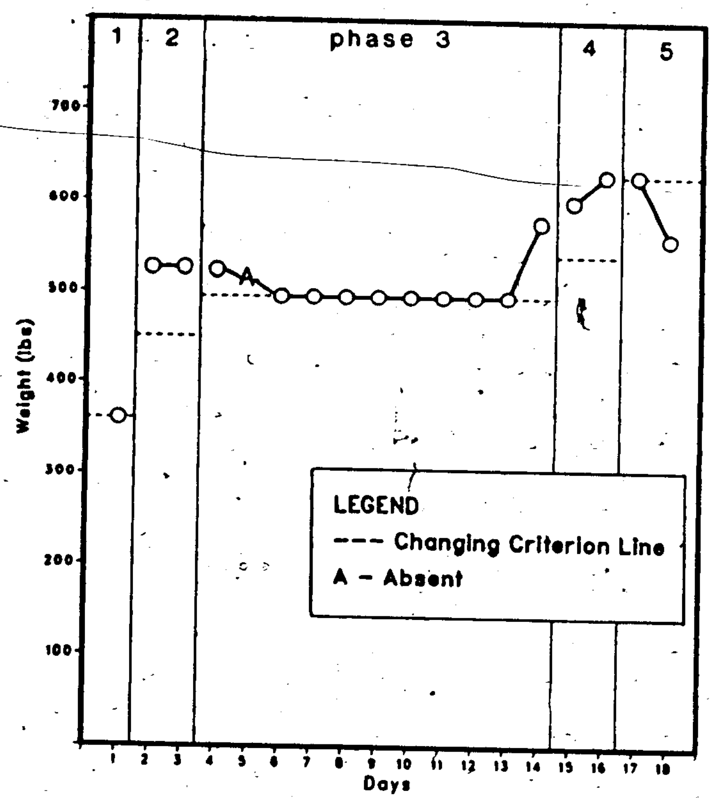


Figure 29: Strength Changes on the Biceps Curl Nautilus Machine for Subject A

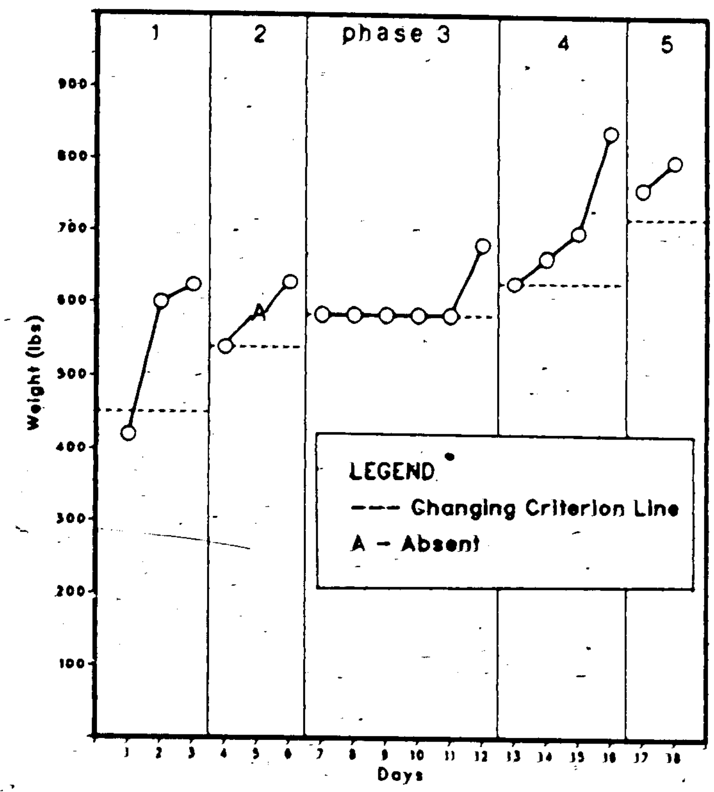


Figure 30: Strength Changes on the Triceps Extension Nautilus Machine for Subject A

Following these sessions, his results were somewhat variable and infact in sessions fourteen and sixteen he could not reach the criterion that was set. In summary, subject B showed some improvement; however, by the final phase he was not very different than he was during the second and third phases. He increased his performance by 65% from an initial weight of 820 lbs to finish at a weight of 1350 lbs.

On the Lateral Raise variable, subject B showed positive performance change during the early phases of the treatment; however, he reached a fairly constant level of performance by the fifth session and he did not change very much after that time. He showed a 54% increase over the six week treatment period which started at 720 lbs and finished at 1105 lbs. In summary, as Figure 32 shows, subject B had initial positive changes in level and trend; however, he reached an asymptote fairly quickly.

Figure 33 presents subject B's performance on the Arm Cross. Again, subject B showed a quick positive performance change during the initial start of the program however, as shown in the Lateral Raise he reached a fairly constant level of performance by the third session and did not change much after that time. He showed an increase of 33% overall finishing at 1232.5 lbs while he started at 950 lbs.

Subject B's performance on the Decline Press is presented in Figure 34. Again, as in the Lateral Raise and Arm Cross; the Decline Press showed positive performance changes during the initial stages of the treatment program; however, he reached a fairly stable training level by the seventh session and did not change much after that time. He increased his performance from an initial weight of 1100 lbs to 1550 lbs which is an overall increase of 41%.

Figure 35 presents the strength changes on the Biceps Curl by subject B. Again, as the figure shows, he had a fairly constant level of performance throughout the entire treatment period as was shown by subject A on the same exercise. He had an overall increase of only 23%; from an initial weight of 660 lbs to 810 lbs at the end of the program.

Subject B's performance on the Triceps Extension is presented in Figure 36. The figure shows similar performances as the Biceps Curl; that is, a fairly constant level of performance

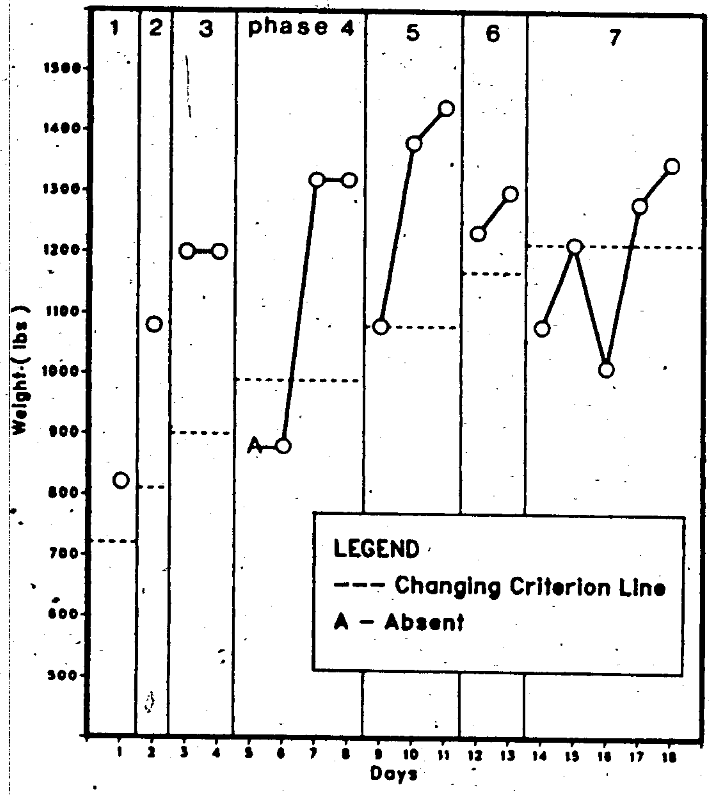


Figure 31: Strength Changes on the Behind Neck Nautilus Machine for Subject B

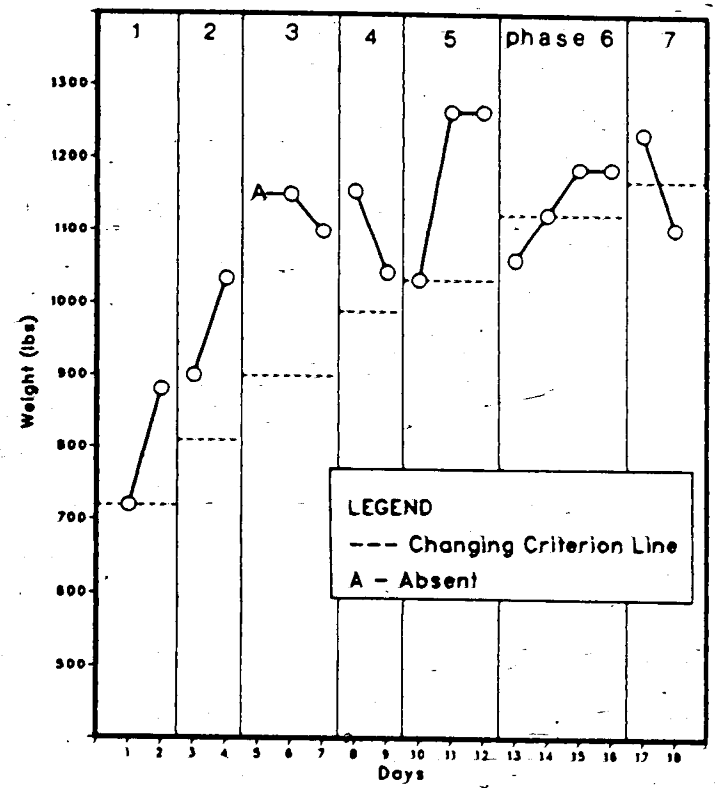


Figure 32: Strength Changes on the Lateral Raise Nautilus Machine for Subject B

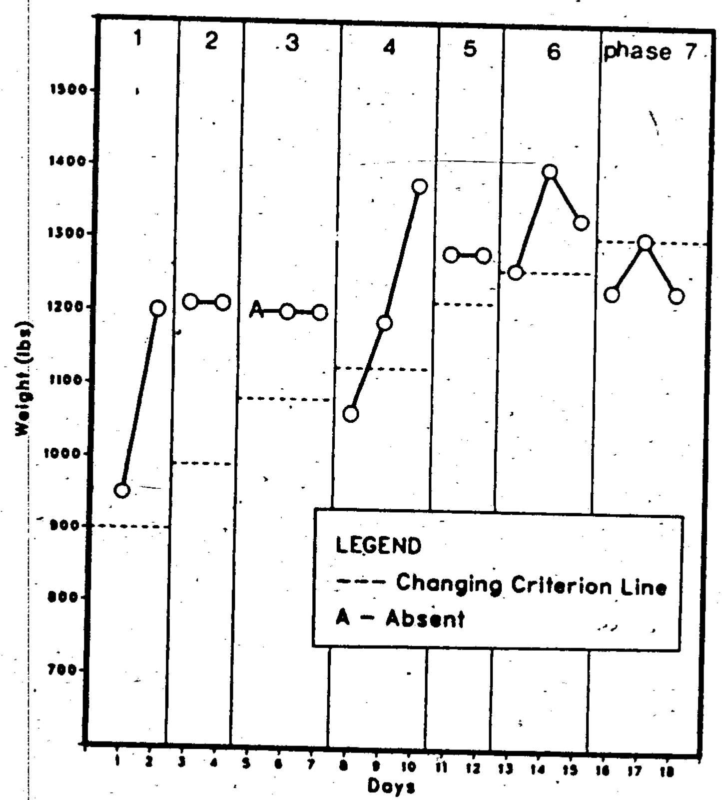


Figure 33: Strength Changes on the Arm Cross Nautilus Machine for Subject B

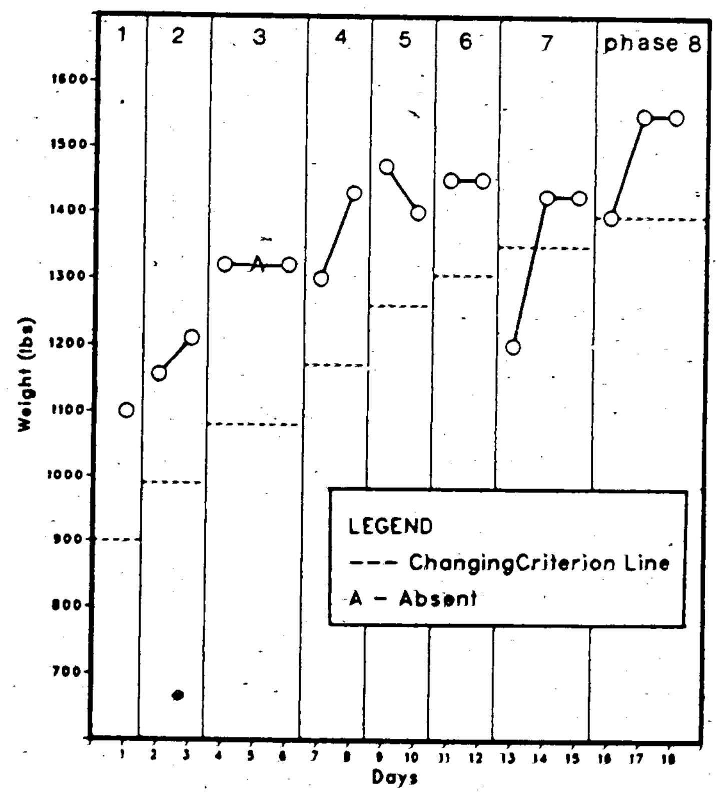


Figure 34: Strength Changes on the Decline Press Nautilus Machine for Subject B

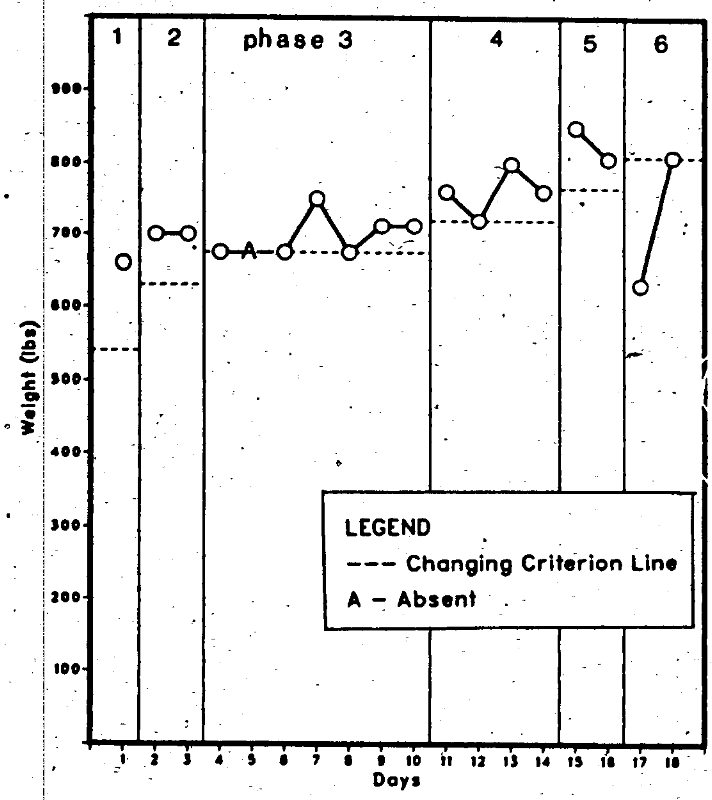


Figure 35: Strength Changes on the Biceps Curl
Nautilus Machine for Subject B

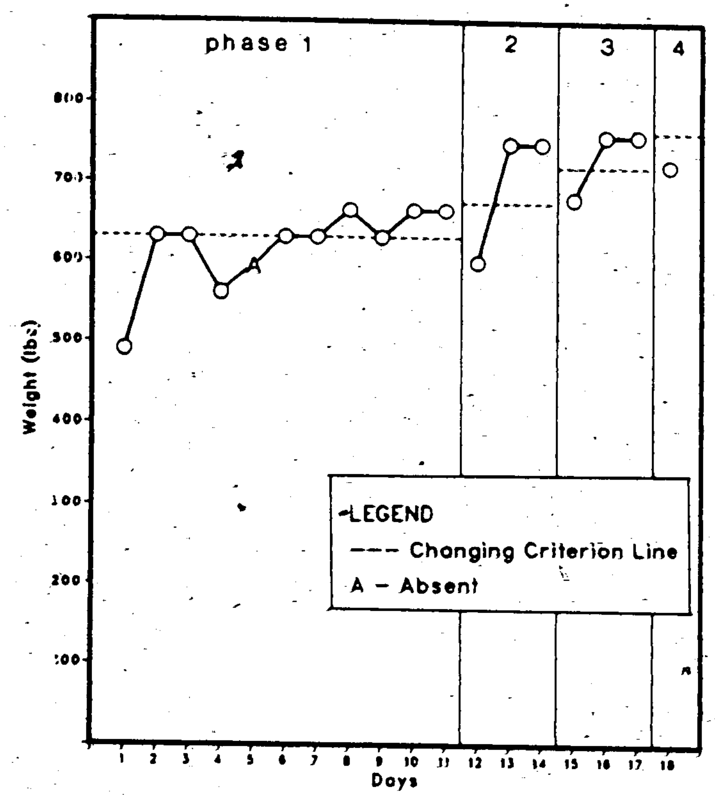


Figure 36: Strength Changes on the Triceps Extension
Nautilus Machine for Subject B

by subject B is executed. Subject B improved his performance on the Triceps Extension variable by 48%; an initial weight of 490 lbs to finish at a weight of 722.5 lbs.

Subject C:

Subject C's performance on the Behind Neck is presented in Figure 37. As the graph shows, he made very impressive gains during the beginning of the treatment program. His performance during stages four, five, and six are somewhat variable; however, during stage seven his performance did not meet the criterion level and dropped down to approximately the same performance level as when he started the exercise program. This is a rather strange pattern and no known cause can be suggested.

Figure 38 presents subject C's performance on the Lateral Raise. Subject C showed a positive performance change during the initial start of the program; however, he reached a fairly constant level of performance by the fourth phase and he did not change much after that time. He showed a 144% increase over the six week treatment program which started at 720 lbs and finished at 1760 lbs.

Subject C's performance on the Arm Cross is presented in Figure 39. This graph shows a steady increase over the eighteen days of the treatment period. It also should be noted that his performance during each phase always exceeded the criterion level that was set for him. In fact, he had an increase of 144%; that is, from an initial weight of 720 lbs to 1760 lbs at the end of the program.

Figure 40 presents the strength changes for subject C on the Decline Press dependent variable. Very positive strength changes were found. His performance exceeded the criterion set for him at each phase except during phase seven where his performance was somewhat variable. He started at 900 lbs and increased to 1837.5 lbs an 104% increase.

Figure 41 presents the strength changes for subject C on the Biceps Curl dependent variable. Again, positive strength changes were found. His performance exceeded or matched the criterion set for him although his performance was somewhat variable. He started at a

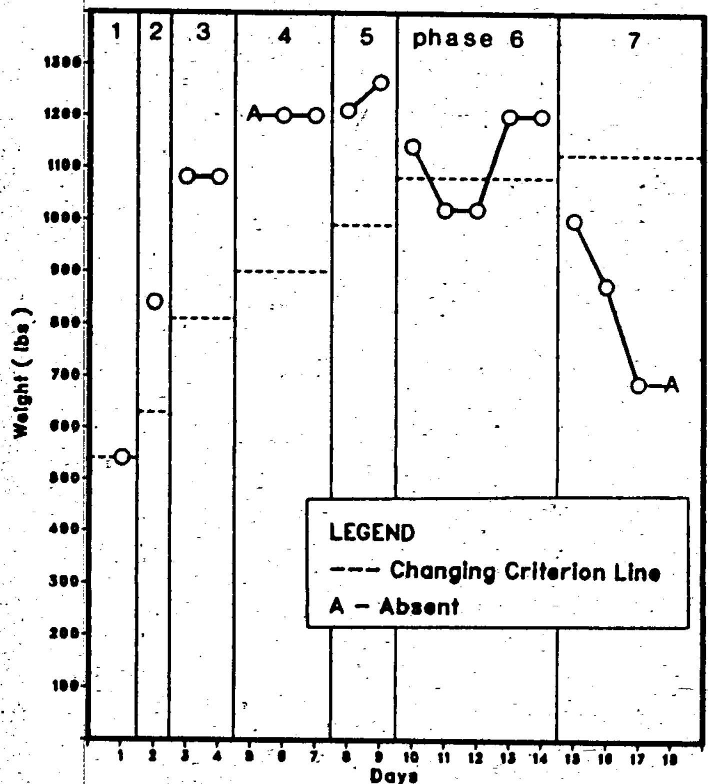


Figure 37: Strength Changes on the Behind Neck Nautilus Machine for Subject C

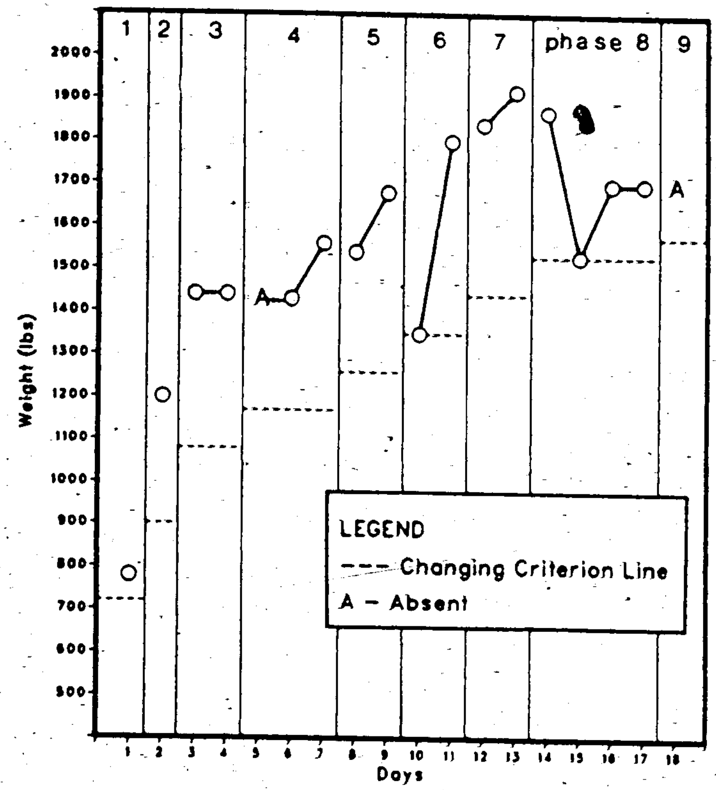


Figure 38: Strength Changes on the Lateral Raise Nautilus Machine for Subject C

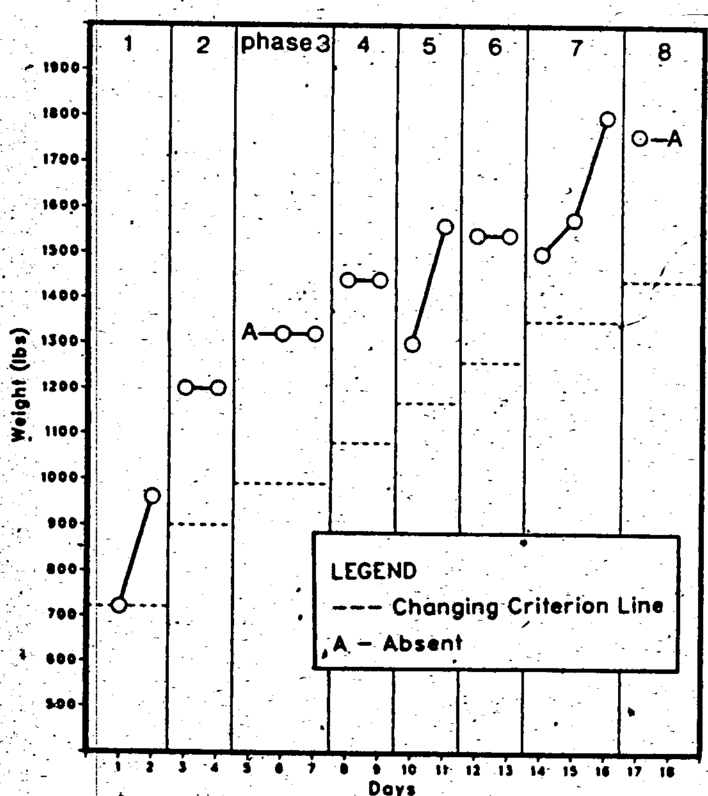


Figure 39: Strength Changes on the Arm Cross Nautilus Machine for Subject C

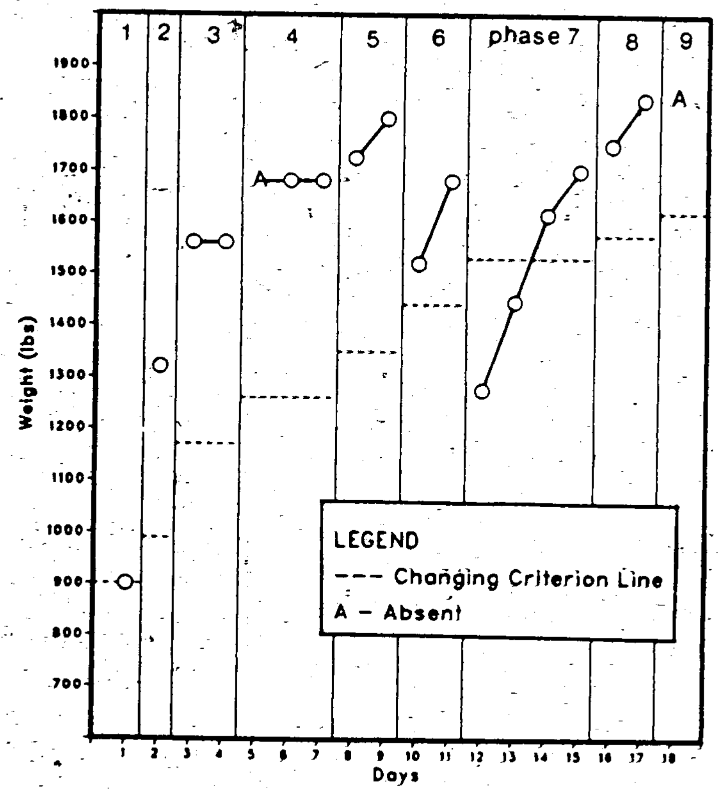


Figure 40: Strength Changes on the Decline Press Nautilus Machine for Subject C

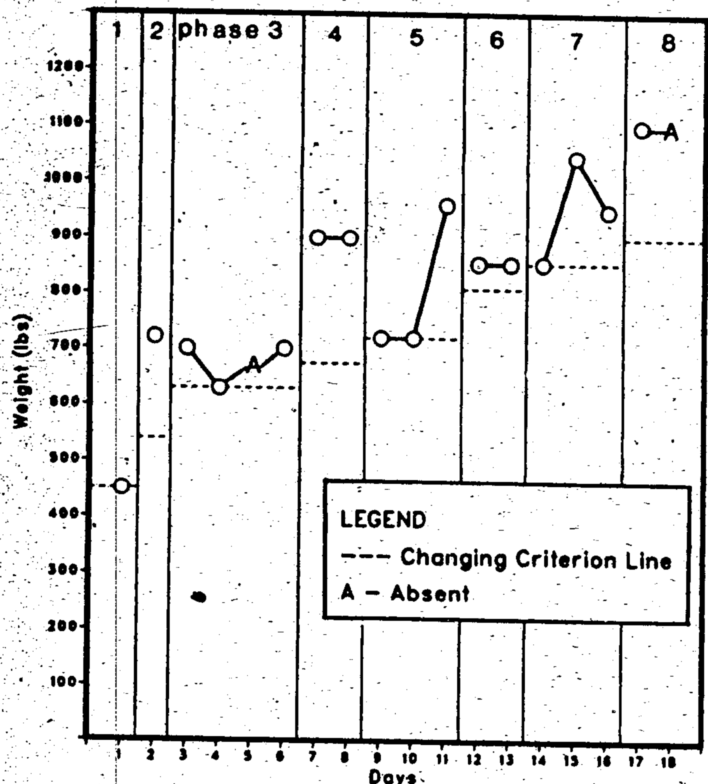


Figure 41: Strength Changes on the Biceps Curl Nautilus Machine for Subject C

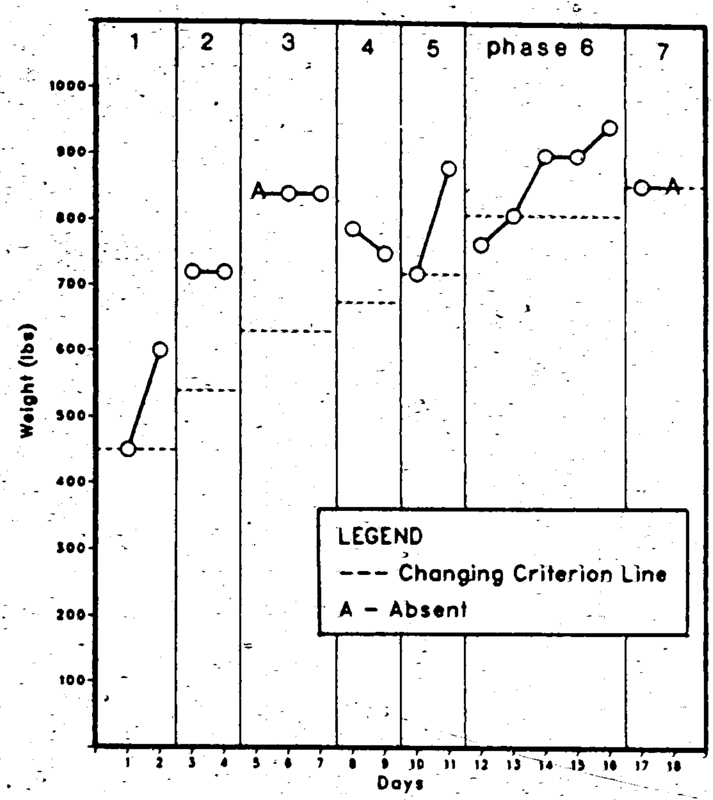


Figure 42: Strength Changes on the Triceps Extension Nautilus Machine for Subject C

weight of 450 lbs and achieved a weight of 1100 lbs at the end of the program; an increase of 144%.

On the Triceps Extension variable, subject C showed positive peformance changes during the early phases of the treatment; however, he reached a fairly constant level of performance by the fifth session and he did not change much after that time. He showed a 90% increase over the six week treatment period which started at 450 lbs and finished at 855 lbs. In summary, as Figure 42 shows, subject C had initial positive cahnges in level and trend; however, he reached an asymptote fairly quickly.

Subject D:

Figure 43 presents the strength changes on the Behind Neck variable by subject D. Quite dramatic changes occurred during the first few phases; however, his performance leveled off from the fifth phase onwards. His performance showed an increase from 660 lbs to 1200 lbs; an increase of 82%.

Figure 44 presents the performance of subject D on the Lateral Raise variable. He demonstrates minimal changes in strength on this variable; that is, he only increased his performance over the eighteen sessions by 3%. Although a somewhat variable performance, subject D matched or exceeded the criterion set for him.

Subject D's performance on the Arm Cross is presented in Figure 45. This graph shows a steady increase over the eighteen sessions of the treatment period. It also should be noted that his performance during each phase always exceeded the criterion level that was set for him. In fact, he had an increase of 178%; from a 540 lbs initial weight to a weight of 1500 lbs at the end of the program.

Figure 46 presents the strength changes on the Decline Press variable by subject D. As the graph clearly shows his performance during the eighteen days of treatment is somewhat variable with a peak performance during the tenth session. Subject D matched or surpassed the criterion level set for his training in nearly all sessions. His performance increased by 60% from

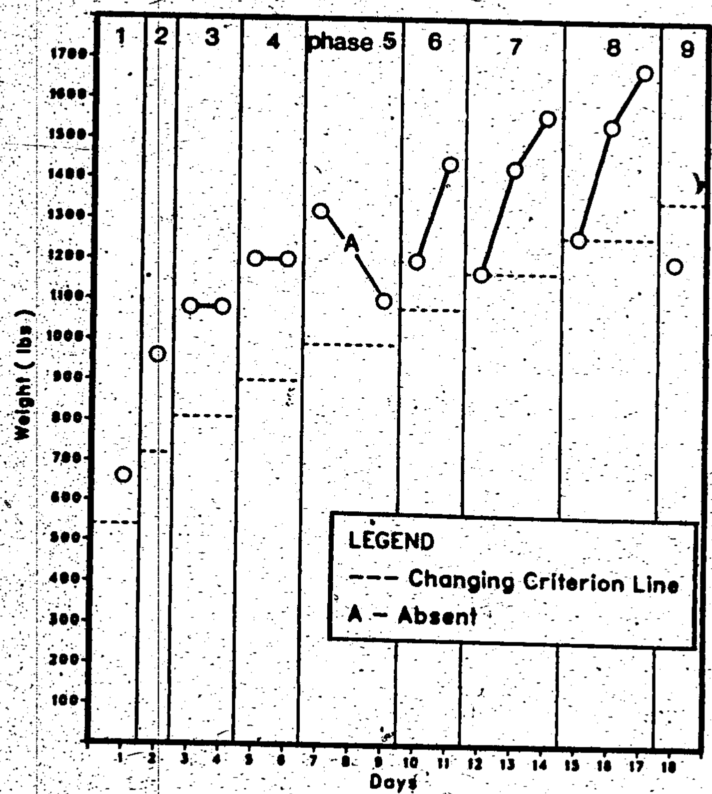


Figure 43: Strength Changes on the Behind Neck Nautilus Machine for Subject D

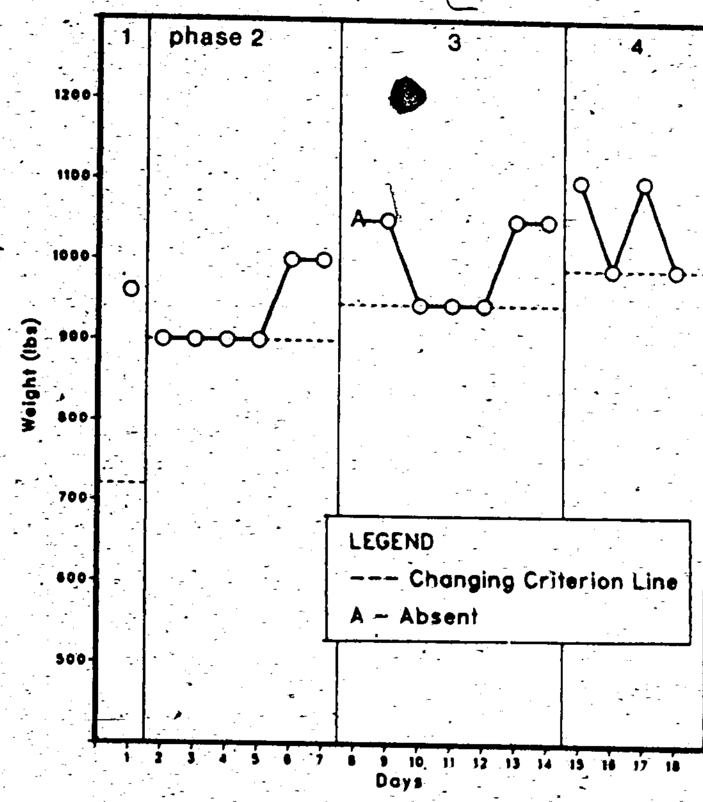


Figure 44: Strength Changes on the Lateral Raise Nautilus Machine for Subject D

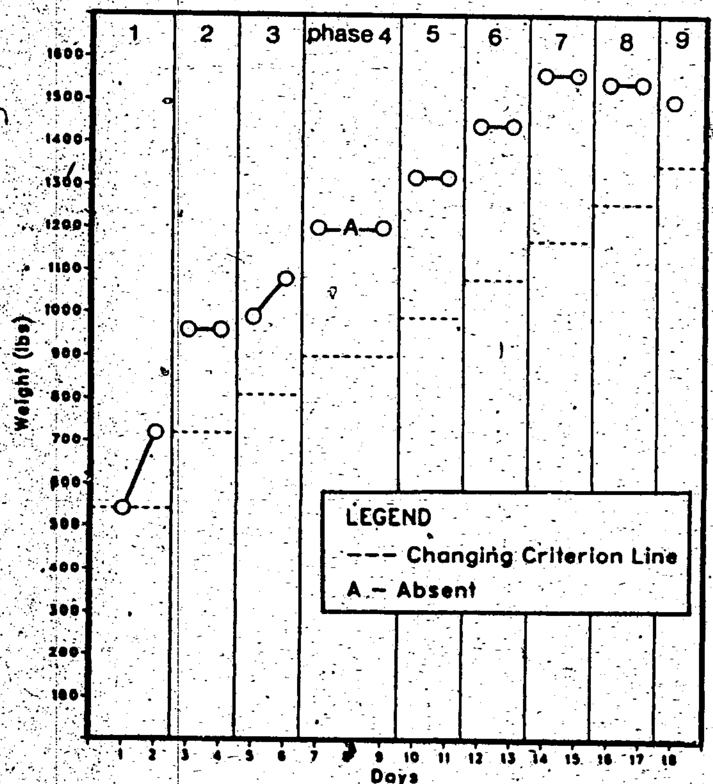


Figure 45: Strength Changes on the Arm Cross Nautilus Machine for Subject D

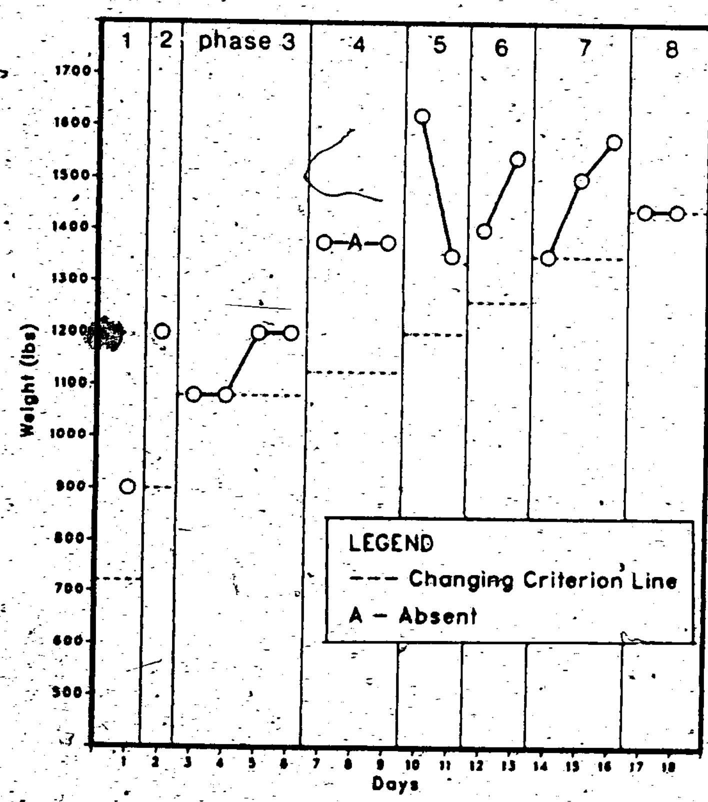


Figure 46: Strength Changes on the Decline Press Nautilus Machine for Subject D

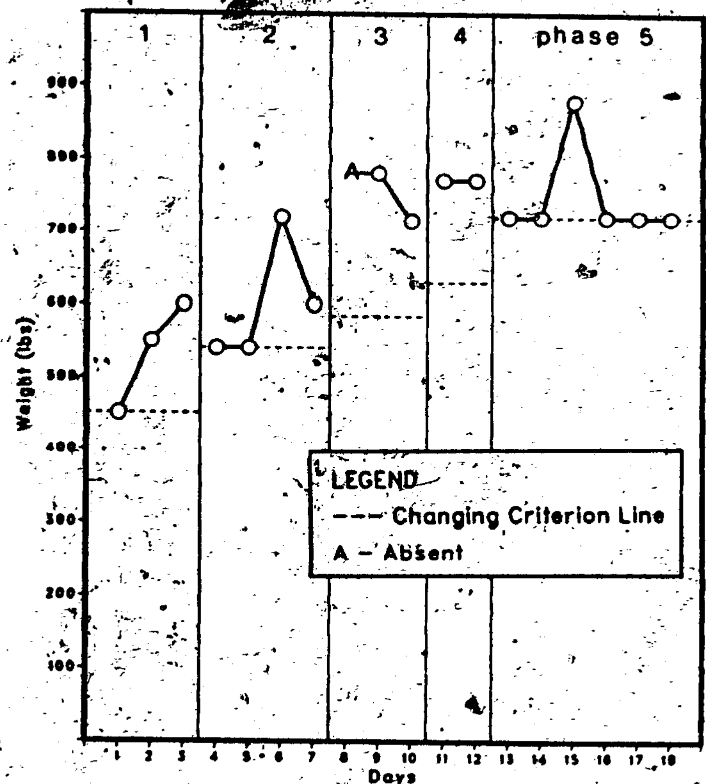


Figure 47: Strength Changes on the Biceps Curl Nautilus Machine for Subject D

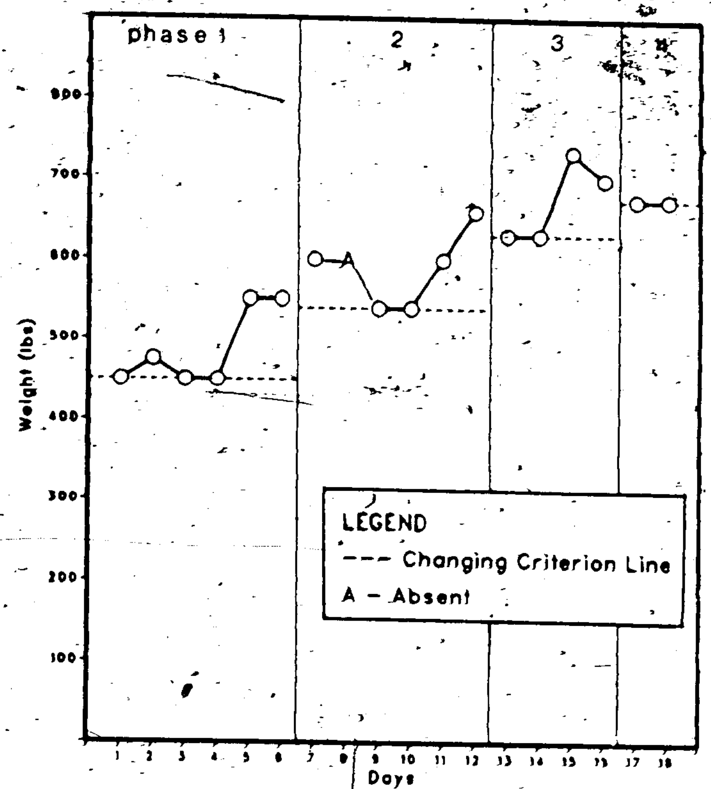


Figure 48: Strength Changes on the Triceps Extension Nautilus Machine for Subject D

a 900 lbs starting weight to 1440 lbs at the finish of the program.

Figure 47 presents subject D's strength changes on the Biceps Curl variable. Similar results are demonstrated as in the Decline Press variable; that is, a somewhat variable performance level throughout the entire eighteen sessions.

The Triceps Extension variable of subject D (Figure 48) shows that he had relatively stable performances during the first phase and achieved criterion levels that were set for him in the next three phases. Clearly, he showed positive strength changes.

Subject E:

Figure 49 presents the strength changes for subject E on the Behind Neck dependent variable. His performance showed a steady increase at the beginning of the program which became somewhat variable following the eighth session. Subject E's performance showed an increase of 41%; an initial weight of 1080 lbs to 1522 lbs at the end of the program.

Subject E's performance on the Lateral Raise variable is presented in Figure 50. Again, a steady increase of strength changes is evident. Subject E exceeded the criterion level set for him throughout the entire treatment period from a 1050 lbs initial weight to a 1785 lbs weight at the end of the program; a 70% increase.

Figure 51 presents the strength changes of subject E on the Arm Cross variable. The same steady increase in performance is evident as in the Lateral Raise variable. Again, he exceeded the criterion set for him during the entire treatment period. This performance showed a 62% increase; an initial weight of 1265 lbs to a 1870 lbs weight at the end of the program.

As indicated in Figure 52, the Decline Press results show similar positive changes in strength for subject E as on the Lateral Raise and Arm Cross.

A fairly steady performance in strength changes is presented in Figure 53 for subject E's performance on the Biceps Curl variable. As the graph shows, even if he had a number of absences, his performance increased from 550 lbs starting weight to a 850 lbs weight at the finish of the program; a 55% increase.

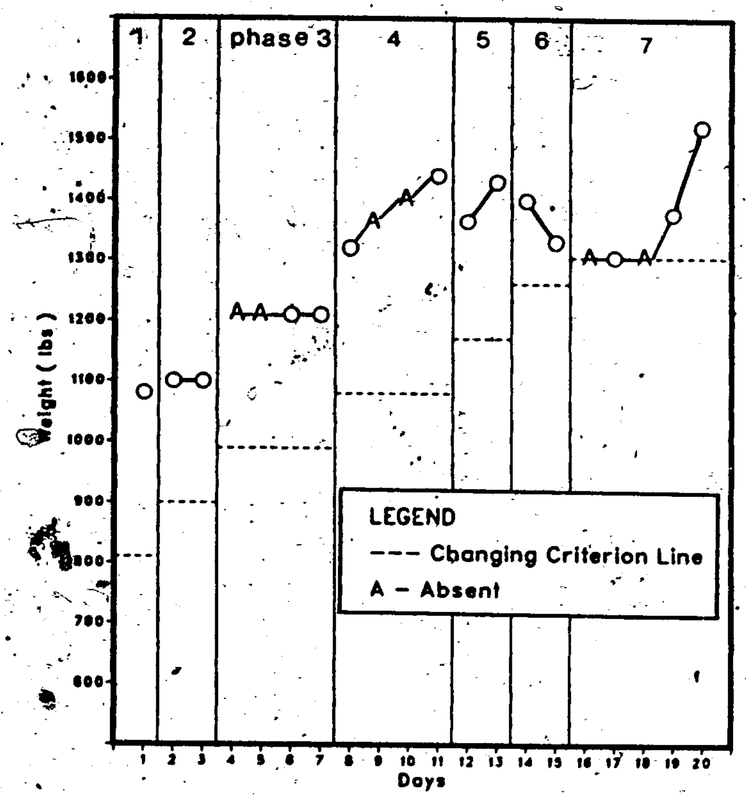


Figure 49: Strength Changes on the Behind Neck Nautilus Machine for Subject E

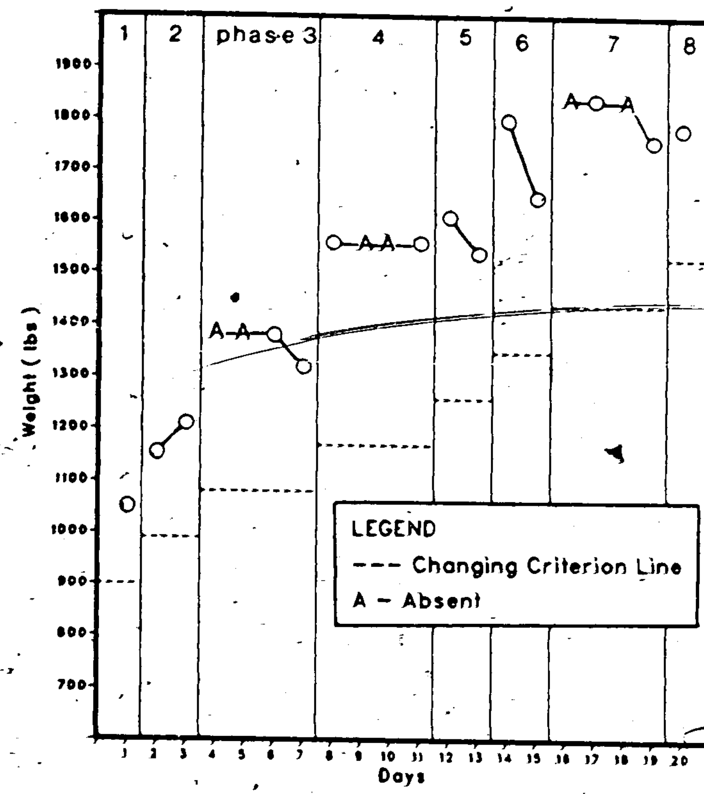


Figure 50: Strength Changes on the Lateral Raise Nautilus Machine for Subject E

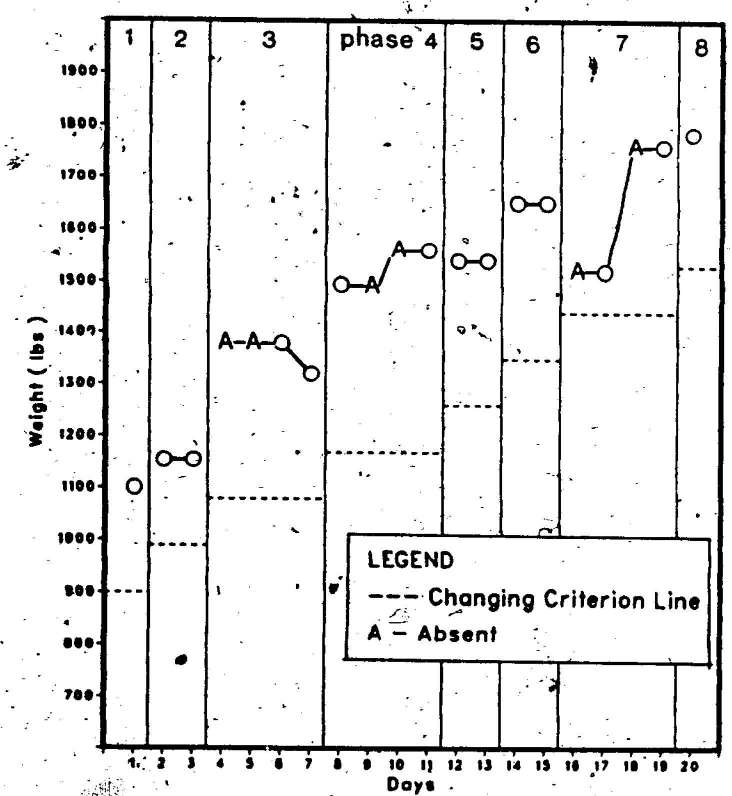


Figure 51: Strength Changes on the Arm Cross Nautilus Machine for Subject E

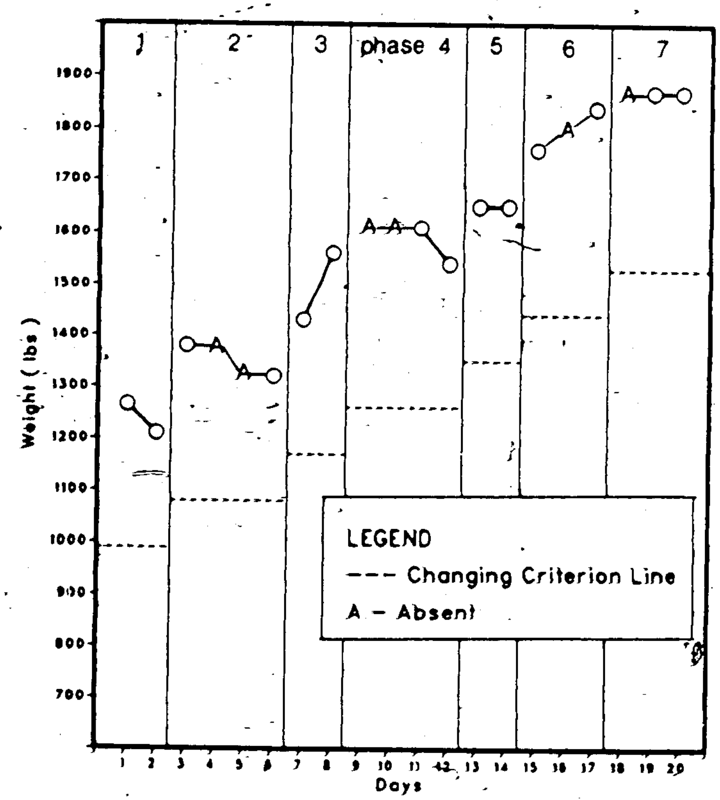


Figure 52: Strength Changes on the Decline Press Nautilus Machine for Subject E

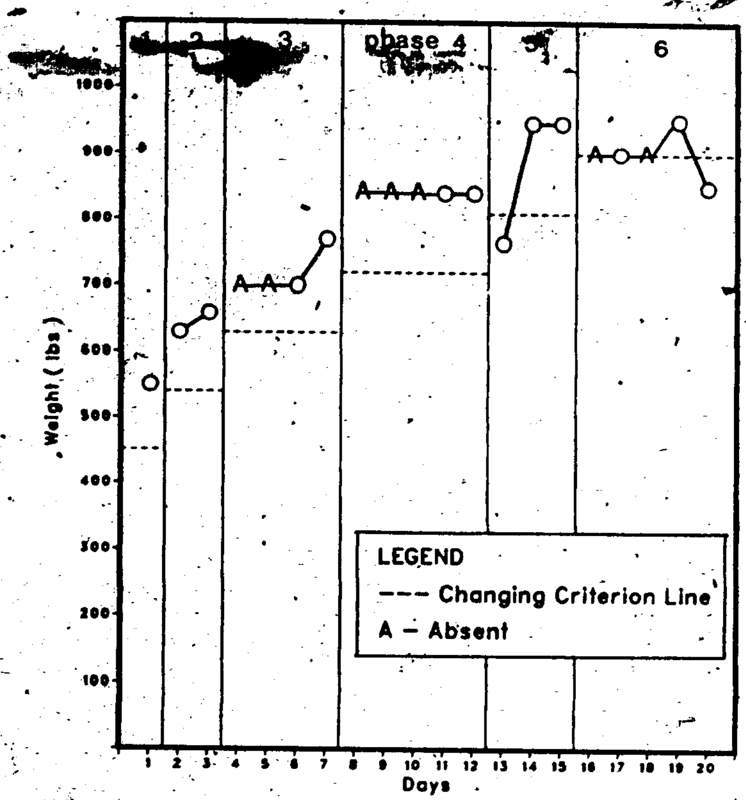


Figure 53: Strength Changes on the Biceps Curl Nautilus Machine for Subject E

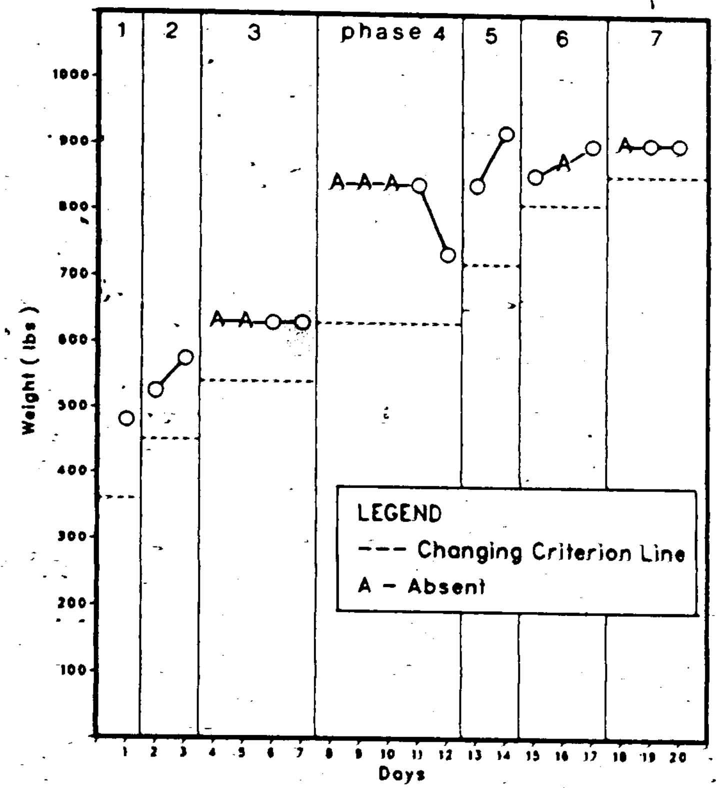


Figure 54: Strength Changes on the Triceps Extension Nautilus Machine for Subject E

Subject E's performance on the Triceps Extension variable is presented in Figure 54. Again, his performance shows that he exceeded the criterion set for each level, which was also evident in the Lateral Raise, Arm Cross, and Decline Press performances. He increased his performance by 88%; from a 480 lbs starting weight to finish at a weight of 902.5 lbs.

C. General Discussion

As indicated in the previous section, all subjects matched or surpassed the criteria set on the different Nautilus exercises (figures 25 - 54). There were instances where performances fell below the criterion, but these instances may have been due to:

a. illness on the day the subjects had to perform a Nautilus workout which was the case for subjects A, B, and C;

b. soreness from the previous session. This was a major complaint at the beginning of the six week treatment period for subject A;

c. performance on the Cybex II testing before their training program. Although there was a fifteen minute rest period in between the two programs, it was possible that a longer recovery time would have minimized this effect for subjects B, C, D, and E;

d. absence from a training session which was the case for all five subjects;

e. performing six exercises in a modified order was necessary to accomodate other clients at the Centre (eg. the Behind Neck exercise was performed second or third instead of first). This change in routine was considered preferable to a wait which would result in muscle cool down and could increase the chance of injury. This could have been the case in subjects A, B, C, and E.

All of these factors were possible threats to internal validity, although, despite the variability, the improvement in the individuals' performances can not be denied.

According to Tawney (1984), the researcher has the responsibility of making criterion changes that are large enough to be detectable, though small enough to be achievable, but not so small that the behaviours will far exceed the criterion level. In this study, the change in criterion was small so that each individual exceeded the new criterion very easily. The criterion was changed by increasing the weight for each repetition by 2 1/2 or 5 lbs. It would have been a little difficult for an individual if the weight was increased by 10 to 20 lbs from one session to the next for each repetition.

In the previous section, the expected performances on the Cybex showed a stable baseline throughout the pre-treatment period followed by an increased trend over the six week Nautilus treatment period. An interruption of training would then result in a decrease in trend. This was not shown on the Cybex II testing in this study.

It is possible that the Cybex II equipment was not an appropriate criterion in this study because of the specificity factor. It appears that it would be necessary to either measure the subjects on the same equipment namely the Nautilus equipment or train the individuals on the Cybex II to effect significant improvement on both. In this study it was not possible to train several individuals at the same time on the Cybex II, whereas, this could be accomplished on Nautilus equipment. In order to demonstrate more pronounced detraining, a longer post treatment phase would have been beneficial.

As Moffroid and colleagues (1969) indicated, a maximal effort in muscular strength performance is dependent on the motivation levels of the subjects. In this study the motivation factor played an important role. All of the subjects in this study indicated an interest in completing a workout on the Nautilus, but disliked the testing on the Cybex II. This was be an internal validity threat of maturation (Tawney,1984) since the individuals were less motivated to perform on the Cybex II. Since Cybex II testing results usually took time to analyze, the subjects did not get immediate feedback on their performance. In contrast, on the Nautilus weight training equipment, feedback was immediate and encouraging. Also if one wants to give immediate feedback, one has to wait after each movement for a short period of time to get immediate feedback which cause fluctuations in effort and performance.

Subjects reported, during the post training period, that they missed their regular workouts and wanted to come back and start their own routine. They indicated that as a result of training, transfers in and out of their wheelchairs were made easier. They were less fatigued from moving around in the chair for a long period of time. Further positive outcomes can be seen from the activity following the study (Table 1).

It is not possible to identify the specific cause and effect relationships in this study on the factors related to the muscular strength increases. It probably was due to an interaction of a number of factors which resulted in the changes in muscular strength. The factors resulting in the changes in muscular strength mentioned by Lesmes (1978); Fox & Mathews (1980); Schmidtbleier (1985); Heusner (1980) were not examined during this study; but in further studies; one could look at muscle fiber types, endocrine and metablism systems.

In this study, it might have been the case, that the individuals' rapid increases of resistance on the Nautilus equipment was a combination of a learning effect and a low starting threshold. Since all subjects were new to this type of training.

In summary, there were several possibilities discussed, which were related to the results in this study. The Nautilus results showed significant improvements over the six week training period. Although no significant changes were found in the Cybex II results, similar results were found by Pipes & Wilmore (1975), Moffroid & colleagues (1969), and MacDougall et al. (1977, 1979, 1980) when testing able bodied individuals. It seems that the specificity factor played an important role in this type of study. There was no relationship of the results when taking into consideration, age, lesion level, and date of injury of the subjects. Motivation was a factor and always is in this type of training. The learning effect and other factors to muscular strength increases might have played a role in this study as well, but further investigation would be necessary to determine the specific effect these factors play in muscular strength training in spinal cord injured individuals.

Chapter V

CONCLUSIONS AND RECOMMENDATIONS

The results on the Cybex II showed relative stable pre-treatment performances by the five subjectson all four variables. The initiation of the treatment program did not result in positive changes in performance. Whereas, the strength changes on the six Nautilus machines showed tremendous increases from only a 3% to a 221% increase over the six week treatment period by all subjects.

Cybex II

No measurable strength changes were observed when the subjects were tested on the Cybex II. This was probably due to the fact that Cybex is not the most appropriate criterion for testing muscular strength. Also, the subjects did not like to perform on the Cybex, because an immediate read out was not available and the machine was very awkward and time consuming.

Nautilus

There were strength changes observed while performing a six week training period on six Nautilus machines three times a week; however, the changes were variable. The subjects were motivated to perform on the Nautilus as immediate feedback was available by seeing the actual weight that had to be lifted. Also the subjects felt that as a result of training, their transfers were easier and they did not fatigued as quickly. The subjects wanted to stay involved in the training program three times a week while they were in the detraining part of the study. Some of the individuals have since stayed involved in fitness and lifestyle pursuits through a regular weight training program three times a week or have been involved in other activities such as baseball.

Recommendations:

The following recommendations are suggested for further investigation into upper body muscular strength changes in spinal cord injured individuals.

1. Researchers should examine the specificity of weight training on testing and treatment equipment more carefully.
2. Investigation on muscle hypertrophy through skinfold and circumference measurements should be examined.
3. An investigation into higher weight increases should be carried out.
4. Research should be conducted by increasing the detraining period and collecting more data points during the detraining period.
5. Investigation into the proper criterion settings on the Nautilus equipment should be examined.
6. Researchers should investigate the muscular fiber types of spinal cord injured individuals.
7. Investigation on how individuals who are familar to the testing and training equipment react when performing a training program.
8. Researchers should investigate the learning effect and motivation levels of spinal cord individuals when performing a weight training program.
9. Protein synthesis in muscle fiber, contractile speed of muscle fiber, and energy metabolism research is required. This means more investigation into the biochemical and endocrine areas.
10. More research should be conducted on the physiological, morphological and neurotrophic areas which occur in the synapses, peripheral nerves, motor end plates of neuromuscular junctions.

REFERENCES

Berger, R.A. (1962). Optimum repetitions for the development of strength. Research Quarterly for Exercise and Sport, 33, 334-338.

Campbell, D.T., & Stanley, J.C. (1963). Experimental and Quasi-experimental designs for research. Chicago: McNally and Company.

Canadian Paraplegic Association. (1985). New spinal cord injuries: 1984-1985. Caliper, 40, 9.

Coleman, A.E. (1979). Nautilus versus universal gym strength training in adult males. American Corrective Therapy Journal, 31, 103-107.

Coplin, T. (1971). Isokinetic Exercise: Clinical Usage. New York: Cybex Division of Lumex, Inc.

Cull, J.G., & Hardy, R.E. (1977). Physical medicine and rehabilitation approaches in spinal cord injury. Illinois: Charles C. Thomas.

Cybex, a Division of Lumex, Inc., (1975). Cybex II testing protocol New York: Author.

Darden, E. (1974). Muscular contraction as a factor in strength training. Deland, Florida: Nautilus Sports/Medical Industries.

Darden, E. (1980). The Nautilus Book: an illustrated guide to physical fitness the Nautilus way. Chicago: Contemporary Books Inc.

Davis, G.M., Kofsky, P.R., Shephard, R.J., Keene, G.C.R., & Jackson, R.W. (1980). Muscular strength in the lower limb disabled. Canadian Journal of Applied Sports Sciences, 5(4), 159.

Davis, G.M., Kofsky, P.R., Kelsey, J.C., & Shephard, R.J. (1980). Cardiorespiratory fitness and muscle strength in wheelchair users. Canadian Medicine Association Journal, 125, 1317-1323.

Davis, G.M., Tupling, S.J., & Shephard, R.J. (1986). Dynamic strength and physical activity in wheelchair users. In C. Sherrill (Ed.), the 1984 Olympic Scientific Congress Proceeding Vol 9 (pp. 139-145). Campaign: Human Kinetics Publishers, Inc.

Dawson, G.A. (1980, May/June). Heart rate and athletics. Sports and Spokes, 13-14.

DeLorme, T.L., Ferris, B.G., & Galliger, J.R. (1952). Effects of progressive resistance exercise on muscle concentration time. Archives of Physical Medicine Rehabilitation, 33, 86-92.

DeLorme, T.L., & Watkins, A.L. (1948). Technics of progressive resistance exercise. Archives of Physical Medicine, 29, 263-273.

Elliot, J. (1978). Assessing muscle strength isokinetically. American Medical Association Journal, 240(22), 2408-2409.

[illegible]eck, S. (1979). [illegible]s of strength training: pros and cons. Swimming Technique, 16(3), 84-88.

Fox, E.L., & Mathews, D.K. (1981). The physiological basis of physical education and athletics. Philadelphia: Saunders College Publishing.

Frey, K. (1975, May/June). Strength training and wheelchair sports. Sports and Spokes, pp. 7-8.

Gains, D. (1982, June). Training for the disabled. Athletics, pp. 18-19.

Gersten, J., Brown, I., Speck, L., & Grueter, B. (1963). Comparison of tension development and circulation in biceps and triceps in man. American Journal of Physical Medicine, 42, 156-165.

Grimby, G. (1980). Aerobic capacity, muscle strength and fiber composition in young paraplegics. In H. Natvig (Ed.), International Medical Congress on Sports for the Disabled (pp. 13-18). Oslo: Royal Ministry for Church and Education.

Guttman, L. (1976). Spinal cord injuries. Oxford: Blackwell Scientific Publications.

Hall, R.V. (1971). Managing behaviour: Behaviour modification, the measurement of behaviour. Lawrence, Kanses: H & H Enterprises.

Hardy, A.G., & Rosier, A.B. (1975). Spinal cord injuries, Stuttgart: Thieme Edition Publishing Sciences Group Inc.

Hartman, D.P., & Hall, R.V. (1976). The changing criterion design. Journal of Applied Behaviour Analysis, 9 (4), 527-532.

Heusner, W. (1981). The theory of strength development for swimming and other sports - part 1. National Strength and Conditioning Association Journal, 3, 36-47.

Heusner, W. (1982). The theory of stength development for swimming and other sports - part 2. National Strength and Conditioning Association Journal, 3, 36-40.

Hislop, H., & Perrine, J. (1967). The isokinetic concept of exercise. Physical Therapy, 47, 114-117.

Hobson, A. (1983, November/December). The truth beneath the pump. Coaching Review, pp. 16-22.

Houltz, S.J., Parrish, A.M., & Hellebrandt, F.A. (1946). Influence of heavy resistance exercise on strength. Physiotherapy Review, 26, 299-304.

Kofsky, P.R., Shephard, R.J., Davis, G.M., & Jackson, R.W. (1986). Classification of aerobic power and muscular strength for disabled individuals who differ in habitual physical activity pattern. In C. Sherrill (Ed.), the 1984 Olympic Scientific Congress Proceeding Vol 9 (pp. 147-155). Campaign: Human Kinetics Publishers, Inc.

Kratochwill, T.R. (Ed.) (1978). Single subject research strategies for evaluating change. New York: Academic Press, Inc.

Lehmann, I.J., & Mehrens, W.A. (1971). Educational research: readings in focus. New York: Holt, Rinehart and Winston, Inc.

Lesmes, G.R., Costill, D.L., Coyle, E.F., & Fisk, W.J. (1978). Muscle strength and power changes during maximal isokinetic training. Medicine and Science in Sports and Exercise, 10, 266-269.

MacDougall, J.D., Ward, G.R., Sale, D.G., & Sutton, J.R.(1979). Biochemical adaptation of human skeletal muscle to heavy resistance training and immobilization. Journal of Applied Physiology, 43, 700-703.

MacDougall, J.D., Sale, D.G., Moroz, J.R., Elder, G.C.B., Sutton, J.R., & Howard, H. (1979). Mitochrondrial volume density in human skeletal muscle following heavy resistance training. Medicine and Science in Sport and Exercise, 11, 164-166.

MacDougall, J.D., Elder, G.C.B., Sale, D.G., Moroz, J.R., & Sutton, J.R. (1980). Effects of strength training and immobilization on human muscle fibers. European Journal of Applied Physiology, 43, 25-34.

McBee, F. (1984, September/October). Wheelers go for the Gold. Sports and Spokes, pp. 8-12,14,16.

Moffroid, M., Whipple, R., Hofkosh, J., Lowman, E., & Thistle, H. (1969). A Study of isokinetic exercise. Physical Therapy, 49, 735-747.

Moore, G.W. (1983). Developing and evaluating educational research. Boston: Little, Brown and Company.

Nautilus Sports/Medical Industries. (1974). Improving functionalability .....in any sport. Deland: Author.

Nautilus Sports/Medical Industries. (1979). Athletic Journal, 59, 43.

Nautilus Sports/Medical Industries. (1982). Nautilus Magazine, 4, 31.

Nilsson, S., Staff, P., & Pruett, E. (1975). Physical work capacity and the effect of training on subjects with long standing paraplegia. Scandinavian Journal of Rehabilitative Medicine, 7, 51-56.

Parsonson, B.S., & Bear, D.M. (1978). The analysis and presentation of graphic data. In T.R. Kratochwill (Ed.), Single subject research strategies for evaluating change (pp. 101-165). New York: Academic Press.

Perrine, J. (1968). Isokinetic exercise and the mechanical energy potentials of muscle. Journal of Health, Physical Education and Recreation, May, 40-44.

Pipes, T.V., & Wilmore, J.H. (1975). Isokinetic versus isotonic strength training in adult men. Medicine and Science in Sport and Exercise, 7(4), 262-274.

Sanders, M.T. (1980). A comparison of two methods of training on the development of muscular strength and endurance. Journal of Orthopaedic and Sports Physical Therapy.

Schmidtbleicher, D. (1985). Strength training - part 1. Ottawa: Science Periodical on Research and Technology in Sport.

Sidman, M. (1960). Tactics of scientific research - Evaluating experimental data in psychology. New York: Basic Books.

Steadward, R.D. (1980). Research and training centres for physically disabled athletes. In H. Natvig (Ed.), International Medical Congress on Sports for the Disabled (pp. 219-226) Oslo: Royal Ministry for Church and Education.

Stull, G.A., & Clarke, D.H. (1970). High resistance, low repetition training as a determiner of strength and fatigability. Research Quarterly for Exercise and Sport, 41, 189-193.

Tawney, J.W., & Gast, D.L. (1984). Single subject research in Special education. Columbus: Charles E. Merrill Company.

Thistle, H.G., Hislop, H.J., Moffroid, M., & Lowman, E.W. (1967). Isokinetic contraction: a new concept of resistive exercise. Archives of Physical Medicine Rehabilitation, 48, 279-282.

White, O.R., & Haring, N.G. (1980). Exceptional teaching (2nd ed.). Columbus, Ohio: Charles E. Merrill.

Zwiren, L., & Bar-Or, O. (1975). Responses to exercise of paraplegics who differ in conditioning level. Medicine and Science in Sport and Exercise, 7, 94-98.

APPENDIX A: Results of 1976, 1980 Olympic Games for the Physically Disabled, the World Wheelchair Games and World Records in Track and Field

Event	Sex	Class	Olympics '76	Olympics '80	World Games '84	World Record
Discus	F	1A	7.58 M	8.42 M	-------	12.76 M
	M	1A	12.63 M	13.72 M	-------	15.04 M
	F	1B	9.52 M	10.22 M	10.10 M	10.22 M
	M	1B	16.66 M	13.52 M	-------	16.66 M
	F	1C	11.97 M	10.14 M	9.36 M	11.97 M
	M	[illegible]	17.10 M	17.14 M	21.26 M	21.26 M
	F	2	13.79 M	16.16 M	15.76 M	17.42 M
	M	2	23.10 M	26.72 M	28.06 M	29.36 M
	F	3	13.74 M	17.54 M	16.24 M	17.54 M
	M	3	27.15 M	30.00 M	29.14 M	30.00 M
	F	4	16.96 M	19.18 M	21.06 M	21.06 M
	M	4	31.12 M	29.80 M	32.42 M	33.60 M
	F	5	16.42 M	-------	17.42 M	28.78 M
	M	5	29.60 M	38.16 M	31.88 M	39.44 M
	F	6	-------	-------	19.38 M	19.38 M
	M	6	36.24 M	-------	41.12 M	43.28 M
Shotput	F	1A	2.81 M	2.94 M	2.18 M	4.81 M
	M	1A	5.42 M	5.90 M	5.33 M	6.66 M
	F	1B	3.86 M	4.46 M	3.93 M	4.46 M
	M	1B	6.50 M	7.05 M	6.62 M	7.18 M
	F	1C	4.49 M	4.07 M	3.59 M	4.49 M
	M	1C	6.94 M	7.37 M	7.88 M	7.88 M
	F	2	4.77 M	5.00 M	5.52 M	5.52 M
	M	2	8.14 M	8.42 M	9.01 M	9.36 M

	F	3	5.43 M	5.74 M	7.19 M	7.19 M
	M	3	8.53 M	8.32 M	8.48 M	9.77 M
	F	4	6.08 M	6.34 M	7.21 M	7.21 M
	M	4	8.59 M	9.80 M	10.54 M	10.54 M
	F	5	6.71 M	7.22 M	6.80 M	7.45 M
	M	5	9.80 M	11.02 M	10.37 M	11.33 M
	M	6	9.87 M	-------	13.90 M	13.90 M
Javelin	F	1B	-------	-------	7.38 M	7.38 M
	M	1B	-------	-------	10.96 M	11.16 M
	F	1C	8.34 M	7.60 M	7.12 M	8.68 M
	M	1C	14.26 M	14.74 M	15.92 M	15.92 M
	F	2	11.42 M	12.44 M	11.80 M	14.50 M
	M	2	18.78 M	21.28 M	24.76 M	26.24 M
	F	3	-------	13.62 M	13.40 M	13.88 M
	M	3	23.81 M	25.08 M	26.24 M	26.24 M
	F	4	12.04 M	15.38 M	16.66 M	17.52 M
	M	4	24.13 M	27.62 M	23.86 M	27.62 M
	F	5	16.93 M	28.78 M	15.76 M	28.78 M
	M	5	23.62 M	32.98 M	24.76 M	33.60 M
	M	6	29.43 M	-------	39.52 M	40.94 M
Club	F	1A	17.79 M	18.05 M	-------	19.88 M
	M	1A	21.36 M	25.00 M	23.54 M	27.50 M
	F	1B	16.71 M	19.68 M	-------	19.81 M
	M	1B	27.02 M	27.12 M	-------	27.12 M
60 M	F	1A	0:21:50 M	0:21:64 M	-------	0:19:00 M
	M	1A	0:20:30 M	0:20:15 M	-------	0:19:90 M
	F	1B	0:19:40 M	0:17:95 M	-------	0:17:95 M

	M	1B	0:15:10 M	0:16:89 M	---------	0:15:10 M
	F	1C	0:18:80 M	0:18:89 M	---------	0:18:80 M
	M	1C	0:14:60 M	0:13:80 M	---------	0:13:80 M
	F	2	0:16:40 M	0:15:07 M	---------	0:15:07 M
	M	2	0:14:30 M	---------	---------	---------
	F	3	0:14:70 M	0:14:00 M	---------	0:14:00 M
	F	4	0:14:20 M	0:13:28 M	---------	0:13:28 M
	F	5	0:14:60 M	0:14:66 M	---------	0:14:60 M
100 M	F	1A	---------	---------	0:27:83 M	0:27:83 M
	M	1A	---------	---------	0:27:70 M	0:27:70 M
	F	1B	---------	---------	0:33:57 M	0:26:50 M
	M	1B	---------	---------	0:23:20 M	0:23:33 M
	F	1C	---------	---------	0:28:91 M	0:28:91 M
	M	1C	---------	---------	0:21:41 M	0:21:39 M
	F	2	---------	---------	0:20:73 M	0:20:50 M
	M	2	0:19:80 M	0:17:83 M	0:17:81 M	0:17:81 M
	F	3	---------	---------	0:20:28 M	0:19:70 M
	M	3	0:19:10 M	0:17:77 M	0:17:02 M	0:16:40 M
	F	4	---------	---------	0:19:30 M	0:18:11 M
	M	4	0:19:00 M	0:17:66 M	0:16:68 M	0:16:68 M
	F	5	---------	---------	0:20:61 M	0:19:70 M
	M	5	0:19:80 M	0:18:07 M	0:16:94 M	0:16:40 M
200 M	F	1A	---------	---------	1:01:80 M	0:53:71 M
	M	1A	---------	---------	0:56:30 M	0:52:42 M
	F	1B	---------	---------	1:10:30 M	0:56:90 M
	M	1B	---------	---------	0:42:53 M	0:42:53 M
	F	1C	---------	---------	0:58:10 M	0:55:40 M

	M	1C	---------	---------	0:43:43 M	0:43:43 M
	F	2	0:59:00 M	0:47:32 M	0:37:10 M	0:37:10 M
	M	2	0:41:40 M	0:36:63 M	0:34:50 M	0:34:50 M
	F	3	0:47:60 M	0:43:24 M	0:40:22 M	0:37:02 M
	M	3	0:41:60 M	0:35:80 M	0:31:99 M	0:31:99 M
	F	4	---------	---------	0:35:73 M	0:35:73 M
	M	4	---------	---------	0:32:00 M	0:32:00 M
	F	5	---------	---------	0:38:44 M	0:38:44 M
	M	5	---------	---------	0:31:10 M	0:30:30 M
400 M	F	1A	---------	---------	2:02:96 M	2:02:96 M
	M	1A	---------	---------	1:50:08 M	1:50:08 M
	F	1B	---------	---------	2:19:82 M	2:14:36 M
	M	1B	---------	---------	1:24:69 M	1:19:00 M
	F	1C	---------	---------	2:05:67 M	2:05:67 M
	M	1C	---------	---------	1:27:85 M	1:27:85 M
	F	2	2:02:80 M	1:35:56 M	1:17:41 M	1:17:41 M
	M	2	1:27:70 M	1:18:08 M	1:08:49 M	1:08:49 M
	F	3	1:42:80 M	1:26:87 M	1:24:05 M	1:19:53 M
	M	3	1:25:00 M	1:14:30 M	1:03:68 M	1:03:30 M
	F	4	---------	---------	1:12:87 M	1:12:54 M
	M	4	---------	---------	1:06:01 M	1:06:01 M
	F	5	---------	---------	1:18:28 M	1:14:30 M
	M	5	---------	---------	1:03:11 M	1:03:11 M
800 M	F	1A	---------	---------	4:15:08 M	4:04:30 M
	M	1A	---------	---------	3:48:21 M	3:48:30 M
	F	1B	---------	---------	---------	4:17:76 M
	M	1B	---------	---------	2:52:97 M	2:50:40 M

	F	1C	---------	---------	4:13:97 M	4:13:97 M
	M	1C	---------	---------	2:58:75 M	2:58:75 M
	F	2	---------	---------	2:46:58 M	2:46:58 M
	M	2	---------	---------	2:14:20 M	2:13:56 M
	F	3	---------	---------	3:00:01 M	2:28:40 M
	M	3	---------	---------	2:17:53 M	2:07:40 M
	F	4	3:14:80 M	2:54:42 M	2:35:40 M	2:35:40 M
	M	4	2:47:00 M	2:25:91 M	2:11:63 M	2:11:63 M
	F	5	3:29:80 M	3:06:96 M	2:43:40 M	2:28:98 M
	M	5	2:44:70 M	2:18:81 M	2:14:70 M	2:07:33 M
1500 M	F	2	---------	---------	5:16:91 M	5:16:91 M
	M	2	---------	---------	4:29:93 M	4:29:93 M
	F	3	---------	---------	5:38:50 M	5:17:95 M
	M	3	---------	---------	4:20:80 M	3:58:50 M
	F	4	---------	5:35:70 M	4:54:79 M	4:54:79 M
	M	4	5:15:50 M	4:46:40 M	4:17:08 M	4:00:10 M
	F	5	---------	6:05:60 M	5:14:03 M	4:42:45 M
	M	5	5:12:80 M	4:17:00 M	4:13:47 M	3:54:65 M
5000 M	F	2	---------	---------	18:21:36 M	18:21:36 M
	M	2	---------	---------	15:30:15 M	15:30:15 M
	F	3	---------	---------	18:21:70 M	18:21:70 M
	M	3	---------	---------	14:46:27 M	14:30:20 M
	F	4	---------	---------	19:04:30 M	19:04:30 M
	M	4	---------	---------	14:41:28 M	14:41:28 M
	F	5	---------	---------	17:40:22 M	16:28:11 M
	M	5	---------	---------	14:58:56 M	14:11:71 M

APPENDIX B: Subject Information Form

SUBJECT INFORMATION FORM

Date: ____________________

Name: ____________________

Address: ____________________

City: ____________________

Province: ____________________

Postal Code: ____________________

Phone: ____________________

Birthdate: ____________________

Date of Injury and Level: ____________________

Cause of Injury: ____________________

Presently taking Medication? Yes: ________ No: ________

If Yes, Name of Medication and Reason for Prescription: ____________________

____

Name of Doctor: ____________________

Name of Physiotherapist: ____________________

Presently receiving Physiotherapy? Yes: ________ No: ________

If Yes, Where? ____________________

Have you ever participated in Non-Disabled Sport? Yes: ________ No: ________

If Yes, Which Sports and for How Long? ____________________

____

APPENDIX C: Subject Consent Form

SUBJECT CONSENT FORM

Thank you for becoming a subject in this study. Please note that your participation is entirely voluntary and that you are free to withdraw yourself as a subject at any time during the course of this project.

The purpose of this study is to determine the changes in upper body muscular strength of spinal cord injured individuals as a result of a training program using Nautilus weight training equipment.

You will be requested to submit to the following procedures:

1. Cybex II isokinetic exercise testing (muscular fitness)
2. Nautilus weight training exercises

The Cybex testing will consist of each subject performing a muscular strength and endurance test on shoulder flexion/extension and elbow flexion/extension of both arms.

The Nautilus training will consist of each subject performing six exercises namely:

1. Behind Neck
2. Double Shoulder (Lateral Raise)
3. Double Chest (Arm Cross and Decline Press)
4. Biceps Curl
5. Triceps Extension

Each subject will perform three sets of six repetitions with one minute rest between the sets.

You will be instructed in the complete operation and procedures of the Cybex II isokinetic system and the Nautilus weight training equipment. In addition, you will be informed about the safety of the equipment and the precautions that will be taken to ensure safety.

Please note, however, that there are possible risks and hazards you may experience over the duration of this study, which are muscular soreness, muscular fatique, and exhaustion.

The investigator will be present at all data collection sessions and will answer any inquiries subjects may have concerning the procedures. At the conclusion of the study, the results will be made available for your review.

Participation in this study is contingent upon the signed consent of each subject. Therefore, please read the statement below and sign where appropriate.

I have read and understand the procedures of this study described above and I am aware of the potential risks involved. I understand that I may withdraw at any time during the course of this investigating. I agree to participate as a subject in all phases of the study described above. I undrstand that data pertaining to my results may be used in professional presentations and publications and that complete anonymity will be retained.

Signed/Dated: ______________________________

APPENDIX D: Medical Consent Form

MEDICAL CONSENT FORM

We request your cooperation in completing this form upon your client's admission into this study to determine the changes in upper body muscular fitness of spinal cord injured individuals as a result of a training program using Nautilus weight training equipment.

Based upon a current review of health states, ______________, is considered suitable for:

A) Testing using Cybex II isokinetic system (muscular fitness) on:

a) Shoulder flexion/extension right arm

b) Shoulder flexion/extension left arm

c) Elbow flexion/extension right arm

d) Elbow flexion/extension left arm

Each subject will be involved in a muscular strength and an endurance test on the movements mentioned above.

B) Treatment using Nautilus weight training equipment on:

a) Behind Neck

b) Double Shoulder (Lateral Raise)

c) Double Chest (Arm Cross and Decline Press)

d) Biceps Curl

e) Triceps Extension

Each subject will perform three sets of six repetitions with one minute interval between the sets on each exercise. The treatment will be three times a week for a period of six weeks.

____ With no restriction ______________________________

____ With avoidance of ______________________________

Special concerns (if any): ______________________________

____

Signed/Dated ______________________________

APPENDIX E: Cybex Calibration

CYBEX CALIBRATION

Cybex calibration in accordance with the directions supplied by Lumex Inc. New York.

Recorder Scale (ft/lbs)	Lever Arm* (inches)	Weight (pounds)	Graph Recording (division)
180	31	32.5	5 major
30	33	5	20 major

* Lever arm is distance from centre of Cybex input shaft to centre of T-tube (lever arm length).

Procedure

1. Turn on Power and allow for 10 minutes warm-up.
2. Select appropriate scale to be calibrated (30 or 180 ft/lbs).
3. With speed selection on at 30 degrees per second or 0.524 r/s and the recorder on, but no torque applied to the lever arm:

   a) Select #2 position on damping control

   b) Select slow chart speed (5 mm/s)

   c) Align stylus with baseline of chart grid paper using "zero adjust button"

   d) Check to see baseline does not shift when range scale is changed from 30 to 180.

   Baseline shift of this nature can be corrected by adjusting with a small screwdriver, the potentiometer on the top right side of the recorder (marked zero).
4. Dynamic calibration is performed by manually lifting the weighted T-bar to the vertical position and allow gravity to swing it down until the weights contact the floor. As the weighted arm passes the horizontal, the graph recording will show this value as a maximum point on the curve. If this point is above or below the correct torque value, adjust the recorder and make it read the correct value by turning the appropriate potentiometer (30 or

180) through the holes on the top right side of the recorder (marked accordingly). Turning the potentiometer clockwise will increase the reading and counter clockwise will decrease it.

APPENDIX F: Data Sheet for Upper Body Cybex II Tests

NAME: ____________________
DATE: ____________________

LIMB OR JOINT	TEST	SPEED (DEG/SEC)	TORQUE (NM)	SPEED (DEG/SEC)	TORQUE (NM)	TORQUE AT 30 SEC (NM)
RT SHOULDER	FLEXION					
LT SHOULDER	FLEXION					
RT SHOULDER	EXTENSION					
LT SHOULDER	EXTENSION					
RT ELBOW	FLEXION					
LT ELBOW	FLEXION					
RT ELBOW	EXTENSION					
LT ELBOW	EXTENSION					

APPENDIX G: Data sheet for Nautilus Weight Training Sessions

NAME: ____________________

DATE	DOUBLE SHOULDER		DOUBLE CHEST		BICEPS/TRICEPS	
	BEHIND NECK	LATERAL RAISE	ARM CROSS	DECLINE PRESS	BICEPS CURL	TRICEPS EXTENSION

APPENDIX H: Cybex Results

Subject A:

Week	Sh Flex at .524 r/s Nm	Sh Ext at .524 r/s Nm	Sh Flex at 3.144 r/s Nm	Sh Ext at 3.144 r/s Nm	Sh Flex at 3.144 r/s at 30 sec Nm	Sh Ext at 3.144 r/s at 30 sec Nm
0	55	84	34	49	28	48
1	46	69	40	53	30	40
2	48	68	37	49	23	37
4	48	65	38	58	29	44
5	48	61	40	54	30	47
6	46	65	35	50	25	42
8	48	72	32	56	22	46
10	56	75	42	58	32	50
12	52	75	37	48	29	48

Subject A:

Week	El Flex at .524 r/s Nm	El Ext at .524 r/s Nm	El Flex at 3.144 r/s Nm	El Ext at 3.144 r/s Nm	El Flex at 3.144 r/s at 30 sec Nm	El Ext at 3.144 r/s at 30 sec Nm
0	45	53	26	28	16	22
1	45	52	30	33	22	23
2	41	44	24	25	20	17
4	43	54	33	28	20	22
5	42	46	31	29	21	20
6	41	46	30	27	20	21
8	46	51	33	31	19	20
10	46	53	28	32	17	22
12	45	53	31	31	20	19

Subject B:

Week	Sh Flex at .524 r/s Nm	Sh Ext at .524 r/s Nm	Sh Flex at 3.144 r/s Nm	Sh Ext at 3.144 r/s Nm	Sh Flex at 3.144 r/s at 30 sec Nm	Sh Ext at 3.144 r/s at 30 sec Nm
0	53	85	32	49	21	38
1	42	67	31	42	26	29
2	43	88	30	49	21	34
4	43	68	31	44	21	35
5	38	81	33	54	20	37
6	42	77	31	52	18	35
8	40	90	35	62	19	31
10	48	82	35	55	17	38
12	50	94	39	44	19	30

Subject B:

Week	El Flex at .524 r/s Nm	El Ext at .524 r/s Nm	El Flex at 3.144 r/s Nm	El Ext at 3.144 r/s Nm	El Flex at 3.144 r/s at 30 sec Nm	El Ext at 3.144 r/s at 30 sec Nm
0	41	49	26	24	7	9
1	36	49	22	26	18	22
2	45	47	29	25	15	17
4	34	48	23	28	18	18
5	34	52	24	29	8	11
6	41	42	29	29	15	18
8	38	55	27	35	8	21
10	42	57	29	35	13	21
12	39	53	29	34	6	5

Subject C:

Week	Sh Flex at .524 r/s Nm	Sh Ext at .524 r/s Nm	Sh Flex at 3.144 r/s Nm	Sh Ext at 3.144 r/s Nm	Sh Flex at 3.144 r/s at 30 sec Nm	Sh Ext at 3.144 r/s at 30 sec Nm
0	50	43	30	26	21	20
1	47	49	31	34	21	27
2	48	51	25	33	19	25
3	48	47	31	40	22	28
4	51	60	34	37	25	28
6	50	53	37	39	26	32
8	52	52	43	43	24	29
10	47	60	38	42	24	22

Subject C:

Week	El Flex at .524 r/s Nm	El Ext at .524 r/s Nm Nm	El Flex at 3.144 r/s Nm	El Ext at 3.144 r/s Nm	El Flex at 3.144 r/s at 30 sec Nm	El Ext at 3.144 r/s at 30 sec Nm
0	35	42	17	24	13	18
1	44	35	21	25	13	19
2	42	45	19	21	11	17
3	39	45	19	22	16	20
4	42	47	18	25	13	21
6	40	52	22	24	18	18
8	40	50	21	26	15	22
10	48	59	23	28	16	21

Subject D:

Week	Sh Flex at .524 r/s Nm	Sh Ext at .524 r/s Nm	Sh Flex at 3.144 r/s Nm	Sh Ext at 3.144 r/s Nm	Sh Flex at 3.144 r/s at 30 sec Nm	Sh Ext at 3.144 r/s at 30 sec Nm
0	46	80	41	55	26	45
1	46	60	33	58	24	42
2	54	85	34	55	20	50
4	52	73	34	55	27	45
5	51	80	33	60	21	44
6	44	77	36	62	27	44
8	44	82	32	61	29	47
10	49	87	46	71	37	50
12	46	96	36	61	21	44

Subject D:

Week	El Flex at .524 r/s Nm	El Ext at .524 r/s Nm	El Flex at 3.144 r/s Nm	El Ext at 3.144 r/s Nm	El Flex at 3.144 r/s at 30 sec Nm	El Ext at 3.144 r/s at 30 sec Nm
0	34	55	26	37	14	21
1	39	45	24	29	13	19
2	40	49	23	27	15	22
4	44	51	27	34	14	19
5	41	54	27	35	13	21
6	43	57	27	35	14	22
8	38	53	25	34	13	18
10	46	47	26	29	15	20
12	42	54	26	33	11	18

Subject E:

Week	Sh Flex at .524 r/s Nm	Sh Ext at .524 r/s Nm	Sh Flex at 3.144 r/s Nm	Sh Ext at 3.144 r/s Nm	Sh Flex at 3.144 r/s at 30 sec Nm	Sh Ext at 3.144 r/s at 30 sec Nm
0	48	77	37	55	27	41
1	51	72	34	46	17	39
2	57	76	32	45	3	12
3	48	62	25	47	21	25
4	...	...	...	...	...	...
6	51	65	32	45	14	28
8	51	65	33	50	17	36
10	50	70	25	44	14	25

Subject E:

Week	El Flex at .524 r/s Nm	El Ext at .524 r/s Nm	El Flex at 3.144 r/s Nm	El Ext at 3.144 r/s Nm	El Flex at 3.144 r/s at 30 sec Nm	El Ext at 3.144 r/s at 30 sec Nm
0	44	66	22	31	19	27
1	42	59	22	30	18	17
2	28	42	19	24	14	18
3	41	43	20	24	15	21
4	...	...	...	...	...	...
6	44	47	22	29	13	19
8	43	60	22	33	17	25
10	41	48	20	20	12	16

APPENDIX I: Nautilus Results

Subject A:

Date	Behind Neck	Lateral Raise	Arm Cross	Decline Press	Biceps Curl	Triceps Extension
8/10	420	450	720	660	360	420
10/10	720	720	840	1080	525	600
12/10	810	720	840	1080	525	625
15/10	840	840	960	1200	522.5	540
17/10	---	---	---	---	---	---
19/10	840	840	960	1200	495	630
22/10	960	960	1080	1320	495	585
24/10	960	960	1080	1320	495	585
26/10	1200	1200	1320	1560	495	585
29/10	1200	1200	1320	1560	495	585
31/10	1440	1260	1365	1800	495	585
2/11	1440	1260	1365	1800	495	682.5
5/11	1610	1105	1050	1530	495	630
7/11	1540	1300	1260	1530	577.5	665
9/11	1500	1170	1400	1700	600	700
12/11	1350	1170	1540	1700	630	840
14/11	1200	1300	1425	1662.5	630	760
16/11	1350	1215	1575	1575	560	800

Subject B:

Date	Behind Neck	Lateral Raise	Arm Cross	Decline Press	Biceps Curl	Triceps Extension
18/3	820	720	950	1100	660	490
20/3	1080	880	1200	1155	700	630
22/3	1200	900	1210	1210	700	630
25/3	1200	1035	1210	1320	675	560
27/3	---	---	---	---	---	---
29/3	880	1150	1200	1320	675	630
1/4	1320	1100	1200	1300	750	630
3/4	1320	1155	1062.5	1430	675	665
5/4	1080	1045	1187.5	1470	712.5	630
8/4	1380	1035	1375	1400	712.5	665
10/4	1440	1265	1282.5	1450	760	665
12/4	1235	1265	1282.5	1450	720	600
15/4	1300	1062.5	1260	1200	800	750
17/4	1080	1125	1400	1425	760	750
19/4	1215	1187.5	1330	1425	850	680
22/4	1012.5	1187.5	1232.5	1395	807.5	760
24/4	1282.5	1235	1305	1550	630	760
26/4	1350	1105	1232.5	1550	810	722.5

Subject C:

Date	Behind Neck	Lateral Raise	Arm Cross	Decline Press	Biceps Curl	Triceps Extension
21/1	540	780	720	900	450	450
23/1	840	1200	960	1320	720	600
25/1	1080	1440	1200	1560	700	720
28/1	1080	1440	1200	1560	630	720
30/1	---	---	---	---	---	---
1/2	1200	1430	1320	1680	700	840
4/2	1200	1560	1320	1680	900	840
6/2	1210	1540	1440	1725	900	787.5
8/2	1265	1680	1440	1800	720	750
11/2	1140	1350	1300	1520	720	720
13/2	1020	1800	1560	1680	960	880
15/2	1020	1840	1540	1275	855	765
18/2	1200	1920	1540	1445	855	810
20/2	1200	1870	1500	1615	855	900
22/2	1000	1530	1575	1700	1045	900
25/2	875	1700	1800	1750	950	945
27/2	687.5	1700	1760	1837.5	1100	855
1/3	---	---	---	---	---	---

Subject D:

Date	Behind Neck	Lateral Raise	Arm Cross	Decline Press	Biceps Curl	Triceps Extension
18/3	660	960	540	900	450	450
20/3	960	900	720	1200	550	475
22/3	1080	900	960	1080	600	450
25/3	1080	900	960	1080	540	450
27/3	1200	900	990	1200	540	550
29/3	1200	1000	1080	1200	720	550
1/4	1320	1000	1200	1375	600	600
3/4	---	---	---	---	---	---
5/4	1100	1050	1200	1375	780	540
8/4	1200	945	1320	1620	715	540
10/4	1440	945	1320	1350	770	600
12/4	1170	945	1440	1400	770	660
15/4	1430	1050	1440	1540	720	630
17/4	1560	1050	1560	1350	720	630
19/4	1260	1100	1560	1500	880	735
22/4	1540	990	1540	1575	720	700
24/4	1680	1100	1540	1440	720	675
26/4	1200	990	1500	1440	720	675

Subject E:

Date	Behind Neck	Lateral Raise	Arm Cross	Decline Press	Biceps Curl	Triceps Extension
5/4	1080	1050	1100	1265	550	480
8/4	1100	1155	1155	1210	630	525
10/4	1100	1210	1155	1380	660	575
12/4	---	---	---	---	---	---
15/4	---	---	---	---	---	---
17/4	1210	1380	1380	1320	700	630
19/4	1210	1320	1320	1420	770	630
22/4	1320	1560	1495	1560	---	---
24/4	---	---	---	---	---	---
26/4	---	---	---	---	---	---
29/4	1440	1560	1560	1610	840	840
1/5	1365	1610	1540	1540	840	735
3/5	1430	1540	1540	1650	765	840
6/5	1400	1800	1650	1650	945	920
8/5	1330	1650	1650	1760	945	855
10/5	---	---	---	---	---	---
13/5	1305	1840	1520	1840	900	900
15/5	---	---	---	---	---	---
17/5	1377.5	1760	1760	1870	950	902.5
20/5	1522.5	1785	1785	1870	850	902.5

APPENDIX J: Changing Criterions on the Nautilus Weight Training Equipment

Subject A:

Phase	Behind Neck	Lateral Raise	Arm Cross	Decline Press	Biceps Curl	Triceps Extension
1	450	450	540	720	360	450
2	540	540	630	810	450	540
3	630	630	720	900	495	585
4	720	720	810	990	540	630
5	900	900	990	1170	630	720
6	1080	1080	1170	1350		
7	1260	1170	1260	1530		
8	1350	1215	1350	1575		

Subject B:

Phase	Behind Neck	Lateral Raise	Arm Cross	Decline Press	Biceps Curl	Triceps Extension
1	720	720	900	900	540	630
2	810	810	990	990	630	675
3	900	900	1080	1080	675	720
4	990	990	1125	1170	720	765
5	1080	1035	1215	1260	765	
6	1170	1125	1260	1305	810	
7	1215	1170	1305	1350		
8				1395		

Subject C:

Phase	Behind Neck	Lateral Raise	Arm Cross	Decline Press	Biceps Curl	Triceps Extension
1	540	720	720	900	450	450
2	630	900	900	990	540	540
3	810	1080	990	1170	630	630
4	900	1170	1080	1260	675	675
5	990	1260	1170	1350	720	720
6	1080	1350	1260	1440	810	810
7	1125	1440	1350	1530	855	855
8		1530	1440	1575	900	
9		1575		1620		

Subject D:

Phase	Behind Neck	Lateral Raise	Arm Cross	Decline Press	Biceps Curl	Triceps Extension
1	540	720	540	720	450	450
2	720	900	720	900	540	540
3	810	945	810	1080	585	630
4	900	990	900	1125	630	675
5	990		990	1200	720	
6	1080		1080	1260		
7	1170		1170	1350		
8	1260		1260	1440		
9	1350		1350			

Subject E:

Phase	Behind Neck	Lateral Raise	Arm Cross	Decline Press	Biceps Curl	Triceps Extension
1	810	900	900	990	450	360
2	900	990	990	1080	540	450
3	990	1080	1080	1170	630	540
4	1080	1170	1170	1260	720	630
5	1170	1260	1260	1350	810	720
6	1260	1350	1350	1440	900	810
7	1305	1440	1440	1530		855
8		1530	1530			