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A COMPARISON OF CONSTANT AND VARIABLE RESISTANCE TRAINING UPON SELECTED ASPECTS OF SHOULDER DYNAMICS

by

(C) JAMES C. McGAVIN

A THESIS

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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 A COMPARISON OF CONSTANT AND VARIABLE RESISTANCE TRAINING UPON SELECTED ASPECTS OF SHOULDER DYNAMICS submitted by JAMES C. McGAVIN, in partial fulfillment of the requirements for the degree of Master of Science in Physical Education.

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DEDICATION

To those who have influenced my life the most, through their constant love and understanding - my dear parents.

ABSTRACT

In order to determine the effects of variable and constant resistance training upon selected aspects of shoulder dynamics, sixty university community male volunteers were assigned to one of three experimental groups. The treatments employed consisted of a Nautilus strength training programme, a progressive resistance programme utilizing the Universal Gymnasium, and a control situation. The exercise programmes were specifically designed to foster alterations in active flexibility and the ability to generate muscular torque in the shoulder region. The three treatments were employed over a six-week period, with the sample eventually being reduced to fifty-four subjects as a result of subject attrition.

Measurements of torque output and angular displacement during the movements of shoulder flexion and shoulder hyperextension were made prior to and immediately following completion of the training period. A two-channel Cybex II isokinetic device was employed for this purpose, with assessments being recorded at a limb speed of thirty degrees per second. A specially constructed chair was utilized in conjunction with the measuring device, in order to isolate the shoulder region on the subject's dominant side and control extraneous body movement.

Test results were analyzed by means of a four-way Analysis of Variance with repeated measures on each of the variables under consideration, and the criterion level of significance set at the .01 level. It was found that there were no significant relationships between the isotonic training programmes employed in the study, and any changes in shoulder dynamics during shoulder flexion and shoulder hyperextension, as determined by the isokinetic testing procedure used for assessment.

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Chapter 1

INTRODUCTION

Statement of the Problem

Researchers and practitioners in the field of sports medicine have universally acknowledged the fact that the development of optimal levels of flexibility and strength are primary objectives of any conditioning programmes aimed at injury prophylaxis. While numerous investigators have demonstrated significant increases in muscular strength as a result of programmes employing progressive resistance exercise, little attention has been focussed on the relative contribution such programmes make towards increased levels of flexibility.

Purpose and Significance of the Study

The purpose of this study was to critically examine the effects of two different modes of isotonic exercise upon active range of motion at the shoulder in university community males. In determining if any significant difference in flexibility development occurred, it was hoped that valid principles would be elucidated that might aid the coach and trainer in developing progressive resistance programmes which not only would have resulted in increased levels of muscular strength, but would have also made a valuable contribution to increased levels of flexibility. Allman (1977:600) pointed out:

The role of conditioning in obtaining top performance in athletes cannot be emphasized too much, yet too few physicians, coaches and trainers fully understand the important components of a conditioning programme and thereby fail to use them effectively.

Null Hypothesis

The null hypothesis upon which this investigation was based, asserted that there would be no significant difference in active flexibility development in shoulder flexion and hyperextension, when assessment was made subsequent to treatment conditions consisting of Nautilus variable resistance training, Universal weight training, and a control programme. The sub-hypothesis of this study stated that no significant difference would be found between treatment groups with respect to the ability to generate muscular torque, when assessment was made utilizing the same actions and isokinetic device used to determine flexibility levels.

Limitations and Delimitations

The limitations of this investigation were as follows:

1) the voluntary nature of subject participation, and
2) individual learning response on the part of the subjects during the testing sessions, due to the nature of the measuring device employed.

The delimitations affecting the interpretation of this study included:

a) the specific nature of the movements being analyzed, and
b) the subjective nature of the instructional and supervisory methods employed in the training programmes.

Main Assumptions

Previous investigations have demonstrated significant increases in muscular strength as a consequence of both constant and variable resistance programmes of progressive resistance exercise (Gettman, Ayres, Pollock, and Jackson, 1978; McKetchen and Mayhew, 1974; Peterson, 1975; Pipes and Wilmore, 1976; Smith and Whitley, 1965; Wilmore, Parr, Haskell, Castill, Milburn, and Kerlan, 1976). Taking these findings into account, the design of the present study was formulated based on the assumption that both forms of resistance training utilized would yield significant changes in muscular strength when employed over the six to ten-week period commonly seen in the literature.

The voluntary nature of subject participation in this investigation appeared to be in line with a further assumption, stating that subjects would be sufficiently motivated to remain on the particular training regimen assigned to them for the duration of the study. In addition, it was assumed that subjects were truthful in the accounts they gave of current and previous participation in chronic forms of physical activity that might have affected shoulder dynamics.

Definitions

The following terms were employed throughout this study, in conjunction with theoretical and practical discussion of the concepts central to the topic under investigation, and were assigned the following definitions:

Active Range of Motion - The range of motion at a particular joint, or series of joints, that required voluntary muscular contraction by agonist muscles (Hartley, 1976).

Constant Resistance Exercise - Muscular contraction against a movable resistance force of constant magnitude, which resulted in a change of length of the working muscle or muscles, and a corresponding skeletal movement (Knuttgen, 1978). Resistance torque varied with the position of the skeletal lever.

Isokinetic Muscular Contraction - Exercise of the variable resistance mode, that was characterized by a speed of movement which remained constant throughout the range of motion under consideration (Knuttgen, 1978).

Isotonic Muscular Contraction - Exercise in which the speed of movement varied, due to various physiological and biomechanical factors acting on the joint or joints involved (Knuttgen, 1978).

Muscular Torque - The quantity consisting of the sum of the perpendicular components of the forces exerted by the muscles assisting in a particular movement, calculated in light of the respective distance of each insertion from the axis of rotation. While this value did not indicate the exact force generated by individual muscles, the fact that the resistance arm could be accurately determined allowed the investigator to attribute significant changes in torque output to alterations in the ability of the working muscles to develop force, keeping in mind that the length of the force arm tended to vary due to the positioning of the anatomical joints of the upper extremity (Hetherington, 1971).

Variable Resistance Exercise - Muscular contraction against a movable resistance force that varied in magnitude throughout the range of motion at a particular joint, or series of joints (Peterson, 1975). As with constant resistance

Chapter 2

REVIEW OF LITERATURE

A Theoretical Basis for Athletic Conditioning

The risk factors common to any sporting situation centre around the nature of the particular activity, the manner in which it is conducted, and the characteristics of any preventative measures designed to reduce the incidence and severity of athletic injuries (Hayes, 1974). Miles (1977) stated that the primary concern of sports medicine was the prevention of athletic injury through a thorough appreciation of the elements of proper conditioning, knowledgeable medical supervision, and efficient management of pertinent environmental factors.

Hirata (1972) subdivided the conditioning of the competitive athlete into components of neuromuscular strength, agility and coordination--each specific to the physiological, psychological, and biomechanical properties of both athlete and activity. Various authorities have cited the necessity of training and conditioning the competitive athlete on a year-round basis, and directing programmes toward the development and maintenance of optimal levels of physical and mental fitness (Kulund, McCue, Rockwell, and Gieck, 1979; Millar, 1978; Ostazewiski and Marshall, 1975).

A theoretical knowledge of the physical properties, ultrastructure and metabolism of connective tissue has been deemed vital in formulating a rationale upon which to base any programme intended to serve the function of injury prophylaxis (Burry, 1975).

The Nature of Connective Tissue

The biological substance referred to as connective tissue is composed of large amounts of intercellular material, consisting of collagen, elastic and reticular fibres, in addition to varying amounts of ground substances. As elastic fibres contain the low modulus material elastin, the high modulus characteristics of ligaments and tendons have been attributed to the collagenous material present (Haut and Little, 1969). Collagen constitutes approximately twenty-five to thirty percent of the total amount of protein found in the human body, and is cross-linked extracellulary with the mucopolysaccharide ground substance (Gould, 1968).

In a dense form of connective tissue, such as muscle tendon, the amount of ground substance present is relatively small, whereas in loose connective tissue, such as epithelium, it exists as a major constituent. The geometrical arrangement of the collagen fibres is determined by the functional demands placed upon them, with the regular parallel fibre course found in muscle tendon due to the linear nature of the forces it is required to transmit (Viidik, 1973).

Viidik (1973) asserted that the biologically-active nature of collagen required it to actively respond to stimuli such as physical training. In reviewing the literature pertaining to the effects of training on connective tissue in laboratory animals, Booth and Gould (1975) found increases in the collagen content of tendons and ligaments to be cited as a major factor contributing to increases in the tensile strength of these structures.

Researchers examining the characteristics of connective tissue have tended to employ enzymolytic experimentation, coupled with various types of mechanical properties testing and microscopic observation (Missirlis, 1977). Dehoff (1978) pointed out, however, that the complex nature of biological tissues precluded the formulation of a single theory that would prove capable of characterizing all tissues, or in fact, even a class of tissues in their various physiological strain environments. The same author also referred to inaccuracies of measurement common in this area of scientific investigation, due to the nature of the measuring devices used and the inconsistencies of procedures used to determine strain rates.

Russell (1979) pointed to the dense, highly organized nature of the fibrous tissue consitutting the tendons, ligaments and joint capsules present in the human body, as being responsible for the similarities of response to biomechanical stress exhibited by these structures. The collagen fibres present in, and characteristic of all fibrous connective tissue, provided considerable strength and rigidity in response to stress loads aligned parallel to their long axes (Frost, 1972).

In vitro, biomechanical studies of collagenous tissue utilize stress-strain relationships--plots of load versus enlongation--borrowed from the field of materials testing. Stress has been defined as the load per unit area to which the material under loading was subjected, whereas strain denoted the increase in length undergone by the specimen (Viidik, 1973). Welsh, Macnab, and Riley (1971) mentioned three regions of the stress-strain curve common to most biological tissues: 1) a "toe region," where large increases in extension were accompanied by small increases in tension; 2) a transitional zone, in which the stiffness of the specimen steadily increased; 3) a linear region, in which the ratio between the load applied and increase in specimen length was equal to one.

As pointed out by these investigators, the shape of the stress-strain curve has an enormous effect upon bodily movement, with biological tissues being able to accommodate rather large external forces, if such forces were applied at a low rate. This resulted in efficient absorption of energy, and a minimal likelihood of injury. The "toe region" of the stress-strain curve corresponded to the straightening of the crimped collagen fibre, and the transitional zone illustrated the fibre's elastic extension. If the strain was not too great, the crimp was perfectly reversible, acting as a mechanical spring (Diamant, Baer, Litt, and Arridge, 1972).

Elliot (1967) found that the stress required to eliminate the appearance of wave-form on the surface of a tendon was less than seven percent of the maximum tension to which it could be submitted. This investigator concluded that the normal range of transmitted tension fell within the "working capacity" of a specific tendon, and that, although the maximum contraction of a muscle may have exceeded this, resulting in a certain amount of semi-plastic change, the tensile strength of a healthy tendon appeared to be more than twice the strength of its muscle's contractile capacity.

Skeletal Muscle Characteristics

Mammalian skeletal muscle can be considered a highly specialized form of connective tissue, containing specialized fibres capable of contracting upon stimulation (Morehouse and Millar, 1976). Stimulation of individual contractile fibres is an "all or nothing" event, taking the form of electrochemical impulses referred to as action potentials. These impulses cause a reversal in polarity that is propagated throughout the entire muscle fibre (Ganong, 1977).

Skeletal muscle consists of microscopic units arranged in parallel fashion, so as to produce force on skeletal points via common linkages. Although there was much less detailed information regarding the neuromuscular properties of human skeletal muscle than has been obtained through animal studies, there did appear to be sufficient data available to suggest that the general patterns observed in other mammals were applicable, at least in principle, to man (Burke, 1975).

Length change in skeletal muscle has been attributed to a relative sliding motion between two sets of protein filaments (Huxley, 1953). Investigators have postulated that the amount of force generated was directly related to the number of cross-linkages formed between these filaments (Best and Taylor, 1966; Goldspink, 1968; Huxley, 1974; Huxley and Simmons, 1971).

In his classical work on the dynamics of skeletal muscle, Hill (1938) stated that active muscle could be conceptualized as a two-component system, consisting of an undamped purely elastic element in series with a contractile element. Wilkie (1950) illustrated, through quantitative analysis, that maximal voluntary movements exhibited a definite relationship between movement velocity and force production, which was constant in nature. As the velocity of movement increased, the amount of force generated has been shown to decrease, a phenomenon consistent with the biochemical nature of skeletal muscle (Katz, 1972).

The contractile proteins within individual muscle fibres are arranged in functional units known as sarcomeres, with various investigations having demonstrated adjustment in fibre length, sarcomere length, and sarcomere number in response to functional demands (Burêsôvá, Gutmann, and Klispeia, 1969; Goldberg, Etlinger, and Jablecki, 1975; Goldspink and Williams, 1971; Gonyea and Ericson, 1975; Gordon, Kowalski, and Fritts, 1967; Sola, Christensen, and Martin, 1973; Tabary, Tabary, Tardieu, Tardieu, and Goldspink, 1972).

Relating Flexibility to Athletic Injuries

Physical educators have long been aware of the importance of optimal levels of flexibility in the competitive athlete, with factors such as anatomical relationships, physiological traits, biomechanical characteristics, and performance requirements influencing the nature of flexibility training. Historically, however, the profession of physical education has failed to direct much research towards this area, with studies on the subject being confined to those activities that require high degrees of flexibility for certain aspects of performance (Sigerseth, 1970).

Although there tends to be continued research and thought on the relationship between range of motion and optimal performance of specific athletic skills (Garfield, 1977; Hogg, 1978), since 1970, an increasing number of investigators have been citing poor flexibility as a primary mechanism involved in numerous types of athletic injuries (Schultz, 1979; Wise, 1977; Wright, 1979).

While the arrangement of joint ligaments and the anatomical structure of the articulating surfaces limit the range of motion possible at a given joint, a condition known as passive insufficiency has been said to exist when a full range of motion, at a joint or series of joints, has been limited to a greater extent due to inextensibility of the musculature involved. O'Connell and Gardner (1972) stated that this condition appeared to be the major contributor to the suboptimal levels of flexibility found in many competitive athletes.

In outlining the various factors related to the incidence of hamstring strains in a group of intercollegiate track athletes, Liebman (1978) asserted that hip-joint flexibility tended to be the most definitive indicator of potential injury candidates. This investigator reported non-injured subjects to be more flexible at the hip than those from the injured group in every case.

Similarly, Kalenak and Morehouse (1975) found a greater frequency of muscle strain injuries in "tight-jointed" athletes, in their study on twenty-six university football players. Assessment of flexibility was performed utilizing both manually and mechanically applied stresses to the knee joint, with the investigators concluding that, as the muscle-tendon unit was the "first line of defense" in protecting joint ligaments, all players involved in contact sports should be required to engage in both flexibility and strength development programmes.

As a result of its complex anatomical nature, the glenohumeral joint is a prime candidate for athletic injury in many sporting activities. This joint possesses a greater range of motion than any other in the human body, due to the shallowness of the glenoid cavity--its main source of stability coming from the soft tissue structures surrounding it. Sudden impact loading of the glenoid cavity frequently exceeds the tolerance of these structures, resulting in subluxation or dislocation of the humeral head. Another feature, unique to the glenohumeral joint, is the subacromial space, which functions as a second joint cavity. It is predisposed to the derangements of repetitive loading, which can result in impingement lesions. The clavicle is subjected to trauma in many sports, with unusual levels of impact forces resulting in frequent fractures and dislocations. In view of the fact that the dynamics of the shoulder are controlled to such a great extent by soft tissue structure, various researchers have advocated conditioning programmes designed to produce optimal levels of muscular strength and flexibility in this area (Kennedy, Hawkins, and Krissoff, 1978; Neer and Welsh, 1971).

Flexibility and Strength Development

In order to obtain the maximal benefit from any training programme, it must be formulated so as to develop the specific physiological capabilities required in the performance of a given sporting skill or activity (Fox, 1977). While most research in this area has centred upon changes in skeletal muscle volume, it is now known that conditioning also illicits adaptations at the neuromuscular junction and in the motor neuron. Included in these are alterations in cellular and subcellular structure, chemical responses, transmission properties, reflex responses and biochemical characteristics within the motor neuron itself (Fox, 1978).

In line with the discussion presented in this paper, Hartley (1976) pointed to the main limiting factors placed upon flexibility as being due to the nature of the various connective tissues involved, and stated that the active range of motion at a joint or series of joints appeared to be highly dependent upon the resistance offered by the extending muscles. The same author hypothesized that increases in the active range of motion may have been more readily illicited through decreases in antagonistic resistance, than through increases in the amount of force generated by agonists.

In an article assessing literature related to the development of muscular strength, Clarke (1973) noted a general belief that in order to develop strength throughout a full range of motion, it was necessary for the athlete to engage in isotonic forms of training employing that range. The same author also related that the use of progressive isotonic exercise has been shown to result in increases in muscular strength when employed for periods of six weeks or longer in duration, even when only sixty percent of a subject's maximally-expressed strength was utilized (Berger, 1962; Gettman et al., 1978; Wilmore, Parr, Haskell, Castill, Milburn, and Kerlan, 1976; Wilmore, Parr, Girandola, Ward, Voldak, Barstow, Pipes, Romero, and Leslie, 1978). Regimens ranging from two repetitions of a maximal nature for one set, to ten such repetitions for three sets, have all been demonstrated to yield significant gains in the ability to generate muscular force; an optimal combination, according to Clarke (1973), may have been six maximal repetitions for three sets, three times per week.

Measurement and Evaluation of Flexibility and Muscular Strength

Until recently in the field of physical education, investigators desiring to examine levels of flexibility in athletes have confined themselves to the use of performance tests such as "palms to floor" and knee hyperextension maneuvers (Grossman and Nicholas, 1977; Parr, Wilmore, Hoover, Bachman, and Kerland, 1978; Wilmore et al., 1976), or to devices such as static flexometers and goniometers (Liebman, 1978; Tucker, 1963). The performance tests tend to give rather general assessments of flexibility centred around spinal and pelvic articulations, and express results in linear units. Such tests yield findings lacking in validity, due to their subjective nature, the many variables involved, and a lack of scoring ranges (Hayes, 1978).

Devices such as flexometers and goniometers, which express results in degrees, lack many of the problems associated with performance tests outlined above--their development having been pioneered by the field of rehabilitation medicine for use in the management of pathological conditions (Sigerseth, 1970). Their use in the field of physical education has been limited, however, due to the fact that most of these instruments can only be used in static situations.

Similarly, in the area of muscular strength assessment, general performance tests ranging from push-ups to squat-thrusts, to static devices, such as hand dynamometers, have been used for research in the area of physical education (Clarke, 1970). As noted by several investigators (Clarke, 1966; Hartley, 1976; Leibman, 1978), the measurement of muscular strength using static-type devices necessitates the taking of readings from numerous joint angles. Due to the specific nature of the variable under consideration, both performance and static evaluations of muscular strength yield results that may be questioned with regards to their validity.

Since its inception in 1970, the Cybex II isokinetic device has been gaining increasing clinical acceptance for the purposes of dynamically assessing muscular strength and flexibility (Elliot, 1978). This instrument was designed to provide a detailed profile of the condition of various muscle groups within the human body, by recording the maximum torque generated throughout a particular range of motion, and automatically plotting a torque curve at pre-selected controlled limb velocities. The inclusion of a second channel and recorder allowed the recording of the degree of angular displacement in conjunction with the measurement of muscular torque (Lumex Corp., 1975).

The Universal and Nautilus Training Systems

The commercial training systems employed in this investigation were of the isotonic type, with both having been designed for large group utilization. The Universal Gym provided resistance that remained constant throughout the range of motion for each exercise, placing biomechanical stresses upon the individual similar to those experienced when engaging in free weight progressive resistance training (Wilmore *et al.*, 1978). The Nautilus system, on the other hand, created a form of variable resistance that was isotonic in nature, and was designed to overload the working muscles to the greatest extent possible with such exercise (Darden, 1977).

While controlled scientific experimentation has illustrated that it is possible to obtain significant increases in the ability to generate muscular torque from progressive resistance programmes of exercise employing the Universal Gym (Wilmore *et al.*, 1976, Wilmore *et al.*, 1978), investigations directed towards the claims offered by the manufacturers of Nautilus exercise equipment have tended to be lacking in validity (Peterson, 1975). Alterations in muscular strength and flexibility have been attributed to the Nautilus system of training, but evidence offered was of a testimonial nature (Jones, 1975; Plese, 1973). In addition, the number of repetitions and sets suggested in the Nautilus literature have not been scientifically evaluated, as has been the case for other forms of progressive resistance training (Clarke, 1973). The Nautilus system was based upon exercise employing the scientific principle of progressive resistance, hence, due to the large amount of literature that validly associated increases in the ability to generate muscular torque with various isotonic exercise programmes, it can be hypothesized that similar gains will be illicited through the Nautilus form of variable resistance exercise.

Chapter 3

METHODOLOGY

Subjects were selected on a voluntary basis from the population of university community males in the city of Edmonton, Alberta, Canada. Although sixty subjects were pre-tested, the sample was reduced to fifty-four subjects over the course of the study, due to several unavoidable factors. One subject was forced to withdraw due to personal reasons, a second was eliminated because of trauma to the shoulder region, and the remaining subjects deleted were randomly selected, in order to re-establish equal numbers in the experimental cells and facilitate statistical evaluation.

The characteristics of the sample are shown in Table 1, with activity pattern being defined as any form of chronic exercise that might influence shoulder dynamics. Height and weight were determined from a single measurement at the beginning of the pre-testing period, utilizing wall-markings and a human laboratory scale. A sample of the Subject Information Sheet is found in Appendix A.

The Cybex II isokinetic device, located in the Paralympic Sports Association (P.S.A.) Centre at The University of Alberta, was employed for both initial and final testing sessions, with test protocol being outlined in Appendix A. Readings for angular displacement were expressed in degrees, and results obtained for the amount of torque generated were given in foot-pound units. A kinesiological analysis of the test movements is presented in Appendix B. Results from the pre-test were used to

Table 1

Anthropometric Characteristics and Activity Patterns of the Sample

(N = 54)

	Age (Years)	Height (Inches)	Weight (Pounds)
Range	18 - 29	58.25 - 77.75	125.6 - 206.1
Mean	22.04	69.85	162.0
Standard Deviation	2.25	3.39	20.5
	High*	**Medium†**	**Low‡**
Activity Level (Percentage)	7	33	59

* Chronic exercise involving the shoulder, performed on a regular basis throughout the six-month period prior to initial testing.

† Chronic exercise involving the shoulder, performed sporadically during the six-month period prior to initial testing.

‡ Absence of any form of chronic exercise that might affect shoulder dynamics during the six-month period prior to initial testing.

equally divide the subjects into high and low flexibility blocks according to active range of motion. They were then randomly assigned to the three treatment groups - both "high" and "low" flexibility equally represented in each group.

The subjects were requested to refrain from any chronic physical activity that might influence shoulder dynamics for the course of the study, other than the particular training programme they were assigned to. Programmes commenced approximately one week after the initial testing session, and utilized the exercise equipment located in the Physical Education Centre at The University of Alberta. The duration of the programmes was set at six weeks and the subjects were required to engage in workouts three times per week, in line with current thought found in literature pertaining to strength training (Clark, 1973; Gettman <u>et al.</u>, 1978). The training programmes and samples of subject record sheets are illustrated in Appendices C and D. Records of the number of workouts engaged in by each subject were kept, and the attempt was made to encourage subjects to attend as many supervised workouts as possible. Control subjects were contacted a minimum of twice during the experimental period, in order to help ensure that any external influences upon shoulder dynamics be held to a minimum. Post-testing was scheduled for all subjects so as to be accomplished within one week after completion of the training programmes.

The analysis of experimental results was made using a four-way Analysis of Variance with repeated measures on each of the independent variables under consideration. The .01 level of significance was chosen in order to ensure that any differences noted were based upon conservative statistical probability. In addition, statistical analysis of a descriptive nature was performed on the quantitative results obtained from records of subject participation and supervision, in order to be able to more accurately describe the nature of the experimental treatments used in this investigation, with the results being presented in Table 2.

Table 2

Quantitative Analysis of Training Programmes*

	Nautilus Programme	Universal Programme
Total Workouts†	317	317
Supervised Workouts (Percentage)‡	49.5	70.3
Individuals Completing All Scheduled Workouts (Percentage)	83.3	83.3

* Calculated to omit subjects not included in final results.

† Workouts completed by subjects included in final results.

‡ Workouts completed with instructor in attendance.

Chapter 4

ANALYSIS OF RESULTS

The five dependent variables statistically analyzed in this study were:

1) the amount of torque generated in flexion
2) the amount of torque generated in hyperextension
3) the range of motion in flexion
4) the range of motion in hyperextension
5) the value obtained from the sum of the score recorded for range of motion in flexion and the score for range of motion in hyperextension.

The analysis of variance tables and cell means for each dependent variable are presented in Appendices E to I with values in the original units of measurement. While statistical significance at the .01 level was found for several of the factors analyzed, no significant interactions between the treatment groups and pre- or post-tests were found for any of the dependent variables under consideration.

The amount of torque generated in flexion was seen to decrease over the course of the three experimental trials across all treatment groups, $F\ (2,\ 192) = 13.468$, $p < .001$. When the mean values for each trial were compared using the Scheffé method, there was found to be a significant difference between the first and third trials at the .01 level. In addition, comparison of the second and third trials also yielded a statistically significant result, $p < .01$.

Analysis of the scores from torque generation in hyperextension presented a contrasting phenomenon, in that the values recorded tended to increase over the three experimental trials, $F\ (2,\ 188) = 11.758$, $p < .001$. Application of the Scheffé test showed a significant difference in mean scores between the first and third trials, $p < .01$.

When the range of motion in flexion was statistically analyzed, it was found that there was a significant difference between the "high" and "low" flexibility groups, $F\ (1,\ 92) = 53.809$, $p < .001$. The larger values obtained for the "high" flexibility group were not surprising, due to the fact that the subjects were blocked into these categories according to the pre-test values obtained from the assessment of range of motion at the shoulder.

Similarly, the analysis of range of motion scores for hyperextension showed a significant difference between "high" and low" flexibility subjects, $F\ (1,\ 92) = 62.771$, $p < .001$. In addition, it was observed that the amount of angular displacement tended to increase over the three experimental trials across all treatment groups, $F\ (1,\ 184) = 6.896$, $p < .001$. The Scheffé test of significance found a difference in means between the first and third trials, $p < .01$.

Finally, examination of the values obtained when the pre-post test for scores for range of motion in flexion and hyperextension were combined to form a single measure, showed a significant difference between "high" and "low" flexibility groups, $F\ (1,\ 88) = 127.345$, $p < .001$. This finding was in agreement with the results obtained from assessment of the other parameters in this investigation pertaining to active range of motion at the shoulder, and reflected the nature of the procedure utilized in blocking the subjects into "high" and "low" flexibility groups.

Chapter 5

DISCUSSION OF RESULTS

The statistical analysis used to examine the final results gleaned from this investigation revealed no significant relationship between the training programmes employed and changes in the active range of motion or ability to develop torque at the shoulder. Any interactions that were found to exist may have been due to fatigue, varying motivation levels, learning effects, the natures of the testing device and treatments employed, or a combination of these factors.

Previous investigations directed towards the expression of muscular strength and power in human subjects have tended to reveal the subjective nature of this phenomenon. Ikai (1970) termed the training effects due to increased cross-sectional area of muscle fibres as "physiologic," and effects not attributable to physiological changes as "psychologic." Whereas both of these factors are involved in any experimental situation created for the purpose of evaluating changes in the ability to voluntarily exert muscular torque, their subtle interaction makes it difficult to assess their relative contribution through purely non-invasive measurement techniques.

In measuring the maximal pulling force exerted by forearm flexors during various psychological states, Ikai and Steinhaus (1961) found human strength expression to be generally limited by psychologically-induced inhibitions. In a subsequent study, Ikai and Fukunaga (1970) demonstrated that increases in the nervous discharge to working muscles could be more easily achieved than increases in the cross-sectional area of muscle fibres, by finding a thirty percent increase in the ability of untrained left arm flexors to exert force, due to the irradiation of neural impulses from the trained contralateral limb.

Inherent to the testing procedure employed in any study on human performance, is the specific nature of the task or tasks that must be performed by the subjects. While the Cybex II has received high reliability ratings for the purpose of muscular strength assessment in children between the ages of fifteen and seventeen years (Molnar and Alexander, 1974), literature pertaining to validation of this instrument was practically non-existent. In addition, the use of this device to assess the active range of motion in the research setting, as opposed to clinical use, lacked scientific validation or reliability determination.

Pipes and Wilmore (1975) referred to the concept of the specificity of training, when asserting that improvements in the ability to generate muscular force were greatest when tests were administered utilizing devices similar in nature to the ones employed during training. In light of this consideration, it was quite possible that any training effects that were invoked by the training programmes employed in the present study were masked by the isokinetic mode of testing.

The universal concept of specificity might also have yielded explanation as to the lack of any significant changes in the active range of motion that was seen in this study. As pointed out by Hartley (1976), the main limiting factors placed upon active flexibility were due to the characteristics of the various forms of connective tissue involved, hence, training designed to bring about alterations in this parameter would have resulted in adaptations that were specific to the nature of the training stimulus employed. Alterations in the active range of motion possible at the shoulder, brought about by the forms of progressive resistance isotonic training used in this study, may not have been validly represented when assessment was performed utilizing the displacement mode of the Cybex II isokinetic measuring device.

A final source of experimental error that should be considered, was the subjective nature of the training programmes employed over the course of the study. While every attempt was made to ensure each subject closely adhered to the particular training regimen assigned to him, it was impossible to completely control for all external influences on shoulder dynamics, and to provide constant supervision during each training session for each subject. In addition, it was not possible to place complete control over the physical activity engaged in by subjects in the control group over the course of the experimental period. Finally, the occasional malfunction of training equipment in both the Nautilus and Universal programmes, although corrected as quickly and efficiently as possible, added a further source of unexplained variation to the final results of the study.

Chapter 6

CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE RESEARCH

In conclusion, the results of this investigation showed there to be no signicant difference in the active range of motion at the shoulder consequent to constant or variable resistance training programmes. In addition, there was no significant difference in the ability to generate muscular torque at the shoulder.

The lack of significant changes in the aspects of shoulder dynamics assessed, suggests that the measuring instrument may not have been utilized to the full extent of its capabilities. It can also be hypothesized that several sources of error, external to the confines of the study, limited the extent of such changes.

[illegible] research in this area might profitably investigate the validity [illegible] ability of various measurements of active flexibility and the [illegible] to generate muscular torque, keeping in mind the specific nature of these parameters. Due to the complicated anatomical structure of the shoulder in the human subject, it would appear that an attempt should be made to develop a measuring technique that will minimize experimental error due to this source of variation. Modifications to the test protocol employed might include: the use of a restraining device to minimize the involvement of the trunk, such as a headband; the use of straps to secure the upper limb to the machine arm and minimize the involvement of the wrist and elbow joints; and other measures designed to more fully isolate the shoulder region.

In addition, due to the relationship between speed of movement and the ability to generate muscular torque (Ikai, 1970; Matter, 1979), it might be profitable to determine the effects of varying limb speeds during isokinetic testing upon the ability to generate muscular torque. Such an analysis could provide a scientific basis from which to choose an appropriate limb speed for assessment purposes, subsequent to a particular training programme.

The specific nature of any physiological or psychomotor adaptations to chronic exercise, may necessitate that future research directed towards their possible contribution to injury prophylaxis be of an empirical nature. Controlled epidemiological research could be supplemented by laboratory investigation, in order to more fully elucidate the physiological nature of adaptations. As such, scientific experimentation under artificial conditions could be viewed as an integral contributor to an overall body of knowledge, rather than merely as an end in itself.

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APPENDICES

APPENDIX A

Cybex II Test Protocol

Cybex II Test Protocol

The assessment of shoulder dynamics was made utilizing a Cybex II isokinetic device with a dual-channel recorder. The device was calibrated according to the manufacturer's instructions at the beginning of each day of testing. Measurements of peak power output and angular displacement were recorded for each movement performed, with three trials of shoulder flexion being followed by three trials of shoulder hyperextension for each subject, utilizing the dominant arm.

A specially constructed chair was utilized in order to permit maximal displacement in hyperextension, with a seatbelt and shoulder harness firmly securing the subject's trunk in the upright position. Floor markings were utilized in order to allow for a recording of the position of the chair in relation to the measuring device (see Plate 1). The height of the measuring device was adjusted to correspond to the distance of the subject's axis of rotation at the shoulder from the floor, with the chair being positioned in order to align the shoulder axis with the axis of the machine, with the arm in the starting position. The length of the lever arm was set to correspond as closely as possible to the upper limb length for each subject, ensuring that the elbow was in the fully extended position. The preceding adjustments were noted and recorded for each subject, and were replicated for all measurements performed in both the pre-testing and post-testing sessions.

Testing was performed by the same operator the duration of the study, with each subject being instructed in an identical fashion with regards to the performance of the test movements. The subject was instructed to position himself in the chair so that his dominant arm was closest to the measuring device. The operator checked to ensure that

Plate 1. The positioning of the Cybex II isokinetic device in relation to the chair, prior to testing.

the spinal column was flush against the chair back, then secured the subject into place by means of the restraining harnesses (see Plate 2). The positions of the chair, measuring device and the mechanical arm length were then determined, as previously outlined, with the subject being requested to grasp the lever handle with a supinated grip.

The chart recorder utilized was then zeroed for both power and displacement readings, with the torque setting being held constant at 180 foot-pounds for each subject, the machine speed being set at thirty degrees per second, and the recorder adjusted to a 300 degree setting for the displacement channel. These adjustments were deemed to be in line with the nature of the movements being tested, and the manufacturer's instructions pertaining to the use of the device.

The subject was allowed to familiarize himself with the flexion movement with several practice trials. When ready, the instructions were given to move the arm forward and upward as fast and as far as possible (see Plate 3). Each subject was given three trials at this movement, with a thirty second recovery period between trials.

Assessment of shoulder hyperextension was made in a similar fashion; however, the subject was required to grasp the lever handle with a pronated grip. The recording device was zeroed once more, and practice of the test movement was allowed without resistance. The subject was then instructed to move his arm backwards and upwards as fast and as far as possible, with this maneuver being performed for three trials dispursed by thirty second recovery periods (see Plate 4).

Results obtained from the chart recordings were then transcribed and placed on a Subject's Data Sheet (see sample).

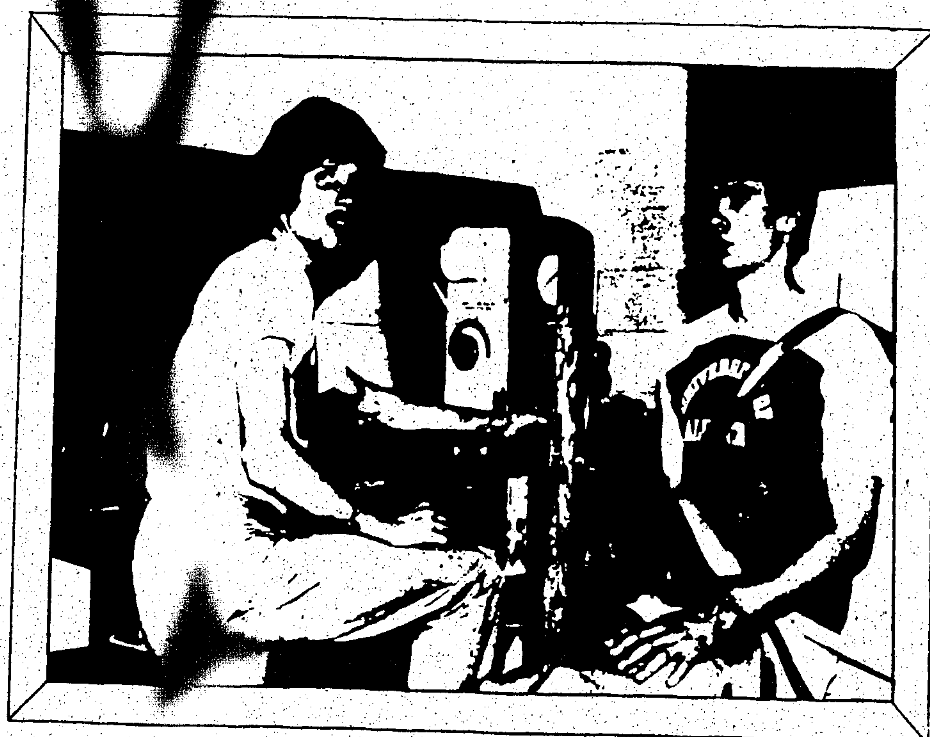

Plate 2. The positioning of the subject in relation to the testing apparatus, prior to assessment.

Plate 3. The performance of shoulder flexion by the subject during isokinetic assessment.

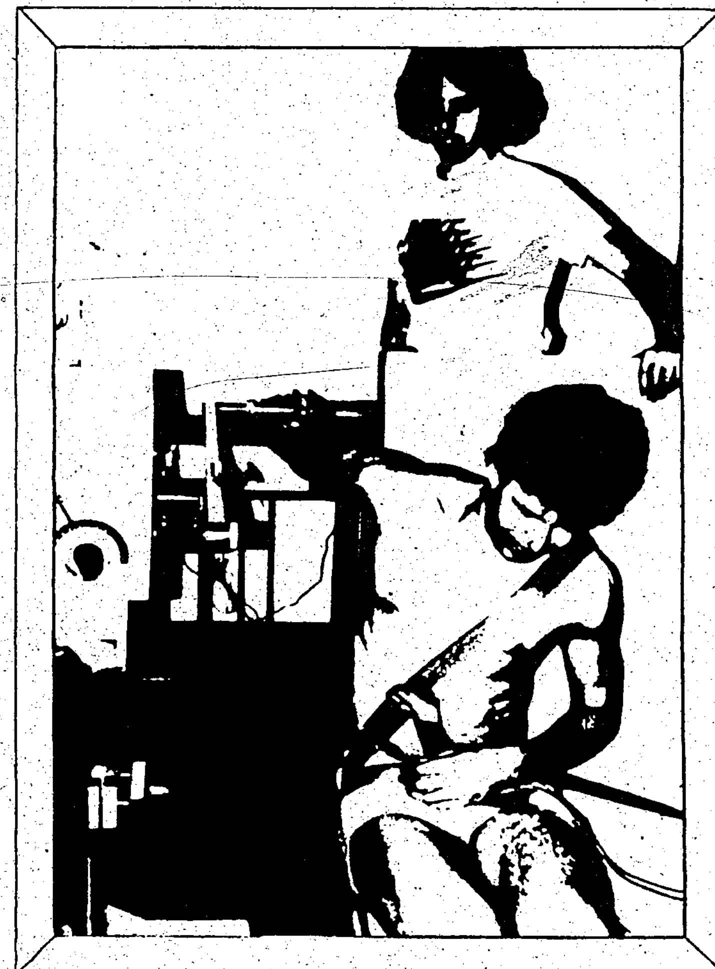

Plate 4. The performance of shoulder hyper-extension by the subject during isokinetic assessment.

SUBJECT DATA SHEET

Chair Position: ____ Machine Height: ____ Lever Arm Length: ____

Group: ____________ Name: ____________

Age: ____________ Height: ____________ Weight: ____________

Previous level of activity in programmes involving regular exercise of the shoulder region within the last six months:

Type of Activity ____________

Duration Per Session: ____________ Frequency Per Week: ____________

Length of Time Engaged In Activity: ____________

PRE-TEST RESULTS

Torque Setting: ____ Limb Speed: ____

	Torque Development: Flexion	Torque Development: Hyper-Extension	Range of Motion: Flexion	Range of Motion: Hyper-Extension	Comments
Trial 1					
Trial 2					
Trial 3					

POST-TEST RESULTS

Torque Setting: ____ Limb Speed: ____

Trial 1				
Trial 2				
Trial 3				

APPENDIX B

Nature of the Movements Under Consideration

Nature of the Movements Under Consideration

The movements being examined in this study included the actions of shoulder flexion and shoulder hyperextension. The former entailed the maximal displacement of the upper limb in the saggital plane, in an anterior-superior direction, the arm initiating the movement from a pendant position, with the subject seated, and the trunk forming an angle of ninety degrees to the floor. The hyperextension movement began from the same starting position, with the upper limb being maximally displaced in the saggital plane, in a posterior-superior direction.

The nature of the movements being evaluated, and the limitations of the testing device used, made it impossible to limit the actions to entail movement only at the shoulder joint. Elements of rotation, retraction and protraction of the scapula, movement at the sternoclavicular and acromioclavicular joints, and rotation of the humeral head were all involved, to one degree or another, in the shoulder actions examined. As a consequence of, and in addition to these adjustments, flexion and extension of the elbow and movement at the wrist joint were also impossible to eliminate. Hence, the subject's axis of rotation at the shoulder continually shifted, in relation to the axis of rotation of the measuring instrument, for each action being tested.

The following is a summary of the actions, joints, and major muscles involved in producing the test movements in the anatomical position:

FLEXION

Action	Joint	Major Musculature
Upward rotation of scapula	Shoulder girdle	Trapezius Serratus anterior Levator scapulae

FLEXION
(continued)

Action	Joint	Major Musculature
Protraction of scapula	Shoulder girdle	Serratus anterior
Flexion of humerus	Glenohumeral	Deltoidus (anterior fibres) Pectoralis major Bicepts brachii Coraco brachialis
Outward rotation of humerus	Glenohumeral	Deltoidus (posterior fibres) Infraspinatus Teres minor
Flexion of forearm	Elbow	Bicepts brachii Brachioradialis Brachialis Pronator teres
Flexion of hand	Wrist	Flexor carpi radialis Flexor carpi ulnaris Palmaris longus Flexor digitorum superficialis Flexor digitorum profundus

HYPEREXTENSION

Action	Joint	Major Musculature
Downward rotation of scapula	Shoulder girdle	Rhomboidus major and minor Pectoralis minor
Retraction of scapula	Shoulder girdle	Trapezieus Rhomboidus major and minor
Hyperextension of humerus	Glenohumeral	Deltoidus (posterior fibres) Tricepts brachii Teres major Latissimus dorsi
Inward rotation of humerus	Glenohumeral	Pectoralis major Latissimus dorsi Teres major Subscapularis Deltoids (anterior fibres)
Extension of forearm	Elbow	Tricepts brachii Anconeus
Flexion/extension of hand	Wrist	Forearm flexors Forearm extensors

APPENDIX C

Nautilus Training Programme

Nautilus Training Programme

The variable resistance exercise programme utilized in this study took the form of brief, intense workouts, with the subjects performing one set of each exercise per session. Subjects were instructed to move through the sequence of exercises as rapidly as possible, and the training sessions were repeated three times per week. The regimen followed was in line with the recommendations of the manufacturers of the training devices (Jones, 1971), with the entire programme being based upon the principle of progressive overload. Instruction on the training apparatus and workout supervision was accomplished by an individual who had three years' work experience at a Nautilus Training Centre, and who was well-versed in the training principles upon which Nautilus training was based. All subjects in the programme were encouraged to attend as many supervised workouts as possible, due to the extreme importance assigned to proper technique by the designers of the system (Darden, 1977).

At the outset of the programme, subjects were instructed to avoid working against too great a resistance, with the instructor stressing proper technique as the paramount concern. The eventual goal set for the subjects' training on the Nautilus equipment was the performance of eight to twelve repetitions of each exercise, with exercise being performed to the point of temporary muscular failure.

In attempting to fatigue the working muscles to the greatest extent possible, the sequence of exercises, number of partial repetitions allowed, and number of repetitions on the rotary portion of the dual exercise machines were adjusted for each subject, depending on individual response. These modifications were in line with the recommendations found throughout the manufacturer's literature pertaining to training technique.

The record sheet given to each Nautilus subject (see sample Nautilus Subject Recording Sheet) was used to supplement direct supervision by the instructor, by providing a record of the individual's response to the exercises employed.

The following Nautilus variable resistance machines were utilized in the programme, and a brief description of each exercise is presented:

Nautilus "Super Pullover" Machine - a) Seat height was adjusted so that axis of cams was in line with horizontal axis passing through subject's shoulder joints. b) Elbows were placed at centre of pads, with hands loosely gripping bar in a pronated position. c) Shoulders assumed extreme flexed position in "pre-stretch" (see Plate 5). d) The bar was brought downward in a controlled movement to the count of two, applying pressure with the hands and forearms relaxed. e) The bar was allowed to make contact with the upper portion of the thighs, then returned to starting position in a controlled manner, to the count of four (see Plate 6).

Nautilus "Double Chest" Machine (Rotary Portion) - a) Seat was adjusted so that axes of cams were in line with vertical axes passing through shoulder joints of subject. b) Ventral aspect of forearms were in contact with pads, with hands loosely gripping handles in a pronated position. c) Subject's shoulders assumed position of extreme horizontal extension in "pre-stretch" (see Plate 7). d) Subject horizontally flexed arms in a controlled movement to the count of two, applying pressure with the hands and forearms relaxed (see Plate 8). e) Handles

NAUTILUS SUBJECT RECORDING SHEET

Record Sheet: Nautilus Programme

Name: ______________________

Exercise	Resistance Number of Plates					Number of Repetitions Per Exercise																	
						1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
"Super Pullover" Machine																							
"Double Chest" Machine - Rotary																							
- Linear																							
"Double Shoulder" Machine - Rotary																							
- Linear																							
"Shrug" Machine - Linear																							

SPECIAL COMMENTS: ______________________

____

Plate 5. Starting position when exercising on the Nautilus "Super Pullover" machine.

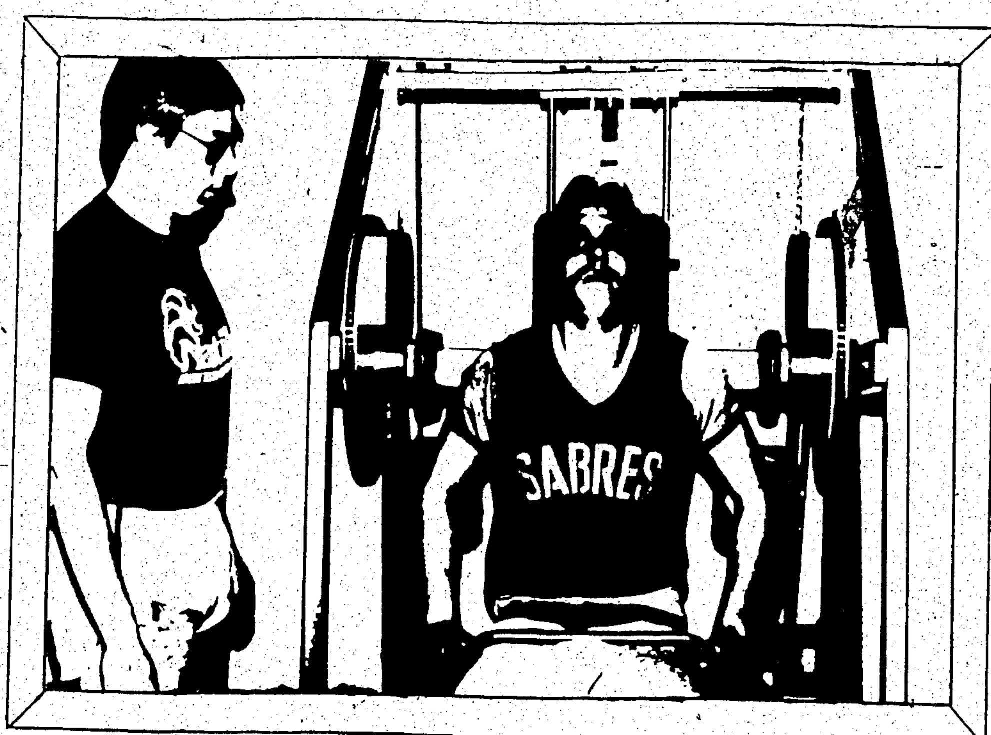

Plate 6. Mid-point position when exercising on the Nautilus "Super Pullover" machine.

Plate 7. Starting position when exercising on the rotary portion of the Nautilus "Double Chest" machine.

Plate 8. Mid-point position when exercising on the rotary portion of the Nautilus "Double Chest" machine.

were allowed to make contact, then returned to starting position in a controlled manner, to the count of four.

Nautilus "Double Chest" Machine (Linear Portion) - a) Immediately upon completion of rotary portion, the subject grasped the linear press handles with a relaxed grip, palms facing inward. b) The shoulders assumed extreme hyperextended position and elbows were fully flexed in "pre-stretch" (see Plate 9). c) Bars were pressed anteriorally in a controlled movement to the count of two (see Plate 10). d) Anterior movement ceased just prior to full elbow extension, and the bars were immediately returned to the starting position in a controlled manner, to the count of four.

Nautilus "Double Shoulder" Machine (Rotary Portion) - a) The seat height was adjusted so that axes of the cams were in line with saggital axes passing through subject's shoulder joints. b) The forearms were in contact with pads, hands loosely gripping handles in pronated position (see Plate 11). c) The subject abducted arms as far as possible in a controlled movement to the count of two, applying pressure with the hands and forearms relaxed (see Plate 12). d) The arms were then returned to the starting position in a controlled manner, to the count of four.

Nautilus "Double Shoulder" Machine (Linear Portion) a) Immediately upon completion of rotary portion, subject grasped linear press handles with relaxed grip, palms facing inwards (see Plate 13). b) Handles were pressed superiorally until the elbows were fully extended, in a controlled movement to the count of two (see Plate 14). c) Handles were returned to starting position in a controlled manner to the count of four.

Plate 9. Starting position when exercising on the linear portion of the Nautilus "Double Chest" machine.

Plate 10. Mid-point position when exercising on the linear portion of the Nautilus "Double Chest" machine.

Plate 11. Starting position when exercising on the rotary portion of the Nautilus "Double Shoulder" machine.

Plate 12. Mid-point position when exercising on the rotary [illegible]on of the Nautilus "Double Shoulder" machine.

Plate 13. Starting position when exercising on the linear portion of the Nautilus "Double Shoulder" machine.

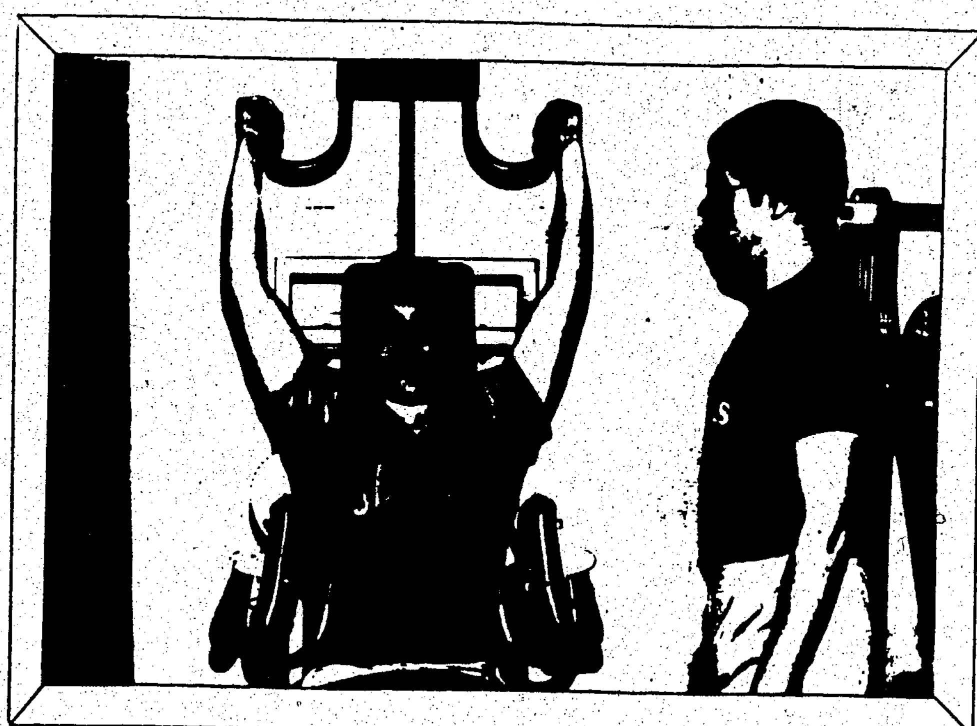

Plate 14. Mid-point position when exercising on the linear portion of the Nautilus "Double Shoulder" machine.

<u>Nautilus "Shrug" Machine</u> - a) The forearms were placed in the machine in a supinated position, so that pads were in contact with ventral aspect (see Plate 15). b) The seat height was adjusted so the forearms were parallel to the floor. c) The subject elevated his shoulders as far as possible in a controlled movement to the count of two, applying force with the hands and forearms relaxed (see Plate 16). d) The shoulders were returned to the starting position in a controlled manner, to the count of four.

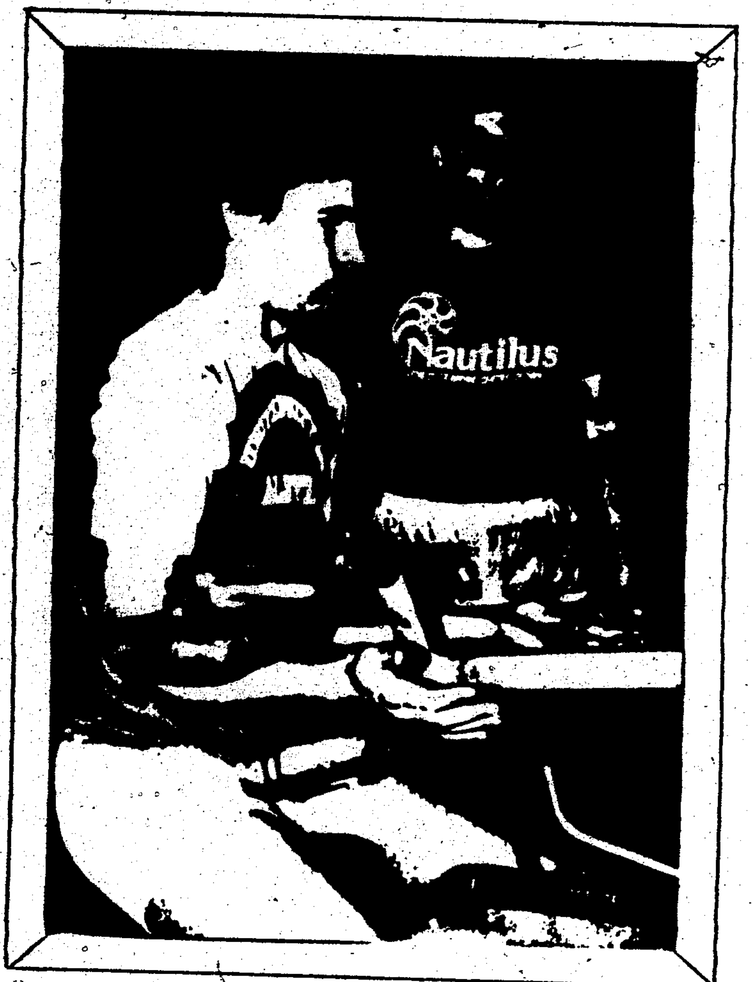

Plate 15. Starting position when exercising on the Nautilus "Shrug" machine.

Plate 16. Mid-point position when exercising on the Nautilus "Shrug" machine.

APPENDIX D

Universal Training Programme

Universal Training Programme

The constant resistance training programme employed in this investigation utilized the Universal Gym apparatus in attempting to involve the shoulder region to the greatest extent possible. The "pre-stretch" component characteristic of the Nautilus style of progressive resistance weight training was simulated, by including various modifications to the exercises traditionally employed on Universal apparatus. Such an approach was in line with recommendations made by Hartley (1976) who asserted that a certain amount of passive stretch would illicit increases in active range of motion, when employed in a systematic fashion.

The initial workloads for each subject were determined by a strict maximal lift at each exercise station, and were set at sixty percent of this value--in accordance with the findings of previous investigations directed towards isotonic exercise (Clarke, 1973). The subjects were instructed to perform as many correct repetitions as possible, with the load being adjusted to result in six to nine repetitions for each of three sets. The load was increased when the subject was able to perform at least nine repetitions for each set in one workout (Berger, 1962). All exercises were performed throughout as full a range of motion as possible, and the subjects were instructed to maintain proper form until the occurrence of momentary muscular failure. Subjects were instructed to make use of a momentary pause at the outset of exercises employing the "pre-stretch" position. Three sets of each exercise were performed prior to continuing to the next station, with a minimum recovery period of two minutes to ensure the training stimulus remained anaerobic in nature. The exercise stations were sequenced in a fashion so that antagonistic muscle groups were alternately overloaded, in order to further enhance the strength training nature of the exercise programme. Workouts were engaged in three times per week, with a minimum of forty-eight hours between each.

As with the Nautilus programme, every attempt was made to supervise each workout, with subject attendance being continually monitored. Initial instruction and subsequent supervision were provided by the investigator on an individual basis, with a sample of the record sheet kept for each subject. The following exercises were employed in the Universal programme:

Universal Gym "Bench Press" Exercise - a) Subject in supinated position with soles of feet resting on wall, bar grasped with a narrow pronated grip (see Plate 17). b) Bench height set to ensure resistance plates were not in contact when elbows were fully flexed and shoulders fully hyperextended. c) Subject forcefully flexed shoulders and extended arms as far as possible in a controlled movement (see Plate 18). d) Bar was returned to starting position in a controlled fashion.

Universal Gym "Lat Pulls" Exercise - a) Subject grasped bar with a pronated grip and the hands as far apart as possible (see Plate 19). b) Knees were flexed so that both kneecaps and ventral aspects of feet were in contact with the floor; if necessary, the use of a barbell placed across the subject's legs to hold the subject down was carried out. c) Bar was brought down and behind the back as far as possible in a controlled movement (see Plate 20). d) Bar was returned to starting position in a controlled fashion.

Universal Gym "Military Press" Exercise - a) Subject sat facing away from machine, grasping bar with a narrow pronated grip (see

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UNIVERSAL SUBJECT RECORDING SHEET

Record Sheet: Universal Programme

* Check (✓) if supervisor is present

Name: ______________________

Load / Reps

	WEEK 1				WEEK 2				WEEK 3				WEEK 4				WEEK 5				WEEK 6				
	*	Set 1	Set 2	Set 3	*	Set 1	Set 2	Set 3	*	Set 1	Set 2	Set 3	*	Set 1	Set 2	Set 3	*	Set 1	Set 2	Set 3	*	Set 1	Set 2	Set 3	
Bench Press																									
Day 1																									Initial Load:
2																									
3																									Final Load:
Bicepts Curl																									
Day 1																									Initial Load:
2																									
3																									Final Load:
Military Press																									
Day 1																									Initial Load:
2																									
3																									Final Load:
Lat Pulls																									
Day 1																									Initial Load:
2																									
3																									Final Load:
Dips																									
Day 1																									Initial Load:
2																									
3																									Final Load:

Plate 17. Starting position when performing the "Bench Press" exercise on the Universal Gym.

Plate 18. Mid-point position when performing the "Bench Press" exercise on the Universal Gym.

Plate 19. Starting position when performing the "Lat Pulls" exercise on the Universal Gym.

Plate 20. Mid-point position when performing the "Lat Pulls" exercise on the Universal Gym.

Plate 21). b) Table height was adjusted so that in a relaxed position with elbows fully flexed and at the sides, resistance plates were not in contact. c) Subject forcefully flexed shoulders and extended arms as far as possible in a controlled movement (see Plate 22). Bar was returned to starting position in a controlled fashion.

Universal Gym "Bicepts Curls" Exercise - a) Subject faced machine, grasping bar with a shoulder-width supinated grip (see Plate 23). b) Subject was positioned just far enough from weight stack to ensure resistance plates were not in contact when arms were fully extended and relaxed. c) Arms were forcefully flexed in a controlled manner as far as possible, with elbows held close to the subject's sides (see Plate 24); upon completion of this action, entire shoulder girdle was protracted (see Plate 25) as far as possible and returned to mid-point position. d) Bar was returned to starting position in a controlled fashion.

"Dips" Exercise (Unsupported) - a) Subject faced away from wall, supporting his body weight with arms fully flexed, shoulders fully extended, palms facing inward, and the legs bent slightly and crossed at the knees with additional resistance strapped on, if necessary (see Plate 26). b) Subject forcefully flexed shoulders and extended arms as far as possible in a controlled movement, keeping vertical axis perpendicular to floor (see Plate 27). Subject returned to starting position in a controlled fashion.

"Dips" Exercise (Supported) - a) This exercise was similar to the technique used for unsupported version, only the calves were allowed to rest on support with knees fully extended and hips flexed (see Plate 28). b) During exercise motion, calves were allowed to roll in an anterior-posterior direction, in order to ensure the trunk maintained

Plate 21. Starting position when performing the "Military Press" exercise on the Universal Gym.

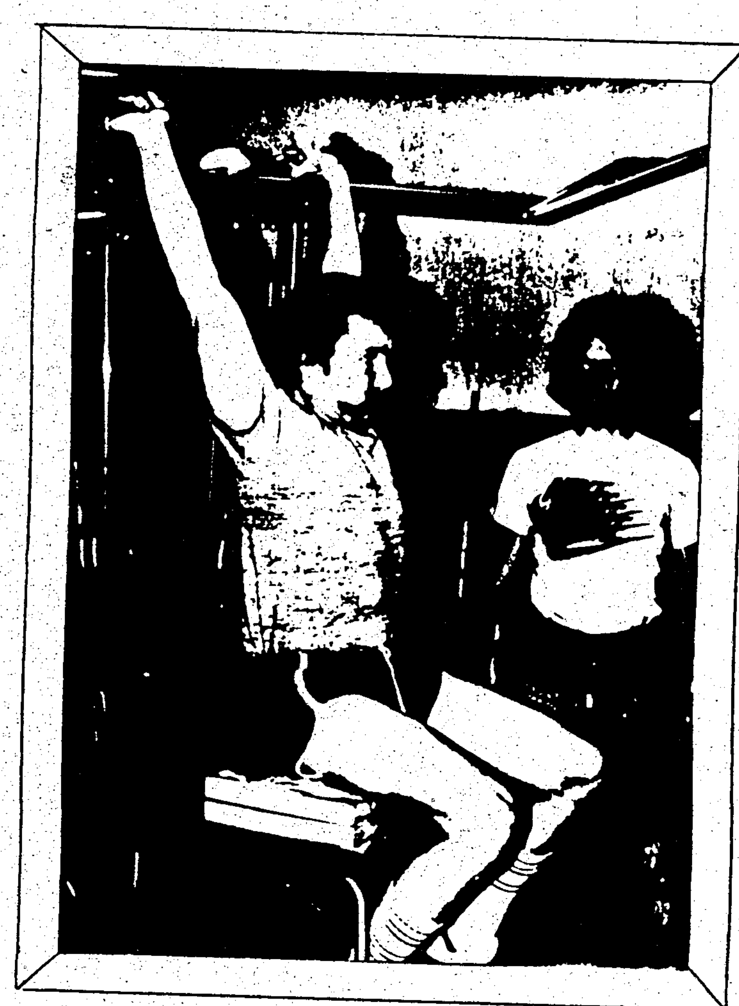

Plate 22. Mid-point position when performing the "Military Press" exercise on the Universal Gym.

Plate 23. Starting position when performing the "Bicepts Curls" exercise on the Universal Gym.

Plate 24. Mid-point position when performing the "Bicepts Curls" exercise on the Universal Gym.

Plate 25. Protracted position when performing the "Bicepts Curls" exercise on the Universal Gym.

Plate 26. Starting position when performing the "Dips" exercise (unsupported).

Plate 27. Mid-point position when performing the "Dips" exercise (unsupported).

the vertical position (see Plate 29). c) Additional weights could have been strapped on to increase resistance, until the subject was able to perform exercise unsupported.

Plate 28. Starting position when performing the "Dips" exercise (supported).

Plate 29. Mid-point position when performing the "Dips" exercise (supported).

APPENDIX E

Analysis of Variance Summary Table and Cell Means for Torque Generated in Flexion

* * * * * * * * * * * * * ANALYSIS OF VARIANCE SUMMARY TABLE * * * * * * * * * * * * *

BETWEEN SUBJECT FACTORS ARE:

A - TREATMT : 1 CONTROL , 2 UNIVERSA , 3 NAUTILUS

B - TEST : 1 PRE-TEST , 2 POST-TES

C - GROUP : 1 HIGH , 2 LOW

WITHIN SUBJECT FACTORS ARE:

D - TRIAL : 1 TRIAL1 , 2 TRIAL2 , 3 TRIAL3

SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARES	F RATIO	PROBABILITY
A	1620.001	2.	810.001	1.889	0.157
B	2710.127	1.	2710.127	6.321	0.014
AB	867.376	2.	433.688	1.012	0.368
C	547.313	1.	547.313	1.277	0.261
AC	1501.314	2.	750.657	1.751	0.179
BC	161.438	1.	161.438	0.377	0.541
ABC	19.125	2.	9.563	0.022	0.978
S-WITHIN	41160.563	96.	428.756		
D	368.438	2.	184.219	13.468	0.001
AD	169.875	4.	42.469	3.105	0.017
BD	29.813	2.	14.906	1.090	0.338
ABD	60.188	4.	15.047	1.100	0.358
CD	59.625	2.	29.813	2.180	0.116
ACD	50.063	4.	12.516	0.915	0.456
BCD	45.000	2.	22.500	1.645	0.196
ABCD	14.625	4.	3.656	0.267	0.899
DS-WITHIN	2626.188	192.	13.678		

* * * * * * * * C E L L M E A N S * * * * * * * *

A	B	C	D	MEAN	STD. DEV.	CASES
1	1	1	1	49.222	11.851	9
1	1	1	2	47.778	11.077	9
1	1	1	3	43.333	8.718	9
1	1	2	1	49.778	12.969	9
1	1	2	2	46.667	13.463	9
1	1	2	3	46.444	15.452	9
1	2	1	1	50.444	9.488	9
1	2	1	2	49.889	11.330	9
1	2	1	3	47.111	13.148	9
1	2	2	1	50.444	18.487	9
1	2	2	2	47.333	18.145	9
1	2	2	3	45.222	17.470	9
2	1	1	1	48.667	11.034	9
2	1	1	2	50.444	14.800	9
2	1	1	3	46.556	12.451	9
2	1	2	1	49.778	12.225	9
2	1	2	2	48.778	12.448	9
2	1	2	3	48.333	13.388	9
2	2	1	1	56.222	13.691	9
2	2	1	2	59.556	17.001	9
2	2	1	3	58.778	17.563	9
2	2	2	1	57.111	11.429	9
2	2	2	2	55.556	12.798	9
2	2	2	3	57.222	13.452	9
3	1	1	1	42.778	5.630	9
3	1	1	2	39.111	7.574	9
3	1	1	3	38.222	10.220	9
3	1	2	1	51.667	9.069	9
3	1	2	2	51.000	8.322	9
3	1	2	3	49.778	9.667	9
3	2	1	1	50.000	9.014	9
3	2	1	2	51.333	10.595	9
3	2	1	3	47.556	9.939	9
3	2	2	1	57.222	9.947	9
3	2	2	2	57.111	7.928	9
3	2	2	3	54.333	6.801	9

NUMBER OF DISTINCT CASES USED = 108

APPENDIX-F

Analysis of Variance Summary Table and Cell Means

for Torque Generated in Hyperextension

* * * * * * * * * * * * * ANALYSIS OF VARIANCE SUMMARY TABLE * * * * * * * * * * * *

BETWEEN SUBJECT FACTORS ARE:

A - TREATMT : 1 CONTROL , 2 UNIVERSA , 3 NAUTILUS

B - TEST : 1 PRE-TEST , 2 POST-TES

C - GROUP : 1 HIGH , 2 LOW

WITHIN SUBJECT FACTORS ARE:

D - TRIAL : 1 TRIAL1 , 2 TRIAL2 , 3 TRIAL3

SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARES	F RATIO	PROBABILITY
A	2716.016	2.	1358.008	4.386	0.015
B	1499.018	1.	1499.018	4.841	0.030
AB	139.925	2.	69.962	0.226	0.798
C	24.038	1.	24.038	0.078	0.781
AC	1647.346	2.	823.673	2.660	0.075
BC	176.843	1.	176.843	0.571	0.452
ABC	148.190	2.	74.095	0.239	0.788
S-WITHIN	29104.750	94.	309.625		
D	280.229	2.	140.114	11.758	0.001
AD	37.297	4.	9.324	0.782	0.538
BD	38.227	2.	19.114	1.604	0.204
ABD	84.616	4.	21.154	1.775	0.136
CD	35.713	2.	17.857	1.498	0.226
ACD	2.824	4.	0.706	0.059	0.993
BCD	5.751	2.	2.876	0.241	0.786
ABCD	22.351	4.	5.588	0.469	0.759
DS-WITHIN	2240.313	188.	11.917		

*** * * * * * * * * * * * * * * * * C E L L   M E A N S * * * * * * * * * * * * * * ***

A	B	C	D	MEAN	STD. DEV.	CASES
1	1	1	1	30.667	8.732	9
1	1	1	2	28.111	9.636	9
1	1	1	3	30.667	11.864	9
1	1	2	1	32.333	12.093	9
1	1	2	2	31.556	13.371	9
1	1	2	3	31.667	12.176	9
1	2	1	1	32.222	9.484	9
1	2	1	2	36.000	12.155	9
1	2	1	3	37.556	11.959	9
1	2	2	1	30.000	14.832	9
1	2	2	2	31.000	14.370	9
1	2	2	3	33.444	14.535	9
2	1	1	1	36.333	9.287	9
2	1	1	2	39.000	9.631	9
2	1	1	3	39.778	7.902	9
2	1	2	1	33.000	9.885	8
2	1	2	2	34.125	11.825	8
2	1	2	3	34.375	12.235	8
2	2	1	1	42.000	8.944	9
2	2	1	2	43.556	12.611	9
2	2	1	3	45.556	12.680	9
2	2	2	1	38.375	8.733	8
2	2	2	2	40.000	8.519	8
2	2	2	3	41.250	10.525	8
3	1	1	1	25.000	9.287	9
3	1	1	2	27.444	9.684	9
3	1	1	3	28.444	8.988	9
3	1	2	1	34.667	6.690	9
3	1	2	2	36.222	6.534	9
3	1	2	3	35.889	6.470	9
3	2	1	1	31.889	11.720	9
3	2	1	2	34.444	9.057	9
3	2	1	3	34.778	10.084	9
3	2	2	1	37.889	8.328	9
3	2	2	2	39.111	7.457	9
3	2	2	3	38.444	8.546	9

NUMBER OF DISTINCT CASES USED = 106

NUMBER DELETED DUE TO MISSING DATA = 2

APPENDIX G

Analysis of Variance Summary Table and Cell Means for Range of Motion in Flexion

* * * * * * * * * * * * * A N A L Y S I S   O F   V A R I A N C E   S U M M A R Y   T A B L E * * * * * * * * * * *

BETWEEN SUBJECT FACTORS ARE:

A - TREATMT : 1 CONTROL , 2 UNIVERSA , 3 NAUTILUS

B - TEST : 1 PRE-TEST , 2 POST-TES

C - GROUP : 1 HIGH , 2 LOW

WITHIN SUBJECT FACTORS ARE:

D - TRIAL : 1 TRIAL1 , 2 TRIAL2 , 3 TRIAL3

SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARES	F RATIO	PROBABILITY
A	319.680	2.	159.840	0.403	0.670
B	146.880	1.	146.880	0.370	0.545
AB	907.201	2.	453.600	1.142	0.324
C	21366.738	1.	21366.738	53.809	0.001
AC	682.561	2.	341.280	0.859	0.427
BC	8.640	1.	8.640	0.022	0.883
ABC	120.960	2.	60.480	0.152	0.859
S-WITHIN	36532.000	92.	397.087		
D	0.0	2.	0.0	0.0	0.999
AD	43.200	4.	10.800	0.524	0.718
BD	129.600	2.	64.800	3.142	0.046
ABD	51.840	4.	12.960	0.628	0.643
CD	25.920	2.	12.960	0.628	0.535
ACD	8.640	4.	2.160	0.105	0.981
BCD	8.640	2.	4.320	0.209	0.811
ABCD	86.400	4.	21.600	1.047	0.384
DS-WITHIN	3795.000	184.	20.625		

* * * * * * * * C E L L   M E A N S * * * * * * * *

A	B	C	D	MEAN	STD. DEV.	CASES
1	1	1	1	224.000	8.631	9
1	1	1	2	223.778	11.088	9
1	1	1	3	223.444	12.381	9
1	1	2	1	205.375	4.438	8
1	1	2	2	205.250	7.498	8
1	1	2	3	207.625	6.346	8
1	2	1	1	215.556	10.725	9
1	2	1	2	215.222	10.305	9
1	2	1	3	216.889	13.052	9
1	2	2	1	203.250	10.780	8
1	2	2	2	200.125	13.043	8
1	2	2	3	201.125	11.594	8
2	1	1	1	222.556	12.177	9
2	1	1	2	224.667	10.037	9
2	1	1	3	222.889	11.921	9
2	1	2	1	201.375	14.17[illegible]	8
2	1	2	2	205.500	14.541	8
2	1	2	3	203.625	14.510	8
2	2	1	1	226.111	13.550	9
2	2	1	2	224.222	12.863	9
2	2	1	3	225.111	12.067	9
2	2	2	1	206.000	14.283	8
2	2	2	2	202.250	14.210	8
2	2	2	3	204.000	20.612	8
3	1	1	1	218.333	8.515	9
3	1	1	2	221.667	8.958	9
3	1	1	3	218.222	10.906	9
3	1	2	1	208.444	12.411	9
3	1	2	2	206.889	17.482	9
3	1	2	3	207.111	13.252	9
3	2	1	1	222.667	9.772	9
3	2	1	2	221.000	11.587	9
3	2	1	3	221.000	12.440	9
3	2	2	1	207.222	9.667	9
3	2	2	2	207.000	11.023	9
3	2	2	3	206.778	12.804	9

NUMBER OF DISTINCT CASES USED = 104

NUMBER DELETED DUE TO MISSING DATA = 4

APPENDIX H

Analysis of Variance Summary Table and Cell Means for Range of Motion in Hyperextension

* * * * * * * * * * * * * A N A L Y S I S   O F   V A R I A N C E   S U M M A R Y   T A B L E * * * * * * * * *

BETWEEN SUBJECT FACTORS ARE:

A - TREATMT : 1 CONTROL , 2 UNIVERSA , 3 NAUTILUS

B - TEST : 1 PRE-TEST , 2 POST-TES

C - GROUP : 1 HIGH , 2 LOW

WITHIN SUBJECT FACTORS ARE:

D - TRIAL : 1 TRIAL1 , 2 TRIAL2 , 3 TRIAL3

SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARES	F RATIO	PROBABILITY
A	1860.302	2.	930.151	1.670	0.194
B	32.940	1.	32.940	0.059	0.808
AB	449.820	2.	224.910	0.404	0.669
C	34963.414	1.	34963.414	62.771	0.001
AC	1085.941	2.	542.970	0.975	0.381
BC	108.540	1.	108.540	0.195	0.660
ABC	635.581	2.	317.790	0.571	0.567
S-WITHIN	51244.000	92.	557.000		
D	440.100	2.	220.050	6.896	0.001
AD	361.800	4.	90.450	2.835	0.026
BD	23.760	2.	11.880	0.372	0.690
ABD	56.700	4.	14.175	0.444	0.776
CD	9.720	2.	4.860	0.152	0.859
ACD	30.780	4.	7.695	0.241	0.915
BCD	11.880	2.	5.940	0.186	0.830
ABCD	85.860	4.	21.465	0.673	0.612
DS-WITHIN	5871.000	184.	31.908		

******** CELL MEANS********

A	B	C	D	MEAN	STD. DEV.	CASES
1	1	1	1	111.444	17.544	9
1	1	1	2	114.333	18.323	9
1	1	1	3	117.111	21.281	9
1	1	2	1	83.667	10.536	9
1	1	2	2	86.778	5.652	9
1	1	2	3	87.444	7.316	9
1	2	1	1	107.778	14.584	9
1	2	1	2	105.667	18.974	9
1	2	1	3	108.556	19.164	9
1	2	2	1	88.556	13.866	9
1	2	2	2	89.889	14.937	9
1	2	2	3	89.889	13.986	9
2	1	1	1	114.875	14.740	8
2	1	1	2	120.250	20.240	8
2	1	1	3	120.125	18.604	8
2	1	2	1	91.125	11.606	8
2	1	2	2	94.250	12.815	8
2	1	2	3	98.500	11.006	8
2	2	1	1	112.875	13.726	8
2	2	1	2	116.125	19.379	8
2	2	1	3	119.750	17.564	8
2	2	2	1	88.500	11.058	8
2	2	2	2	91.875	8.839	8
2	2	2	3	92.625	7.891	8
3	1	1	1	111.222	13.664	9
3	1	1	2	107.667	10.630	9
3	1	1	3	109.889	14.365	9
3	1	2	1	94.444	6.425	9
3	1	2	2	94.556	6.106	9
3	1	2	3	94.667	8.139	9
3	2	1	1	113.111	19.186	9
3	2	1	2	112.778	14.738	9
3	2	1	3	113.778	19.886	9
3	2	2	1	96.778	12.081	9
3	2	2	2	95.222	12.706	9
3	2	2	3	96.889	11.994	9

NUMBER OF DISTINCT CASES USED = 104

NUMBER DELETED DUE TO MISSING DATA = 4

APPENDIX I

Analysis of Variance Summary Table and Cell Means

for Combination Range of Motion

• • • • • • • • • • • • A N A L Y S I S O F V A R I A N C E S U M M A R Y T A B L E • • • • • • • • • •

BETWEEN SUBJECT FACTORS ARE:

A - TREATMT : 1 CONTROL , 2 UNIVERSA , 3 NAUTILUS

B - TEST : 1 PRE-TEST , 2 POST-TES

C - GROUP : 1 HIGH , 2 LOW

WITHIN SUBJECT FACTORS ARE:

D - TRIAL : 1 TRIAL1 , 2 TRIAL2 , 3 TRIAL3

SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARES	F RATIO	PROBABILITY
A	1792.920	2	896.460	1.001	0.372
B	470.951	1	470.951	0.526	0.470
AB	1602.887	2	801.443	0.895	0.412
C	114077.625	1	114077.625	127.345	0.001
AC	3850.234	2	1925.117	2.149	0.123
BC	8.262	1	8.262	0.009	0.924
ABC	371.803	2	185.902	0.208	0.813
S-WITHIN	78832.000	88	895.818		
D	603.148	2	301.574	4.141	0.017
AD	611.410	4	152.853	2.099	0.083
BD	231.345	2	115.672	1.589	0.207
ABD	115.672	4	28.918	0.397	0.811
CD	41.312	2	20.656	0.284	0.753
ACD	148.721	4	37.180	0.511	0.728
BCD	223.082	2	111.541	1.532	0.219
ABCD	123.935	4	30.984	0.425	0.790
DS-WITHIN	12816.000	176	72.818		

A	B	C	D	MEAN	STD. DEV.	CASES
1	1	1	1	336.556	24.850	9
1	1	1	2	338.111	21.473	9
1	1	1	3	340.556	19.184	9
1	1	2	1	289.875	9.250	8
1	1	2	2	292.375	7.671	8
1	1	2	3	286.250	9.647	8
1	2	1	1	323.333	14.866	9
1	2	1	2	322.000	13.426	9
1	2	1	3	336.556	28.736	9
1	2	2	1	289.375	17.606	8
1	2	2	2	286.375	23.525	8
1	2	2	3	289.375	21.672	8
2	1	1	1	336.750	15.453	8
2	1	1	2	344.500	16.665	8
2	1	1	3	342.000	15.446	8
2	1	2	1	291.286	18.400	7
2	1	2	2	297.000	22.196	7
2	1	2	3	298.857	22.401	7
2	2	1	1	336.375	19.018	8
2	2	1	2	337.750	26.032	8
2	2	1	3	341.250	23.861	8
2	2	2	1	292.000	16.503	7
2	2	2	2	290.429	16.989	7
2	2	2	3	292.857	21.782	7
3	1	1	1	329.556	9.126	9
3	1	1	2	329.333	9.721	9
3	1	1	3	328.111	16.617	9
3	1	2	1	302.889	13.430	9
3	1	2	2	300.222	17.225	9
3	1	2	3	301.889	18.176	9
3	2	1	1	335.778	23.910	9
3	2	1	2	332.667	21.500	9
3	2	1	3	334.778	24.478	9
3	2	2	1	304.000	14.739	9
3	2	2	2	302.222	16.107	9
3	2	2	3	303.667	15.149	9

NUMBER OF DISTINCT CASES USED = 100

NUMBER DELETED DUE TO MISSING DATA = 8