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PRELIMINARY ISOKINETIC DYNAMOMETRY DATA FOR CLINICAL USE IN UPPER EXTREMITY CASES IN FEMALES

by

IAN PIKE

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH
IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE
OF MASTER OF SCIENCE

DEPARTMENT OF PHYSICAL EDUCATION AND SPORT STUDIES

EDMONTON, ALBERTA
FALL 1986

ISBN 0-315-32288-8

THE UNIVERSITY OF ALBERTA

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DEGREE FOR WHICH THESIS WAS PRESENTED MASTER OF SCIENCE

YEAR THIS DEGREE GRANTED FALL 1986

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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 PRELIMINARY ISOKINETIC DYNAMOMETRY DATA FOR CLINICAL USE IN UPPER EXTREMITY CASES IN FEMALES submitted by IAN PIKE in partial fulfilment of the requirements for the degree of MASTER OF SCIENCE.

S. M. Mendryk

Supervisor

Dan Syrotuik

Date July 17, 1986

DEDICATION

This thesis is dedicated to

Bobbe and Cori

without whose love and help in life, I couldn't do.

ABSTRACT

The objectives of this study were: 1) to describe standard positioning techniques employed in the isokietic evaluation of the upper extremity; 2) to present preliminary normative isokinetic dynamometry data; and 3) to describe the significance of any differences noted in peak torque production, and angle of peak torque between right and left, and preferred and non-preferred limbs. Supine shoulder flexion/extension, internal/external rotation, and elbow flexion/extension isokinetic data (60°/sec.) were obtained on 74 university aged females (18 - 22 years). The principles of parallel alignment, rotational alignment and stabilization of limb segments were strictly adhered to. The peak torque, and angle of peak torque responses indicated that there were significant differences ($p<0.05$) between right and left, and preferred and non-preferred limbs. Since these differences were noted on the torque development variables, separate percentile ranking tables of normative data were presented for each limb and limb movement. The normal contra-lateral limb ratios were presented in the form of histograms with an illustration of the percentage difference between limbs, and an indication of imbalance one and two standard deviations below the mean. Finally, the normal agonist-to-antagonist muscle group ratios were presented in a manner calculated to illustrate the range of normal ratios. Several cautions relative to the use of these norms were presented, and several recommendations for further study were outlined.

ACKNOWLEDGEMENTS

The author would like to thank the members of his thesis committee for their time, patience, and guidance during the completion of this study: Dr. S. Mendryk, chairman, for his personal attention as supervisor; Dr. R. Steadward who generously allowed the use of his [illegible] equipment and laboratory space; and Dr. D. Syrotuik who was always available with advice and time.

The author also wishes to thank the many people who made the stay at the University of Alberta a most enjoyable one. In particular, Jerry, Michael and Sally, Moira, Garry and Carol, Karen, Dru and Marg - your friendship made it all a lot easier to be here.

To Mum and Dad, thanks for all the years of encouragement and help when it was really needed.

Finally, I would like to thank my wife Bobbe, and daughter Cori, for their love and extreme understanding during my year away from home. I love you both.

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1. INTRODUCTION

The concept of isokinetic exercise was developed during the early 1960's by J.J. Perrine, and was first reported by Hislop and Perrine in 1967. Since then, isokinetic exercises have been used in clinical settings as a therapeutic modality, as a testing and training device for athletes, and as a method of scientific investigation of the relationships between force and velocity, and muscle agonist; antagonist action (Osternig, Barry and Stanley, 1977; Johnson and Siegel, 1978; Goslin and Charteris, 1979; MacDougall, *et al*, 1980; Smith, *et al*, 1981; Knapik, Mawdsley and Ramos, 1983).

Much of the work has been concentrated in determining the relative efficacy of isometric, isotonic and isokinetic training for muscular strength and power development. A review of the isokinetic literature reveals three basic deficiencies:

1. A lack of investigation into the effects of isokinetic exercises with respect to the upper extremity.
2. A prevalent lack of standardization of subject position during isokinetic evaluation, and
3. although relative comparisons have been made, very little firm upper extremity isokinetic normative data exists for the use of clinical practioners as well as research workers.

Moffroid, *et al* (1967), established the reliability and validity of the isokinetic device for the measurement of torque, work and power, and presented some preliminary norms. Goslin and Charteris (1979), and Davies (1982), have presented preliminary normative data for clinical use in lower extremity cases. Molnar and Alexander (1971), have suggested that the establishment of isokinetic normative data would benefit in the assessment of muscular strength, and aid practitioners in the rehabilitative process following injury.

1.1 STATEMENT OF THE PROBLEM

The purpose of the study is threefold:

1. To describe the positioning technique employed for isokinetic evaluation of shoulder flexion/extension, internal/external rotation and elbow flexion/extension exercises,

2. To present preliminary normative isokinetic dynamometry data for the test positions used in the assessment of the shoulder and elbow joints, and
3. to determine the significance of any differences noted between right and left, and preferred and non-preferred limb in peak torque production capacity, and angle of peak torque.

1.2 HYPOTHESES

In this study the following null hypotheses were tested at the $p<0.05$ level of significance. Also reported are those differences that achieved significance at the $p<0.01$ level.

There would be no significant difference in the means of data for peak torque, and angle of peak torque from: 1) right and left limb; and, 2) preferred and non-preferred limb.

1.3 LIMITATIONS

The scope of the study was subject to the following two limitations:

1. The inability to ensure that the subjects were making maximal efforts in the shoulder and elbow exercises. However, verbal encouragement for maximal performance was given to each subject by the tester during all testing sessions.
2. The degree of external validity; *to wit* a randomly selected sample of female university residence students adequately represent the normal female university student populus.

1.4 DELIMITATIONS

The scope of the study was subject to the following four delimitations:

1. The use of 74 normal, healthy female university volunteers between the ages of 18 and 22 years.
2. The use of the Cybex II[1] isokinetic dynamometer and integrated dual channel recorder.
3. The testing of shoulder flexion/extension; shoulder internal/ external rotation; and elbow flexion/extension exercises at a dynamometer speed of 60°/second, and damp setting of 2.

---

[1] Cybex, a division of Lumex, Inc., Bay Shore NY.

4. The use of a standard goniometer to ensure correct and consistent positioning of joint angles.

1.5 DEFINITIONS OF TERMS

Within the scope of this study the following definitions of terms will apply:

1. TORQUE - the product of a force that acts about an axis of rotation multiplied by its perpendicular distance from that axis. (Osternig, *et al*, 1976). Torque is measured in units of force multiplied by the distance (Newton.meters or foot.pounds) (Kelley, 1971; Hay, 1973; MacDougall, Wenger and Green, 1982).
2. PEAK TORQUE - the highest point generated on the isokinetic torque curve, excluding any "overshoot" artifact (Sapega, Sokolow and Saraniti, 1982).
3. PREFERRED LIMB - that arm that is used for writing.
4. AGONIST - those muscles most directly involved in a muscle contraction (Kelley, 1971).
5. ANTAGONIST - those muscles that work in opposition to the agonist muscle (Kelley, 1971).
6. ISOKINETIC CONTRACTION - a muscle contraction that accompanies a constant angular velocity of a limb.

There is confusion in the literature regarding the term isokinetics; that is, does the term refer to constancy of change of muscle length or to a constancy of angular movement of a limb? Whereas most authors state that isokinetics are dynamic muscular contractions which involve a constant time period within which the contraction is performed, there is contradiction as to whether it is the limb or the muscle which is moving under the constant conditions.

Thistle, *et al* (1967); Moffroid, *et al* (1969); and DeLateur, *et al* (1972), present the viewpoint that isokinetics refers to the type of muscular contraction which accompanies a constant angular velocity of a limb. A second viewpoint is offered by Hislop and Perrine (1967); Perrine (1968); and Van Oteghan (1975), who appear to consider isokinetics a term referring to a constant linear rate of muscular contraction.

Any existing confusion requires a clarification for purposes of this study. Practically, it must be noted that the instrumentation currently available for isokinetic measurement (in this case the Cybex II) is based on the provision of resistance which can only be overcome at a pre-set velocity. It follows then, that the manufacturers of this equipment understand isokinetics to be that type of contraction that results from constant angular velocity of a limb. Theoretically, it is also necessary to explain the mathematical relationship between velocity of a shortening muscle and angular velocity of a limb.

Figure 1.1 is a representation of the upper arm (A), the distance (B) between the elbow joint and the point of muscular attachment on the lever arm, and the concentric flexor muscle of the elbow joint (L), where beta (β) is taken to be the angle of flexion. Since the muscle can only contract linearly, the angular velocity of the lower arm as the elbow flexes must be related to the linear velocity of the muscle as it shortens.

By definition, it is known that the angular velocity is equal to the time rate of angular displacement:

$$\text{angular velocity} = d\beta / dt \qquad (1)$$

The length of the muscle (L) may be found at any angle of elbow flexion by applying the law of cosines. Since β is an external angle, the law may be stated:

$$L^2 = A^2 + B^2 + 2AB\cos\beta \qquad (2)$$

and

$$L = (A^2 + B^2 = 2AB\cos\beta)^{1/2} \qquad (3)$$

Linear velocity (V) is known, by definition, to be equal to the rate of linear displacement:

$$V = dL / dt \qquad (4)$$

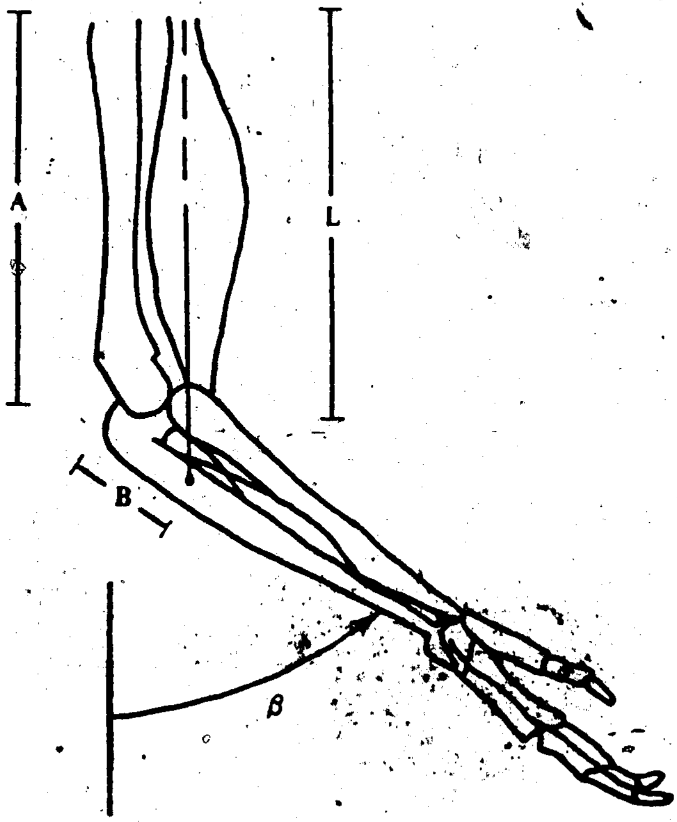

Figure 1.1 Representation of the Arm

Substituting for L from formula (3) and performing the differentiation, one sees:

$$V = dL / dt = -1/2(A^2 + B^2 + 2AB \cos \beta)^{-1/2} (2AB \sin \beta \, d\beta / dt) \quad (5)$$

$$V = (-AB \sin \beta / \sqrt{A^2 + B^2 + 2AB \cos \beta}) \text{ . angular velocity} \quad (6)$$

and

$$V = f(\beta, d\beta / dt) \quad (7)$$

(adapted from: Kelley, 1971; Hay, 1973)

It will be noted that the linear velocity of the muscle as it contracts has been found to be a function (f) of the angle of elbow flexion (β) and the angular velocity of the lever arm, $d\beta / dt$. Since the isokinetic device is intended to provide constant angular velocity, one may assume $d\beta / dt$ to be constant. The angle of elbow flexion is not constant, however, and must not be overlooked.

Figure 1.2 represents linear velocity as a function of beta, the angle of elbow flexion. The negative values yielded by the calculations are reflective of the fact that the muscle is progressively shortening. Positive velocity values would indicate an eccentric or lengthening contraction. Arbitrary values of 6 units and 1 unit were assigned to the lengths of the upper arm (A) and the insertion point (B), respectively, and a value of one unit per time interval was assumed for angular velocity. Resulting values at various angles of elbow flexion are those plotted in Figure 1.2. The dotted portion of the curve must be viewed as theoretical since the soft tissues of the arm will prohibit flexion of the elbow to, or even approaching 180° (Adapted from: Kelley, 1971; Hay, 1973).

It is seen that only around the mid-point of elbow flexion is the velocity of contraction somewhat constant. Between 0° and approximately 70°, contraction velocity increases rapidly; beyond 120°, it slows with similar rapidity.

As this example demonstrates, constancy of change of muscle length and constancy of change of angular movement of a limb require separate defining terms. Due to the understanding of the term isokinetics by the manufacturers of isokinetic devices, it is

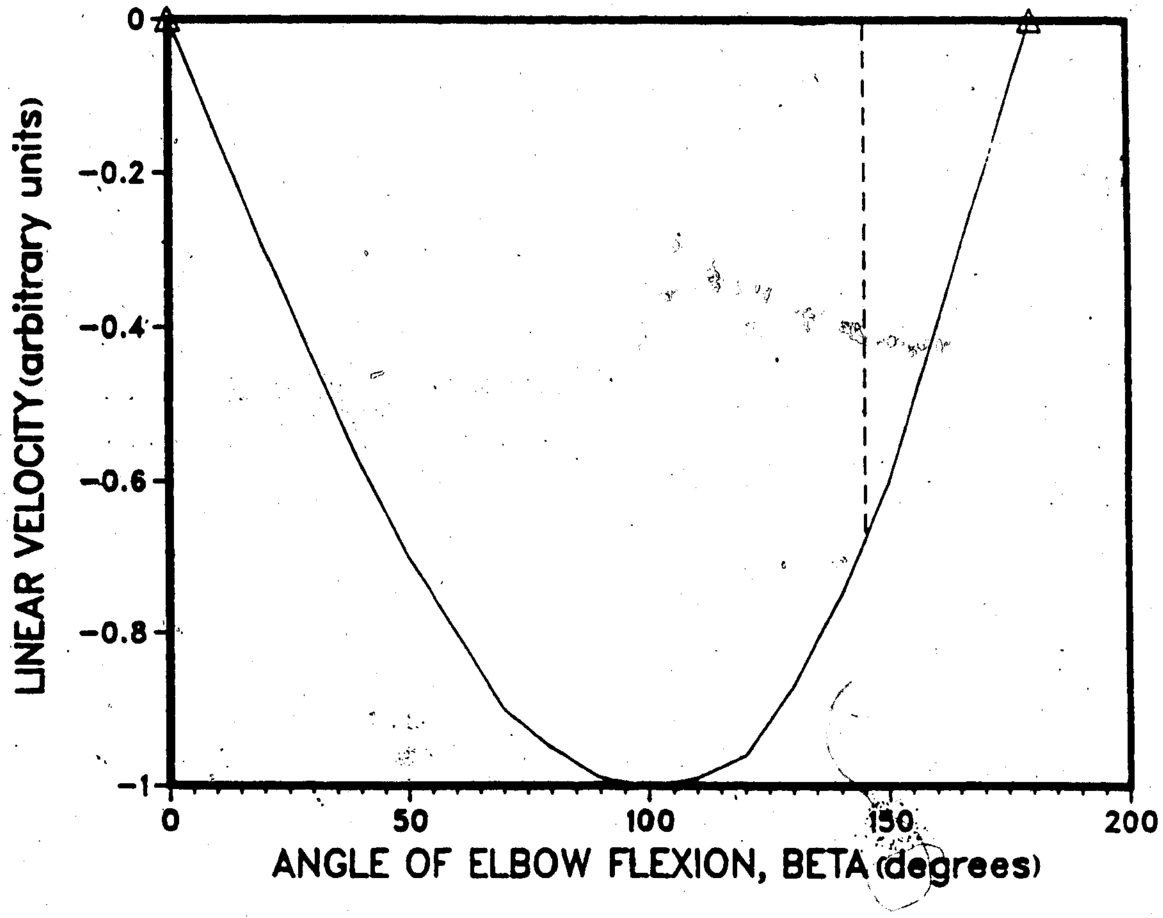

Figure 1.2 Linear velocity of muscular contraction as a function of angle of elbow flexion, β

recommended that isokinetics be used to describe the muscular contraction that accompanies constant angular movement of a limb. Indeed, within the context of this study, this definition of isokinetics will be used.

2. REVIEW OF THE LITERATURE

Since the concept was introduced in 1967, many research articles have been published in the area of isokinetics.[2] Very few, however, have been devoted to the establishment of normative data. Those that have, have concentrated their descriptions on the relationships of the muscle groups of the lower limb, and fewer have concerned themselves with the effects of isokinetics on the upper extremity.

This discussion will not attempt to review all 456 of the published articles in the area, but rather, will concentrate on those selected references that are pertinent to this study. The review will be organized under the following general headings:

1. The concept of isokinetic exercise.
2. Measuring isokinetic muscle torque and angular displacement.
3. Isokintic exercise and rehabilitation.
4. Limb and muscle balance; and,
5. The need for normative data.

2.1 THE CONCEPT OF ISOKINETIC EXERCISE

Until the early 1960's only two concepts of resistive muscular exercise were understood: isometric and isotonic. Isometric muscular contractions are ones in which the length of the total muscle remains unchanged during the exercise. Resistance is equal to the force applied and velocity is zero. Isometric contractions are therefore exertional without resultant motion (Marino and Gleim, 1984).

Isometric contractions can obstruct bloodflow to the contracting muscle. This feature of isometric contractions depends upon the intensity of the contraction (Astrand and Rodahl, 1977). Increased blood pressure (Donald, *et al,* 1967), both systolic and diastolic may also result from isometric contractions. High intensity isometric exercise will stimulate the Valsalva

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[2] Cybex publishes a bibliography of the research articles that have utilized Cybex II isokinetic dynamometry as a tool for measurement in the study. To date, the bibliography contains 456 citations.

maneuver (making an expiratory effort with the glottis closed), which initially increases blood pressure. The heart is loaded more during isometric exercise than during any other form of muscular contraction (Astrand and Rodahl, 1977), resulting in reflex blood pressure responses. Isometric strength gains are limited to the angle where the contraction occurs in the range of motion (Pipes, 1977; Davies, 1982). For example, if a limb is trained with the elbow flexed at 90°, the limb would become stronger when flexed at that angle (90°). But it might not become stronger when flexed at 135° or 70°.

The clinical value of isometric exercise is limited to the extent that the demand it places on the neuromuscular system parallel the individual's needs.

An isotonic muscle contraction is a contraction that causes a change in the length of the muscle, causing a movement of the part(s) to which it is attached. Resistance remains constant and velocity is inversely proportional to the load applied. There are two types of isotonic contraction. A concentric contraction occurs when muscle shortens, causing joint motion in the direction of pull, decreasing the joint angle (Marino and Gleim, 1984). This is known as positive work. An eccentric contraction occurs during the lengthening of muscle. The muscular force generated to resist the lengthening is known as negative work (Fox and Mathews, 1981).

The magnitude of an isotonic resistance normally must be limited to the largest load that can be moved at the weakest point in the range of movement (Perrine, 1968). The resistance has its greatest mechanical advantage on the muscle at the extremes of the range. Here the lever system is most extended or flexed, and consequently, the load on the muscle is greatest at these points. Conversely, closer to the mid-range where the lever is most efficient, the load on the muscle is proportionately less (Hislop and Perrine, 1967; Perrine, 1968).

The clinical value of isotonic exercise, therefore, is limited by its inability to impose maximal tension and work demands on the muscle throughout its range of movement, because a weight must be selected which accommodates the weakest point in the range so that the patient may accomplish a complete movement.

An isokinetic muscle contraction is a dynamic contraction performed at constant speed (angular velocity). Resistance accommodates to the varying force applied through the range of motion, causing a shortening of the muscle. Constant angular velocity is maintained by a special isokinetic device.

Although, strictly speaking, a means of speed control, and not a load in the usual sense, is applied in isokinetic exercise, load and resistance are present and available in relatively unlimited amounts (Hislop and Perrine, 1967; Perrine, 1967).

The load acting in isokinetic exercise cannot be traced to a familiar agent such as gravity or friction, but is the result of the mechanical process of energy absorption which an isokinetic device performs in order to keep the exercise velocity constant.

In isokinetic exercise, energy cannot be dissipated by acceleration because this is mechanically prevented by the device. Because the energy is not dissipated anywhere in the process, it completely converts to a resisting force which is always proportional to the magnitude of the input (muscular) force. Thus, it varies in relation to the efficiency of the skeletal lever (Hislop and Perrine, 1967; Perrine, 1968).

In effect, the resistance can accommodate all factors causing force variations through a range of motion. At the extremes of the range of motion where the muscle has its least mechanical advantage, the resistance offered is least. As the motion approaches the point in the range where the mechanical advantage is greatest, the resistance increases proportionately. With resistance accommodating the varying force of the skeletal lever, the muscle is able to maintain a state of maximum contraction through its full shortening range. This situation permits a maximum demand to be placed on the work capacity of the muscle (Hislop and Perrine, 1967; Perrine, 1968; Davies, 1984).

The clinical applications of isokinetic exercise have been cited by Davies (1982), and others, and will be expanded upon in relation to its role in rehabilitation, later in this review.

Much research has addressed the question, which type of muscular exercise is best? In order to answer this question, one must respond with a second question, "Best for what?"

Thistle, *et al* (1967), made a comparison of isokinetic, isotonic and isometric programs. All programs were performed 4 days per week for 8 weeks. The isokinetic program was superior to the other programs in both strength and endurance gains. As DeLateur, *et al* (1972), point out, caution should be exercised when comparing the results of varying muscular training programs because the nature of the tasks are different. And, attempts to equate tasks in each of the types of muscular exercise has been a stumbling block in many comparative studies, to date.

Knapik, *et al* (1983), compared the effects of isometric training of the elbow flexors at a specific joint angle (90°) versus isokinetic training (30°/second) through a range of joint motion (45° to 135°) on isometric and isokinetic tests. The results of the test demonstrated; 1) there were no significant differences between the isometric and isokinetic training groups when tested isometrically, indicating that both forms of exercise will improve isometric strength; 2) there were significant differences between the isometric and isokinetic training groups when tested isokinetically - the isokinetic group demonstrated more improvement - indicating that isometric training is not as effective in increasing isokinetic strength.

Fox and Mathews (1981), have synthesized the research findings into a comparative table (see Table 2.1) which rates isometric, isotonic and isokinetic exercises on eleven criterion measures. Any one of these criteria may be considered more important than another, depending upon the specific requirements of the individual.

2.2 MEASURING ISOKINETIC MUSCLE TORQUE AND ANGULAR DISPLACEMENT

The device used to measure isokinetic muscle torque and angular displacement is the Cybex II isokinetic dynamometer, with electrogoniometer, and integrated dual channel recorder. The Cybex Upper Body and Exercise and Testing Tables (UBXT) is designed to provide anatomically correct positioning, positive stabilization and specialized input accessories for testing of the upper limbs (Isolated Joint Testing and Exercise, 1980).

The Cybex II isokinetic dynamometer consists of a lever arm which can be adjusted to the length of the limb being tested. The lever arm is attached to the limb being tested, and is

Table 2.1 SUMMARY OF ADVANTAGES AND DISADVANTAGES OF THE THREE MOST COMMON TYPES OF RESISTANCE TRAINING PROGRAMS

CRITERION	COMPARATIVE RATING		
	Isokinetic	**Isometric**	**Isotonic**
Rate of strength gain	Excellent	Poor	Good
Rate of endurance gain	Excellent	Poor	Good
Strength gain over range of motion	Excellent	Poor	Good
Time per training session	Good	Excellent	Poor
Expense	Poor	Excellent	Good
Ease of performance	Good	Excellent	Poor
Ease of progress assessment	Poor	Good	Excellent
Adaptability to specific movement patterns	Excellent	Poor	Good
Least probability of muscle soreness	Excellent	Good	Poor
Least probability of injury	Excellent	Good	Poor
Skill improvement	Excellent	Poor	Good

Source: Fox, E.L. and D.K. Mathews. The Physiological Basis of Physical Education and Athletics. 1981.

limited to movement at a pre-selected constant velocity. The lever arm is prevented from surpassing the pre-selected velocity by the internal mechanics of the dynamometer, and any attempts to do so result in resistance rather than acceleration.

There is often confusion regarding the effect of lever arm length adjustment. It is true that a longer lever arm would provide the subject with a greater leverage advantage on the dynamometer. However, the subject's limb is also a lever arm. As the distance from the joint to the point at which resistance is placed on the skeletal lever arm increases, so the subject's joint is placed at an increasing disadvantage. Because the distances from the joint's axis of rotation and the dynamometer's input shaft to the point of application of resistance are the same, any leverage advantage on the dynamometer is cancelled out by an exactly equal leverage disadvantage to the subject's joints and muscles (Perrine, 1968; Isolated Joint Testing and Exercise, 1980). So then, the use of the Cybex II isokinetic dynamometer provides a standardized measurement of torque which properly matches the joints and muscles; which are torque producing mechanisms (Hislop and Perrine, 1967; Perrine, 1968).

The dual channel recording device, integral to the Cybex II isokinetic dynamometer, allows for the selection of a torque range scale, position angle degree scale, position angle calibration, damp setting, and two paper speeds. The first channel records torque and the second angular displacement.

The manufacturers suggest that for the evaluation of peak torque in shoulder and elbow exercises, a speed of 60°/second should be selected; the torque range scale should be set at 180 ft.lbs; the position angle scale at 300°; and the damp set at 2. For tests of peak torque a paper speed of 5 mm/second is adequate, while measurements of angular displacement require a paper speed of 25 mm/second (Isolated Joint Testing and Exercise, 1980). See Appendix F for example of Cybex II recording chart. The peak torque and angular displacement data is interpreted from the dual channel recorder chart with the Cybex II Chart Data Card® (Appendix G). Recent technological advances have seen the introduction of the Cybex Data Reduction Computer® which reduces all information regarding torque, work, power and angular displacement to final numerical summary form.

Despite the advantages of the Cybex II isokinetic dynamometer for the evaluation of torque and angular displacement, there are one or two cautionary notes to be made regarding the stylus damp setting, and the "overshoot" artifact evident on some Cybex II result charts.

The damp setting on the recorder controls the speed of response of the torque channel stylus. The control is important because, according to the manufacturer, it "damps out" unwanted, high frequency mechanical oscillations such as dynamometer gear noise, and it helps to control the phenomenon of "overshoot".

Overshoot typically appears as a prominant, initial spike in the subject's torque output curve which may or may not be followed by a series of progressively diminishing secondary oscillations (Sapega, Sokolow and Saraniti, 1982). This spike, it appears, is the result of a very small amount of mechanical freeplay in the dynamometer which allows the limb segment being tested to accelerate beyond the pre-selected velocity of the dynamometer for a very short time period. The spike is a reflection of the torque required to decelerate this initially overspeeding limb-lever system (Sapega, Sokolow and Saraniti, 1982).

The implications that overshoot is most likely to have, is in the misinterpretation of peak torque. A large initial overshoot spike will often be the peak point in the torque curve, and if it is interpreted as the subject's peak muscular torque output, then it will artifactually inflate peak torque data as well as alter contra-lateral and agonist-to-antagonist ratios.

Sapega, Sokolow and Saraniti (1982), have suggested that the overshoot artifact can be eliminated by the use of the damping control. Care, however, must be used when interpreting such "damped" curves. Sinacore, *et al* (1983), have reported on the effects of damp on Cybex II curves, and have shown alterations in the amplitude and temporal relationships of the torque curve with varying damp settings.

Both groups conclude, however, that for routine clinical assessment in the lower velocity range ($<$ 60°/second) a damp setting of 2 provides a torque curve that is both readily interpretable and relatively free from overshoot artifact. Further studies are required to evaluate the effectiveness of damp settings at faster (> 60°/second) vecolities.

2.3 ISOKINETIC EXERCISE AND REHABILITATION

Most injuries, whether acute or chronic, lead to diminished muscle function and joint control. Effective rehabilitation is very important because unless total restoration is achieved, the stresses to which the musculoskeletal system is regularly exposed will lead to further injury in the same, or a previously uninvolved, area of the body (Steele, 1980).

Providing effective rehabilitation is more complex than is often realized: exercises are frequently prescribed without a clear understanding of their actual effect (Sherman, *et al* 1982; Smodlaka, 1977). Controversy continues regarding the relative merits of isometric and isotonic exercises for improving muscle function. It is difficult to compare the two forms of muscle activity because, as yet, researchers have found it impossible to impose exactly comparable exercise regimens in terms of energy expenditure and effort (Osternig, Barry and Stanley, 1977; Knapik, Mawdsley and Ramos, 1983). Further, improvement is difficult to quantify because an isotonic muscle test does not necessarily reflect isometric tension; the converse is also true.

Zohn, *et al* (1964), compared an isometric and isotonic exercise program for quadriceps rehabilitation following knee injury. They found that the former type of exercise produced more rapid strength gains, and fewer treatments before the patient was considered "fit for discharge". Conversely, Thistle, *et al* (1967), found that an isotonic program produced increases of 27.5% and 28.6% in endurance and strength respectively, whereas isometrics of the same duration only yielded endurance increases of 9.2% and strength increases of 13.1%. These results confirmed the findings of an earlier study by Rasch and Morehouse (1957), who suggest that a significant factor in their findings may have been that the group performing isometric contractions "felt bored" because this form of exercise did not offer a challenge. Further research questioning the motivation of subjects to perform various types of resistance exercises and resultant strength gains would seem appropriate.

Isometric exercises have commonly been given by therapists early in the rehabilitative process to maintain or improve muscular performance where active movement is undesireable (Steele, 1980); generally, isotonic exercises predominate in the later stages of treatment. It must be remembered that with isometrics, improvement is confined to the point in the range at which resistance is imposed, and therefore a series of isometric contractions at various joint angles should be employed (Pipes, 1977).

Isotonic exercise can be imposed in many ways, for example with the use of free-weights, pulleys, springs, and most multigym units. Weight-bearing exercises using body weight and/or additional loading as the opposing force are common, both in rehabilitation and athletic training. The main limitation is, as previously reported, that maximal resistance is imposed at the weakest part of the range of movement, thus overall improvement throughout the entire range of movement is not achieved (Hislop and Perrine, 1967).

Manual resistance enables the therapist to impose an accommodating resistance to the contracting muscles. The advantage with this type of exercise is that maximal contraction can, with the patient's co-operation and effort, be maintained throughout the movement. Manual resistance is probably a safe method of introducing resistance exercises to weak muscles (Steele, 1980). A satisfactory resistance regimen can be given manually during the early stages, but as strength is gained increasing resistance becomes necessary. The disadvantage of manual resistance exercises is that they are reliant upon an experienced therapist who can provide the necessary resistance to be beneficial in the rehabilitative process.

The concept of isokinetic exercise has been previously presented in this review, but a discussion regarding the value of isokinetics during rehabilitation is warranted.

Isokinetic contractions provide muscle rehabilitation and training throughout the range of motion of a joint at constant velocity of contraction while automatically accommodating the resistance to the developed muscular tension (Hislop and Perrine, 1967; Perrine, 1968). Other advantages of isokinetic training for rehabilitation include:

1. "Safe" muscle contractions (Sherman, *et al* 1982; Davies, 1982). The contraction is

considered "safe" because the resistance is never greater than the produced muscular tension. Therefore, it provides protection of painful areas in the range of motion (Steadman, 1979), and the risk of re-injury through resistance overload is eliminated. However, one group have reported a tendancy for subjects to "back off" during slow speed testing (30°/second) of the upper limb following surgery (Elsner, Pedegana and Lang, 1983). They suggest that the fast speeds (> 60°/second) tend to yield more accurate results, but that further research to determine the optimum speed for testing and rehabilitation is necessary.

2. Maximal resistance through the "velocity spectrum" (Davies, 1982). Because of the control over velocity of limb movement capable with Cybex II (0° to 300°/second), high-speed low-resistance and high-resistance low-speed rehabilitation programs are possible.
3. Recipirocal exercise patterns (Sherman, *et al* 1982), for example, flexion/extension, internal/external rotation.
4. Minimal post exercise soreness (Davies, 1982), because most isokinetic devices allow only concentric muscular contractions. The exception being the Kin-Com® device[3]which does permit eccentric isokinetic contractions.
5. Isokinetics also provide for: efficiency of muscular contractions; decreased joint compressive forces at high speeds; objective feedback for the subject; and objective supervision of rehabilitative programs (Davies, 1982).

2.4 LIMB AND MUSCLE BALANCE

The need for a balanced state in terms of muscle function between the contra-lateral limbs has been shown to be desireable for injury-free functioning, particularly in manual labour vocations, and sports participation (Steele, 1980). Abbott and Kress (1969), tested the thigh strength of 90 new cadets, all of whom had histories of pre-Academy knee injuries, before they embarked on military training. It was found that those that demonstrated a

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[3] Chattecx, Chattanooga, TN.

differential in strength in the quadriceps or hamstrings in excess of 10 lbs (measured by a multi-angle isometric testing technique) between the two limbs were more susceptible to injury (re-injury) than those who achieved similar scores. Further, a group who then undertook a specific isometric conditioning program sustained significantly fewer injuries compared with those with proven weaknesses who merely continued with normal military training (20 injuries among 33 cadets). Generalizations, regarding limb balance and the incidence of injury, from the results of this single study should be made cautiously. Further investigation and documentation is needed before firm conclusions can be drawn.

Bender, *et al* (1964), also discussed the potential risks attributed to imbalance between the lower limbs. Using isometric tests they found that an imbalance in excess of 10% rendered the subject injury-prone; they also suggested that people with poor strength values *per se* in relation to body weight are more susceptible to injury than their stronger counterparts. Davies (1982), has stated that contra-lateral comparisons within 10% to 15% are usually considered to be within "normal limits". He does not, however, state whether these normal limits apply to upper or lower extremity musculature.

Perhaps one of the better attempts to quantify contra-lateral strength ratios in the lower limb has been presented by Goslin and Charteris (1979). Using standard scores, the authors demonstrated a significant difference in the leg (knee) extensor mechanism between dominant and non-dominant limbs, for both male and female subjects. The size of the difference was in the order of 13.3% for males and 18.8% for females. The authors failed to show any significant differences when standard scores from left and right limbs were compared. They were careful to state that the noted bilateral differences were normal only for the population sampled, and for the velocity tested (30°/second). Comparisons to other populations (i.e. asymmetrical sports participants), and to other test velocities should be made with caution, and in fact warrant separate research.

The implications are clear. Firstly, a balanced state between the two limbs should be sought. Secondly, the weak or overweight should be encouraged to undertake a general program to improve muscle function, and where applicable, reduce weight. Finally, research that yields objective contra-lateral ratios, particularly with respect to the upper limb, needs to be conducted.

Balance between agonist and antagonist muscle groups has also been shown to be important in the prevention of injury, and a key to normal healthy functioning (Coplin, 1971; Davies, *et al* 1981; Goslin and Charteris, 1979; Osternig, *et al* 1977; Smith, *et al* 1981; Rankin and Thompson, 1983).

Coplin (1971), has suggested that the hamstrings of college-aged athletes should have strength values of about 60% of the quadriceps. Alteration in this ratio is thought to increase the risk of knee injury. Davies, *et al* (1981), found hamstring to quadriceps ratios of 60.9% at 45°/second and 80.4% at 300°/second in their study of professional football players. Goslin and Charteris (1979), studied 60 untrained men and women at 30°/second and found a hamstring to quadriceps ratio of .44. That study was an attempt to establish norms for quadriceps and hamstring strength. The authors concluded they could not set a norm based on a standard score for hamstring to quadriceps ratio as the value at the top and bottom of the scale would be pathalogical, not extremes or normal. Osternig and co-workers (1977), studied undefined college athletes, and found ratios of .57 at 50°/second and .77 at 400°/second. They concluded that at speeds approximating actual performance, the hamstring to quadriceps ratio was closer to unity. At these speeds it seems that the hamstrings can exert a greater proportion of their strength than can the quadriceps.

In a study of elite amateur and professional ice-hockey players, Smith, *et al* (1981), also concluded that as velocity of limb movement increases, hamstring to quadriceps ratio approaches unity (.62 at 30°/second, and .81 at 180°/second). In paired abduction/adduction measures of the shoulder joint, the same group demonstrated differing ratios by test speed, and by player position. Goalies demonstrated ratios of .69 and .66; defencemen .72 and .85; and, forwards .74 and .73, at test speeds of 30°/second and 180°/second, respectively.

Rankin and Thompson (1983), have completed an extensive study presenting normative hamstring and quadriceps data for incoming college athletes for 31 sports at 3 different test speeds. They have established average strength to body weight values, as well as hamstring to quadriceps ratios. They suggest that this normative information is essential for athletes, coaches and therapists for purposes of training and rehabilitation, in particular, and that further research is needed to establish norms for upper extremity exercises in various populations.

2.5 THE NEED FOR NORMATIVE DATA

In the absence of specific normative isokinetic dynamometry data, clinicians, therapists and research workers have relied upon a contra-lateral or uninjured limb to provide information about that individual's normal capability. This information may give some measure of suitable goals. However, Smodlaka (1977), states that additional scales for comparison are needed when the uninjured limb is a poor indicator of such characteristics as strength, power and endurance.

There are several important points to consider that might be better answered by referral to normative data.

Firstly, is the contra-lateral limb the dominant or non-dominant limb?

Clinical and research work indicates that the non-dominant lower musculature is commonly 5% to 10% weaker (peak torque at 30°/second) than the dominant limb (Davies, 1982; Goslin and Charteris, 1979). This problem is particulary acute in the upper extremity where dominant and non-dominant limbs present very different physiological and performance characteristics (Edwards and Vitti, 1982). This is probably due to the fact there is no shared weight bearing requirement, and that the dominant arm is predominantly used for the most demanding activities. In one study, for example, a 25% superiority in dominant limb shoulder musculature was common among Jai-Alai players (Isolated Joint Testing and Exercise, 1980). In another study of elite amateur and professional ice-hockey players Smith, *et al* (1981), stated that right-left side muscle imbalances related to specific favoured player movement responses, and noted that testing would provide valuable corrective information for the player and the coach.

A second question to consider, in terms of prescribing rehabilitative programs is, has the capability of the uninjured limb decreased because of disuse or interuption of training due to injury?

Research has demonstrated the effects of immobilization on the degree of atrophy and strength losses (MacDougall, *et al* 1980; Jensen and Schultz, 1965). These findings are also true of the uninjured limb in cases where the subject is bedridden or has to compensate his/her normal activity level (Jensen and Schultz, 1965). In college athletes, losses of 1.5% to 3% per day have been observed in the uninjured limb due to confinement (Jensen and Schultz, 1965). This factor must be taken into account when setting rehabilitative and retraining goals. Without knowing the degree of decrease in function of the uninjured limb, difficulty arises in accurately setting goals for the injured limb. The development of normative data would provide the therapist and the patient with goals to achieve, both for the injured and uninjured limbs.

Thirdly, the question must asked, is the subject's normal muscular capabilty sufficient for his/her activities?

It may well be that injury was caused, and rehabilitation is necessary because the subject's normal capabilities are less than desired. This being the case, in addition to a rehabilitative program, an injury prevention program consisting of strength exercises for both limbs should be indicated. Normative information could establish rehabilitative and strengthening goals.

The final point that must be addressed is the somewhat subjective and empirical information that many therapists have, to date, based rehabilitation programs on.

As an example, exercise has been difficult to monitor, since there has been no criteria other than pain as an indicator of overload and increase in strength (Nirschl and Sobel, 1981). Unfortunately, human pain thresholds vary so widely that pain is unreliable in many cases.

Monitoring strength is a much more objective measure, and to do so profiles and normative information would be of great assistance.

Rehabilitation is an area where further research is required to ensure that optimum treatments can be offered to the patient (Steele, 1980; Eriksson, 1981; Edwards and Vitti, 1982). It is extremely important in the care of injured athletes, and indeed any other patient that the therapist cares for, that the therapist has the necessary knowledge and ability. Rehabilitation is challenging work and often the therapist is working without scientifically established programs in terms of the ultimate goals he/she is aiming for. It is the belief of this author that the development of normative isokinetic dynamometry data will help to shed some light, and assist in the provision of rehabilitation and retraining program goals.

3. METHODS

3.1 SUBJECTS

The subjects in this study involved 74 informed and consenting female volunteers between the ages of 18 and 22 years (mean = 20.99 ±1.19). Subjects were university residence students from various faculties, who were randomly selected, and were identified as being in good health and having no known pathologic condition nor previous surgery of either of the upper extremities. The students represented a variety of faculties, which is noted for information in Appendix A. It was assumed that the females in this sample were a good representation of the normal female university populus.

3.2 MEASUREMENT APPARATUS

The Cybex II isokinetic dynamometer was used to measure the peak torque values of flexors and extensors of both the elbow and the shoulder joints, as well as the internal and external rotators of the shoulder joint. The construction features of the Cybex II dynamometer have not been published, but the dynamometer apparently consists of a small DC servomotor employing tachometer feedback control. Once a particular velocity has been set, the motor resists accelerations that would otherwise have been caused by applied torques. Thus, the isokinetic (constant velocity) condition has been achieved (Sale and Norman, 1982).

The Cybex II allows torque to be applied and measured in two opposite directions. The servomotor does not rotate in both directions; hence the bi-directional capability is most likely achieved by the use of a pair of unidirectional gears.

A noteable safety feature of the Cybex II is that the input shaft does not rotate with the motor. The shaft must be accelerated (by the subject) and will engage the servomotor when its velocity matches that of the motor; in fact engagement occurs when the subject attempts to accelerate the input shaft beyond the pre-set velocity of the servomotor.

The Cybex II two-channel thermal recorder, integral to the Cybex II, was used to record the results; one channel displayed torque, and the second displayed angular displacement. The Cybex II dynamometer was calibrated at 60°/second for torque according to the manufacturer's recommendations as documented in the Cybex II Handbook (Lumex, Inc., 1980) and verified by Moffroid, *et al* (1969). Certified calibration weights were placed on the calibration input arm (attached to the dynamometer input shaft) which was positioned above the horizontal plane. The attachment was then released and the peak torque was registered as the attachment passed along the vertical plane and through the horizontal plane. Reliability of measurement (Moffroid, *et al* 1969; Johnson and Siegel 1978; Thorstensson, *et al* 1976) and clinical applicability of the dynamometer have been well documented. The reported reliabilities for various controlled parameters include:

1. r = 0.995 for test-retest of 2.27 - 27.27 kg (5 - 60 pounds) at any one lever arm position,
2. r = 0.999 for predicted to obtained torques far various lever arm positions, and
3. r = 0.946 for predicted to obtained power for 27.27 kg (60 pounds) with 60.96 cm (2 feet) lever arm at three different speeds (3).

Calibration was completed at the start of each testing session. Detailed calibration procedures for the Cybex II isokinetic dynamometer appear in Appendix B, C, and D of this document.

3.3 TESTING PROCEDURE

Three principles of positioning, as outlined by Goslin and Chartiers (1979), were strictly adhered to during the data collection phase:

1. *Parallel alignment* - all moving limb segments were aligned parallel to the input shaft of the dynamometer.
2. *Rotational alignment* - the axis of rotation of the joint and the axis of rotation of the dynamometer input shaft coincided.
3. *Stabilization* - all limb segments were firmly strapped to the dynamometer or the Upper Body Exercise Table (UBXT) as appropriate, and the trunk position was maintained

relative to the axis of rotation at all times, through the use of straps tightly secured at the pelvis and upper torso. Limb segments not actively moving the input shaft of the dynamometer were not allowed to participate.

The test positions employed for the assessment of shoulder and elbow function were consistent with those recommended in Isolated Joint Testing and Exercise (Lumex, Inc. 1980), and described below:

1. Shoulder Flexion/Extension:

The subject laid in a supine position on the UBXT. The upper body and hips were secured by the use of straps. The non-exercising arm was allowed to rest beside the body and the hand grasped a handgrip attached to the UBXT at hip level (Plate 3.1).The test arm was positioned on the input shaft using a neutral handgrip so as not to position the wrist at a disadvantage in either direction of movement. The goniometer was centered on the shoulder just below the acromion. One arm of the goniometer was placed parallel to the midaxillary line of the trunk; the other arm of the goniometer was placed parallel to the longitudinal axis of the humerus along the lateral side of the subject's arm (Kottke, *et al*, 1982). Shoulder extension began at 180° of flexion, and shoulder flexion began at 0° or neutral (Figure 3.1). Motion was limited to the individual capabilities of the subject, and exceeded 180° in all cases.

2. Shoulder Internal/External Rotation:

The subject laid in a supine position on the UBXT. The upper body and hips secured by the use of straps. The non-exercising arm was allowed to rest besides the body and the hand grasped a handgrip attached to the UBXT at hip Level (Plate 3.2). The test arm was placed in a position of 90° of abduction which assisted in stabilization of the scapula, and placed the arm in a position to accommodate the dynamometer. A neutral handgrip was used so as not to position the wrist at a disadvantage in either direction of movement. The goniometer was centred on the elbow joint. One arm of the goniometer was held parallel to the midaxillary line of the thorax. The other arm of the goniometer was aligned with the longitudinal axis of the forearm (Kottke, *et al*, 1982). Internal and external rotation were completed through a maximal individual range

Plate 3.1 Subject Position for Shoulder Flexion/Extension Measurements

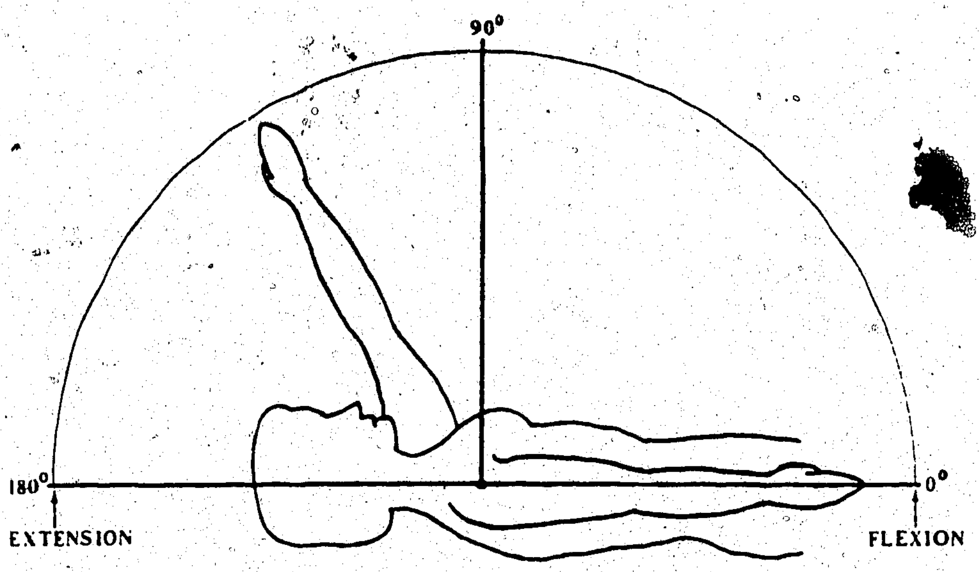

Figure 3.1 Movement Arc in Shoulder Flexion/Extension Measurements

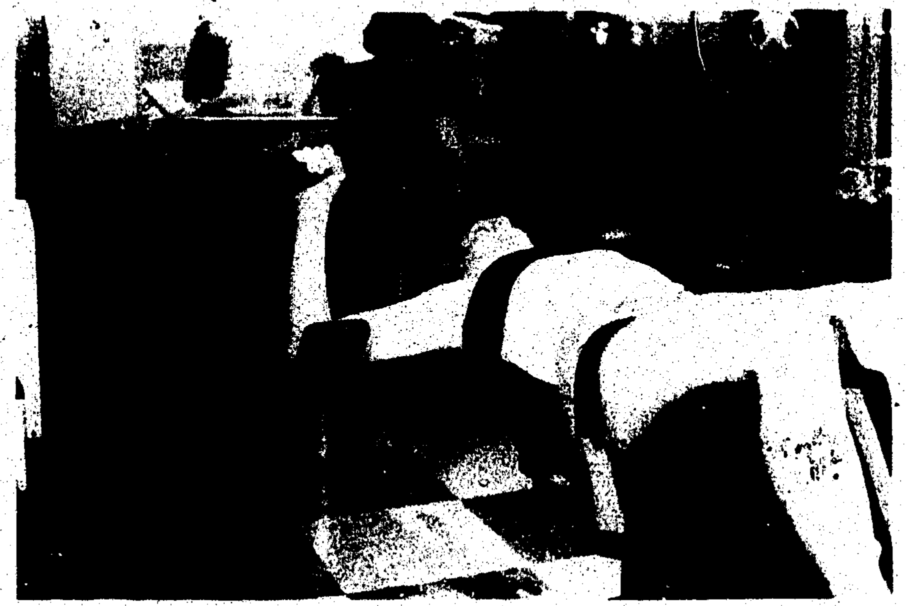

Plate 3.2 Subject Position for Shoulder Internal/External Rotation Measurements

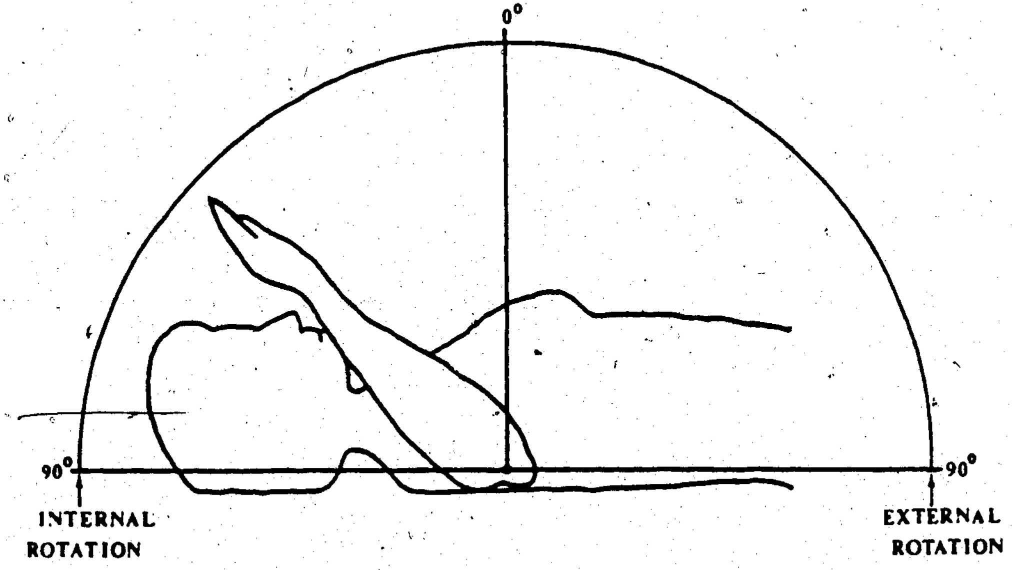

Figure 3.2 Movement Arc for Shoulder Internal/External Rotation Measurements

of motion (Figure 3.2).

Elbow Flexion/Extension Measurements:

The subject was positioned in a supine position on the UBXT and the upper body and hips were secured by straps (Plate 3.3). The exercising arm was placed in a position of 90° of abduction which assisted in stabilization of the scapula , and placed the arm in a position to accommodate the dynamometer. A neutral handgrip was used so as not to place the wrist at a disadvantage in either direction of movement. Subjects were not permitted to raise the upper arm from the UBXT and a strap was used to maximize stabilization. The goniometer was centered over the elbow joint laterally. One arm of the goniometer was placed parallel to the longitudinal axis of the humerus, and the other arm was placed parallel to the longitudinal axis of the radius (Kottke, *et al*, 1982). Elbow flexion and extension were completed through a maximal individual range of motion (Figure 3.3).

All subjects completed a consent form and were assumed, because of interest in the test, to be making maximal efforts in each test situation. A copy of the explanation and informed consent form appear in Appendix E.

All testing was undertaken at a dynamometer speed of 60°/second. All subjects were conversant with the testing device and its principles of operation, having read a complete explanation of the purpose of the study and the testing procedure to be followed, and having completed 5 sub-maximal practice/warm-up movements for the shoulder and elbow exercises prior to each test.

All measures were obtained from the maximum score of three paired trials through the maximal individual range of motion, where each effort was followed by a 30-second rest period. Each effort was recorded on a dual channel heat sensitive recorder, integral to the Cybex II system, at a damp setting of 2. A paper speed of 5 mm/second for the first two trials, and 25 mm/second for the third trial was used in all cases (Isolated Joint Testing and Exercise, 1980).

Plate 3.3 Subject Position for Elbow Flexion/Extension Measurements

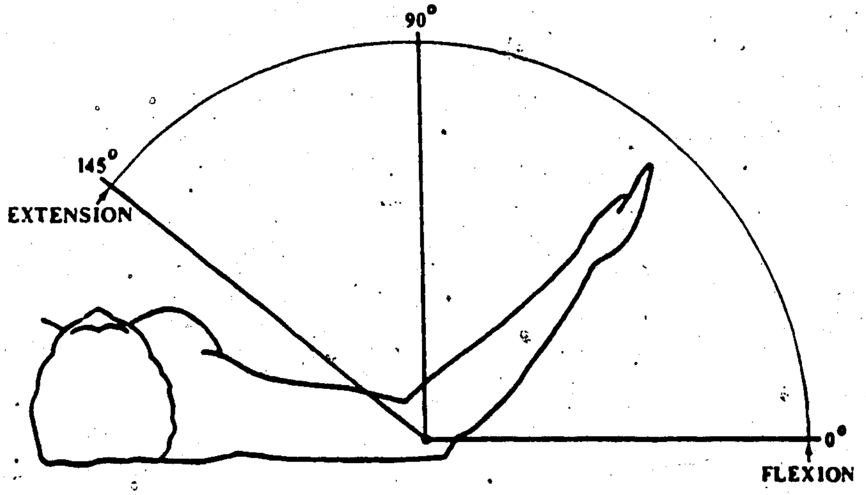

Figure 3.3 Movement Arc for Elbow Flexion/Extension Measurements

Both right and left limbs were evaluated, and note was made of which hand the subject used to write with; this was then referred to as their "preferred" limb. Peak torque (ft.lbs) was measured directly from the recorded trace, by simply noting the maximal "height" of the recorded trace in paper divisions and multiplying by the amplification setting. Peak torque values were then converted to Newton.meters (N.m) using the following conversion factor : 1 ft.lb = 1.355818 N.m. In all testing the 180 ft.lbs amplification scale was selected, as per the manufacturer's recommendations (Isolated Joint Testing and Exercise, 1980), and in agreement with other studies determining upper extremity torque values (Smith, *et al* 1981; Osternig *et al* 1977; Knapik, *et al* 1983).

3.4 LEAN BODY WEIGHT

Body weight was measured to the nearest 50 gm using a Homs beam balance scale. Height was measured with a standard stadiometer to the nearest 0.5 cm. Percent body fat was calculated from skinfolds using the technique of Durnin and Wormesley (1974). Duplicate measurements of four skinfolds were obtained (bicep, tricep, subscapular and suprailiac) using a Harpenden caliper. The means of duplicate trials were used in all analyses. Lean body weight (LBW) was obtained by subtraction (LBW = BW - fat weight). Lean body weight was determined primarily for descriptive purposes, such that the female in this study could be compared with "normal" females described in previous studies ("Reference Woman"; Behnke and Wilmore, 1974; and "Canadian Reference Female Student"; Carter, 1982).

3.5 STATISTICAL TREATMENT

The statistical treatment of these data, i.e. peak torque and angle of peak torque, involved application of Student's *t*-tests to examine the significance of any differences noted between the means of data from:

1. right limb and left limb, and
2. preferred limb and non-preferred limb.

Normative data for each of the limb movement measurements were compiled into tables of percentile rankings where the mean is the 50th percentile. The normal percentage difference in peak torque production capacity of right to left, and preferred to non-preferred limbs were presented in the form of histograms for each limb action measured. Imbalance was indicated by the percentage difference (left of right, and non-preferred of preferred) one and two standard deviations below the mean. Finally, the mean agonist-to-antagonist ratios for 60°/second of movement were presented to show the range of normal ratios, and to give indication of ratios at two and three standard deviations above and below the mean.

4. RESULTS AND DISCUSSION

4.1 RESULTS

The physical characteristics of the university aged female in this study are summarized in Table 4.1.

The female in this study is taller (165.37 vs 158.03 cms) and heavier (60.45 vs 56.75 kg), has a higher lean body weight (45.13 vs 41.43 kg) and lower percent body fat (25.45 vs 27.0 %) than the "Reference Woman", previously described by Behnke and Wilmore (1974). It should be noted, however, that these differences were not statistically significant ($p<0.05$). The female in this study is heavier (60.45 vs 57.5) than the "Canadian Reference Female Student", as described by Carter (1982). Other physical characteristics are very similar to the Canadian Reference Female Student (age: 20.6 vs 20.99 years, height: 165.7 vs 165.37 cms.), suggesting that the female in this study is a good representation of the normal university aged female.

When right and left limbs were compared, significant differences ($p<0.01$) were noted in peak torque production for all limb movements measured, with the exception of shoulder flexion and elbow extension. The same was also true when preferred and non-preferred limbs were compared. Tables 4.2, 4.5 and 4.8 provide a summary of the peak torque production values for each of the three paired limb movements measured, for right and left, and preferred and non-preferred limbs. Since these differences exist; it is appropriate to present the normative (percentile rankings) data for each limb and limb movement seperately (Tables 4.3, 4.4, 4.6, 4.7, 4.9, 4.10).

Figures 4.1 to 4.6 illustrate the normal relationships in university aged females between the movement mechanisms (shoulder flexion and extension, internal and external rotation, and elbow flexion and extension) of right to left, and preferred to non-preferred arm. Goslin and Charteris (1979), have proposed that contra-lateral limb balance is within "normal limits" up to a maximum of 10% to 15% difference in peak torque production capacity. They further

Table 4.1 PHYSICAL CHARACTERISTICS OF FEMALE UNIVERSITY STUDENTS

CHARACTERISTIC	MEAN	S.D.	RANGE
Height (cm)	165.37	6.43	147.0 - 177.5
Weight (kg)	60.45	6.55	46.5 - 79.5
Age (yr)	20.99	1.19	18.19 - 22.99
% Fat	25.45	4.78	15.7 - 36.1
LBW	45.13	4.78	33.65 - 57.72

n = 74

Table 4.2 MEAN MAXIMAL ISOKINETIC SHOULDER FLEXION/EXTENSION PEAK TORQUE AND RATIO TEST NORMS FOR UNIVERSITY AGED FEMALES AT 60°/SECOND (n = 74)

LIMB	MOVEMENT	PEAK TORQUE (N.m) ± S.D.	RATIO (Fl:Ex)
Right	Flexion	36.3 ± 6.5	1:1.25 (80%)
	Extension	‡45.4 ± 8.2	
Left	Flexion	35.7 ± 6.1	1:1.21 (82%)
	Extension	‡42.5 ± 7.9	
Preferred	Flexion	36.5 ± 6.4	1:1.25 (80%)
	Extension	‡45.5 ± 7.7	
Non-preferred	Flexion	35.5 ± 6.2	1:1.21 (82%)
	Extension	‡43.2 ± 8.4	

‡ *Significant difference ($p<0.01$)*

Table 4.3 PERCENTILE RANKINGS FOR MAXIMAL ISOKINETIC SHOULDER FLEXION PEAK TORQUE TEST NORMS FOR UNIVERSITY AGED FEMALES AT 60°/SECOND (n = 74)

PERCENTILE	PEAK TORQUE (N.m)			
	Right	Left	Preferred	Non-preferred
100	52.8	48.8	52.8	50.1
95	49.2	47.8	46.8	48.8
90	44.7	44.7	44.7	44.7
85	42.0	43.0	43.0	40.7
80	40.7	40.7	40.7	40.7
75	40.7	40.7	40.7	40.7
70	40.0	39.3	40.7	39.3
65	37.9	37.6	38.9	36.6
60	37.9	36.6	37.9	36.6
55	36.6	36.6	36.6	35.2
50	36.6	35.2	36.6	34.6
45	35.2	33.9	35.2	33.9
40	33.9	33.9	35.2	33.9
35	33.9	32.5	33.9	32.5
30	33.2	32.5	33.2	31.8
25	32.2	31.2	33.2	31.2
20	31.2	31.2	31.2	31.2
15	28.8	29.8	28.8	29.8
10	27.1	28.5	28.5	28.5
5	25.7	25.4	25.7	25.4
0	21.7	23.0	21.7	23.0

Table 4.4 PERCENTILE RANKINGS FOR MAXIMAL ISOKINETIC SHOULDER EXTENSION PEAK TORQUE TEST NORMS FOR UNIVERSITY AGED FEMALES AT 60°/SECOND (n = 74)

	PEAK TORQUE (N.m)			
PERCENTILE	Right	Left	Preferred	Non-preferred
100	69.1	66.4	61.0	69.1
95	58.6	58.6	58.6	58.6
90	55.6	55.6	55.6	54.9
85	54.2	50.1	54.2	51.2
80	52.8	48.8	52.8	48.8
75	51.8	48.8	51.8	48.8
70	50.1	47.4	50.1	47.4
65	48.4	44.7	48.8	44.7
60	47.4	44.7	47.4	44.7
55	46.1	43.7	46.1	43.4
50	46.1	43.4	46.1	42.0
45	44.4	42.0	44.7	40.7
40	42.0	40.7	43.4	39.3
35	[illegible]	39.3	42.0	39.3
30	40.7	39.3	40.7	37.9
25	39.3	37.6	40.3	36.6
20	37.9	36.6	39.3	36.6
15	36.6	35.2	36.9	34.2
10	35.2	33.9	35.2	33.9
5	33.2	31.5	33.5	30.5
0	27.1	28.5	27.1	28.5

Table 4.5 MEAN MAXIMAL ISOKINETIC SHOULDER INTERNAL/EXTERNAL ROTATION PEAK TORQUE AND RATIO TEST NORMS FOR UNIVERSITY AGED FEMALES AT 60°/SECOND (n = 74)

LIMB	MOVEMENT	PEAK TORQUE (N.m) ± S.D.	RATIO (Ex:In)
Right	Int. Rot.	‡19.8 ± 5.2	1:1.12 (88%)
	Ext. Rot.	‡17.7 ± 4.2	
Left	Int. Rot.	‡18.4 ± 4.7	1:1.12 (88%)
	Ext. Rot.	‡16.5 ± 4.0	
Preferred	Int. Rot.	‡19.8 ± 5.1	1:1.10 (90%)
	Ext. Rot.	‡17.9 ± 4.1	
Non-preferred	Int. Rot.	‡18.4 ± 4.8	1:1.13 (88%)
	Ext. Rot.	‡16.2 ± 4.0	

‡ *Significant difference ($p<0.01$)*

Table 4.6 PERCENTILE RANKINGS FOR MAXIMAL ISOKINETIC SHOULDER INTERNAL ROTATION PEAK TORQUE TEST NORMS FOR UNIVERSITY AGED FEMALES AT 60°/SECOND (n = 74)

	PEAK TORQUE (N.m)			
PERCENTILE	**Right**	**Left**	**Preferred**	**Non-preferred**
100	33.9	28.5	33.9	28.5
95	28.5	26.1	28.5	26.1
90	26.4	24.4	26.4	24.4
85	24.4	24.4	24.4	24.4
80	24.4	23.0	24.4	23.0
75	23.0	23.0	23.0	23.0
70	23.0	20.3	23.0	20.3
65	23.0	20.3	23.0	20.3
60	21.7	20.3	21.7	20.3
55	21.7	18.9	20.7	18.9
50	20.3	17.6	20.3	17.6
45	18.9	17.6	18.9	17.6
40	17.6	16.2	17.6	16.2
35	16.2	16.2	16.2	16.2
30	16.2	16.2	16.2	15.6
25	16.2	14.9	16.2	14.6
20	16.2	13.5	16.2	13.5
15	13.9	13.5	14.9	13.5
10	13.5	12.2	13.5	12.2
5	9.5	11.5	9.5	11.5
0	8.1	6.8	8.1	6.8

Table 4.7 PERCENTILE RANKINGS FOR MAXIMAL ISOKINETIC SHOULDER EXTERNAL ROTATION PEAK TORQUE TEST NORMS FOR UNIVERSITY AGED FEMALES AT 60°/SECOND (n = 74)

	PEAK TORQUE (N.m)			
PERCENTILE	**Right**	**Left**	**Preferred**	**Non-preferred**
100	32.5	27.1	32.5	27.1
95	24.7	24.4	24.7	24.4
90	23.0	23.0	23.0	21.7
85	22.7	21.7	23.0	20.3
80	21.7	20.3	21.7	18.9
75	20.3	18.9	20.3	18.9
70	18.9	17.6	19.6	17.6
65	18.6	17.3	18.9	16.2
60	17.6	16.2	17.6	16.2
55	17.6	16.2	17.6	16.2
50	16.2	16.2	16.2	16.2
45	16.2	14.9	16.2	14.9
40	16.2	14.9	16.2	14.9
35	16.2	14.9	16.2	14.9
30	16.2	14.9	16.2	14.9
25	14.9	14.9	14.9	13.5
20	13.5	13.5	14.9	12.2
15	13.5	12.2	13.5	12.2
10	12.9	12.2	13.5	12.2
5	12.2	10.5	12.2	9.5
0	8.1	6.8	12.2	6.8

Table 4.8 MEAN MAXIMAL ISOKINETIC ELBOW FLEXION/EXTENSION PEAK TORQUE AND RATIO TEST NORMS FOR UNIVERSITY AGED FEMALES AT 60°/SECOND (n = 74)

LIMB	MOVEMENT	PEAK TORQUE (N.m) ± S.D.	RATIO (Fl:Ex)
Right	Flexion	‡24.8 ± 5.4	1:1.20 (83%)
	Extension	30.0 ± 6.9	
Left	Flexion	‡23.3 ± [illegible]	1:1.26 (79%)
	Extension	29.4 ± [illegible]	
Preferred	Flexion	‡25.1 ± 5.5	1:1.19 (84%)
	Extension	29.9 ± 6.4	
Non-preferred	Flexion	‡23.1 ± 5.1	1:1.27 (78%)
	Extension	29.4 ± 6.8	

‡ *Significant difference ($p<0.01$)*

Table 4.9 PERCENTILE RANKINGS FOR MAXIMAL ISOKINETIC ELBOW FLEXION PEAK TORQUE TEST NORMS FOR UNIVERSITY AGED FEMALES AT 60°/SECOND (n = 74)

PERCENTILE	PEAK TORQUE (N.m) Right	Left	Preferred	Non-preferred
100	40.7	35.2	40.7	35.2
95	32.8	33.9	33.9	32.8
90	32.5	31.2	32.5	31.2
85	31.2	29.5	31.2	28.5
80	29.8	28.5	29.8	27.1
75	28.[illegible]	26.1	28.8	25.7
70	27.1	25.7	28.5	25.1
65	27.1	24.4	27.1	24.4
60	25.7	24.4	27.1	24.4
55	25.7	23.0	25.7	23.0
50	24.4	23.0	25.1	23.0
45	24.4	23.0	24.4	23.0
40	24.4	21.7	24.4	21.7
35	23.0	20.7	23.0	20.3
30	21.7	20.3	21.7	20.3
25	20.3	20.0	20.3	20.3
20	20.3	18.9	20.3	18.9
15	19.3	16.6	18.9	17.6
10	16.9	16.2	16.2	16.2
5	16.2	14.9	16.2	15.9
0	10.8	14.9	14.9	10.8

Table 4.10 PERCENTILE RANKINGS FOR MAXIMAL ISOKINETIC ELBOW EXTENSION PEAK TORQUE TEST NORMS FOR UNIVERSITY AGED FEMALES AT 60°/SECOND (n = 74)

	PEAK TORQUE (N.m)			
PERCENTILE	**Right**	**Left**	**Preferred**	**Non-preferred**
100	56.9	48.8	48.8	56.9
95	43.4	42.0	43.4	42.4
90	39.3	36.6	38.6	36.6
85	37.6	33.9	37.6	33.9
80	33.9	32.5	33.9	32.5
75	32.5	32.5	32.5	32.5
70	32.5	32.5	32.5	31.8
65	32.2	31.2	32.5	31.2
60	31.2	31.2	31.2	31.2
55	29.8	31.2	31.2	30.2
50	28.5	29.8	29.1	29.1
45	28.5	28.5	28.5	28.5
40	27.1	27.1	27.1	27.1
35	27.1	25.7	27.1	25.7
30	26.4	25.7	25.7	25.7
25	25.7	24.4	25.7	24.4
20	24.4	24.4	24.4	24.4
15	23.0	23.0	23.0	23.0
10	22.4	22.4	22.4	22.4
5	20.0	18.6	20.3	18.6
0	16.2	17.6	16.2	17.6

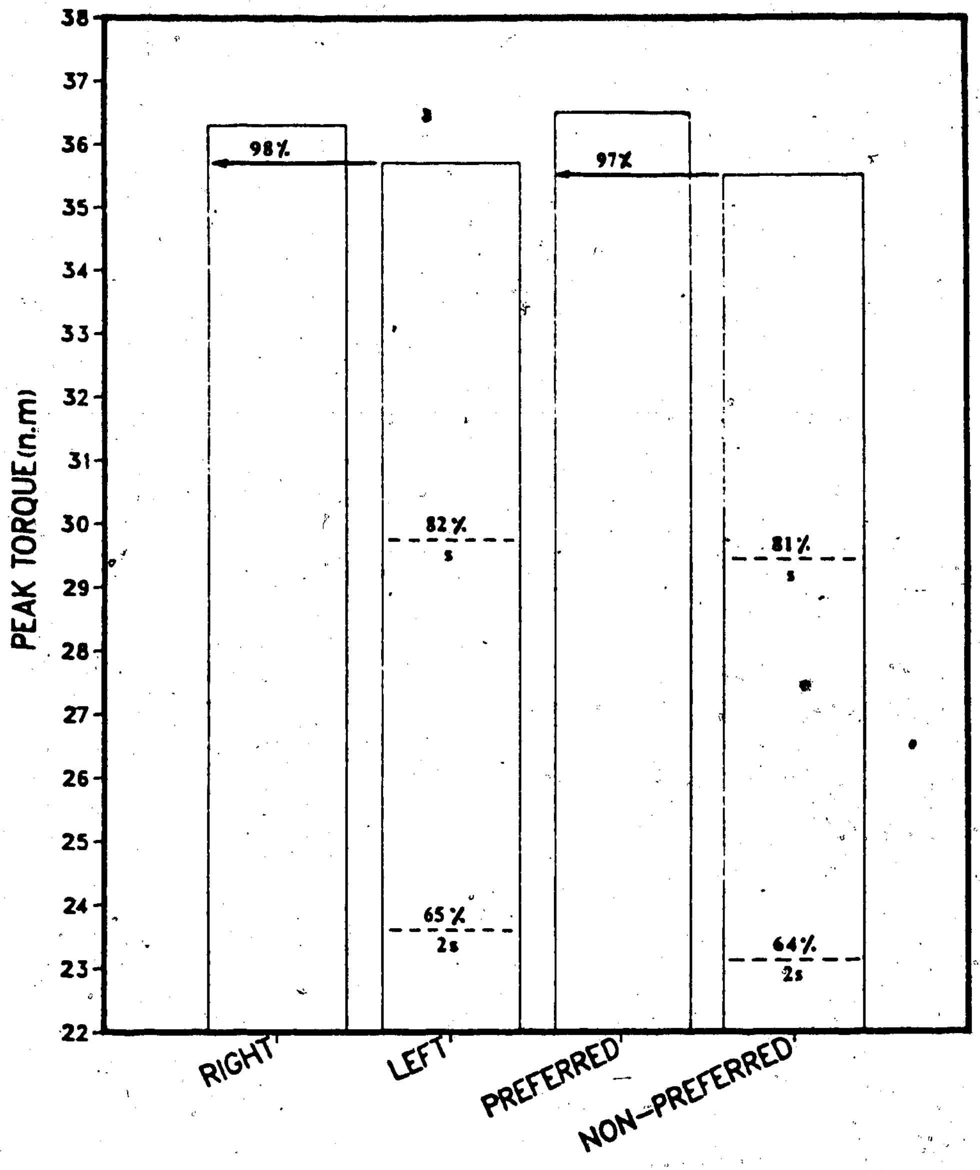

Figure 4.1 Normal relationships in university aged females between the shoulder flexor peak torque production capacity; the percentage difference of right to left, and preferred to non-preferred arm.

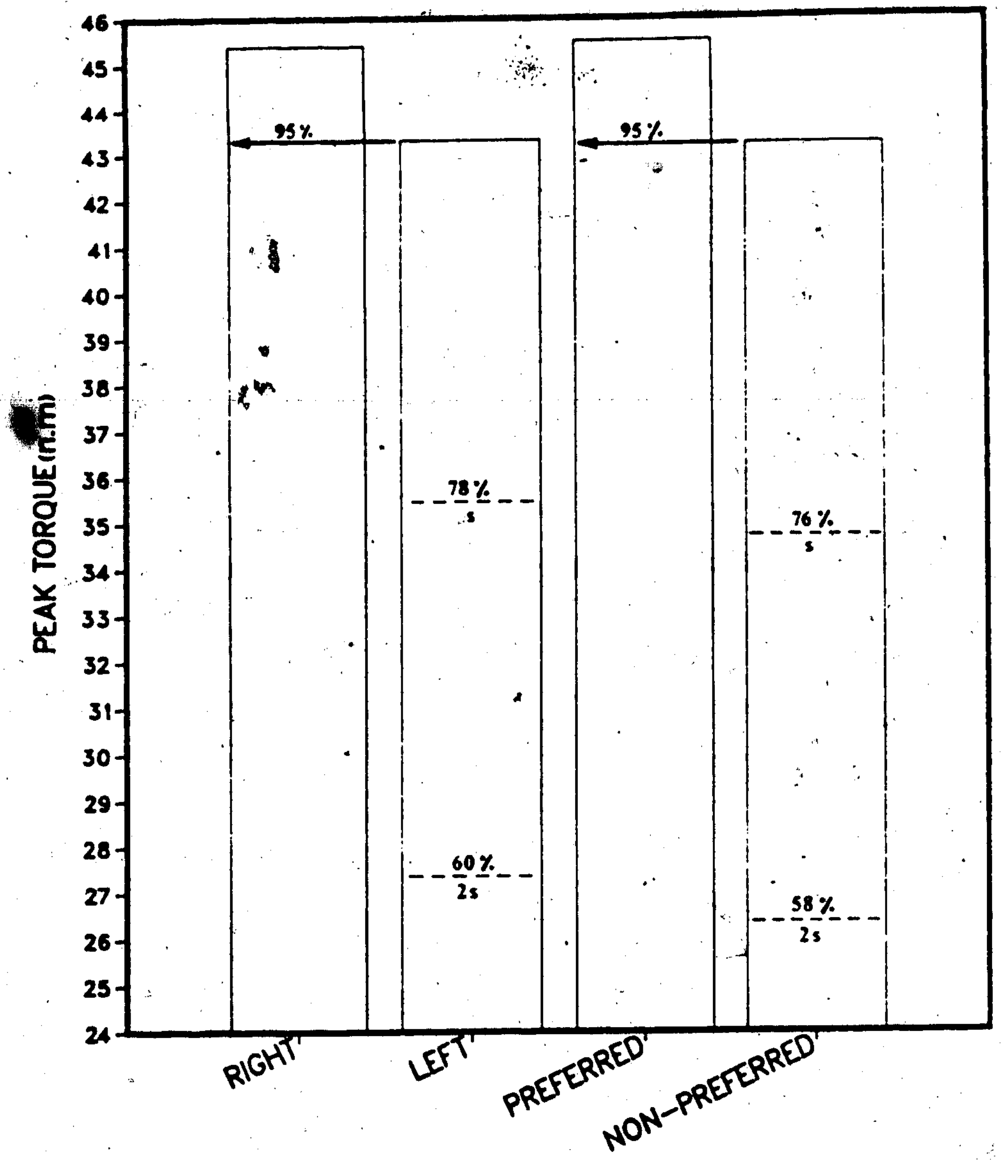

Figure 4.2 Normal relationships in university aged females between the shoulder extensor peak torque production capacity; the percentage difference of right to left, and preferred to non-preferred arm.

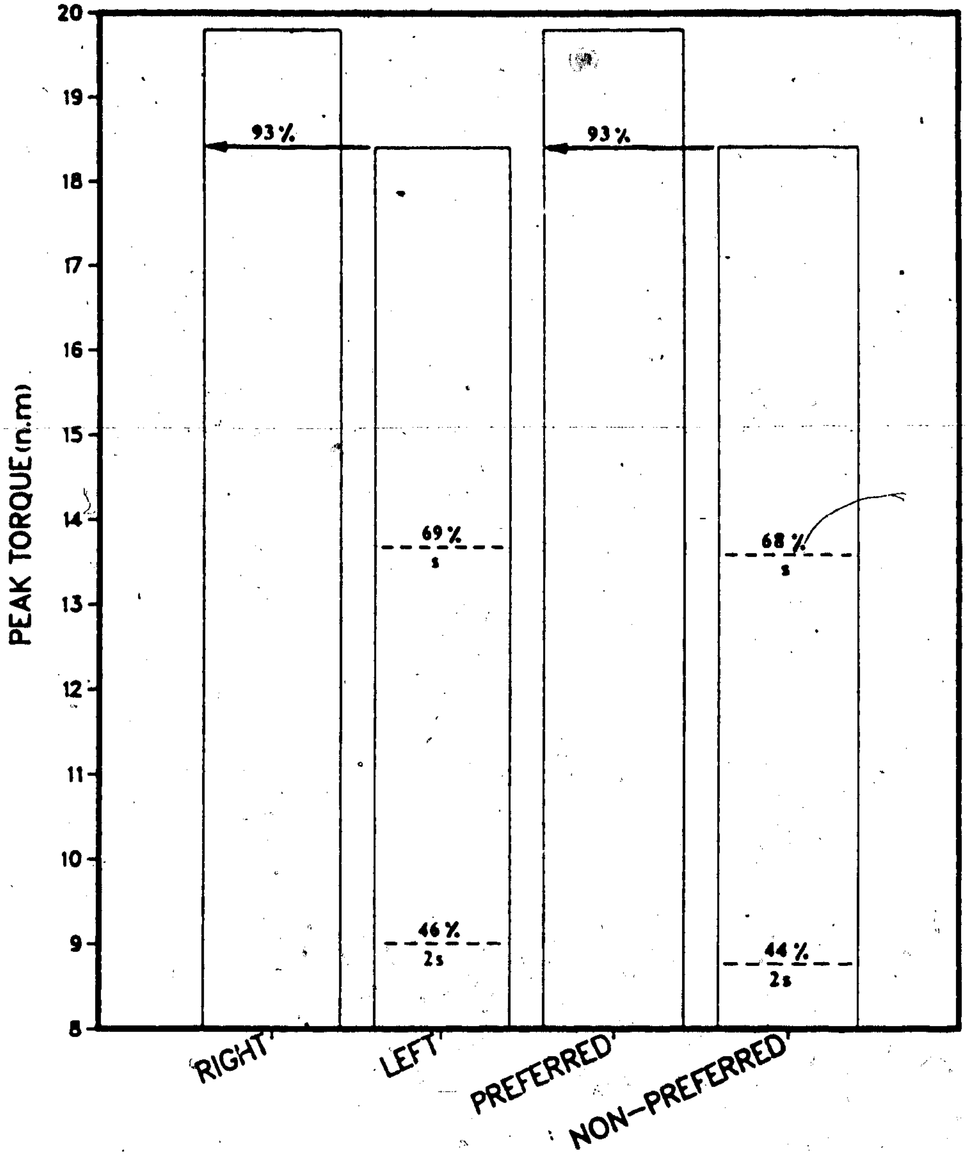

Figure 4.3 Normal relationships in university aged females between the shoulder internal rotator peak torque production capacity; the percentage difference of right to left, and preferred to non-preferred arm.

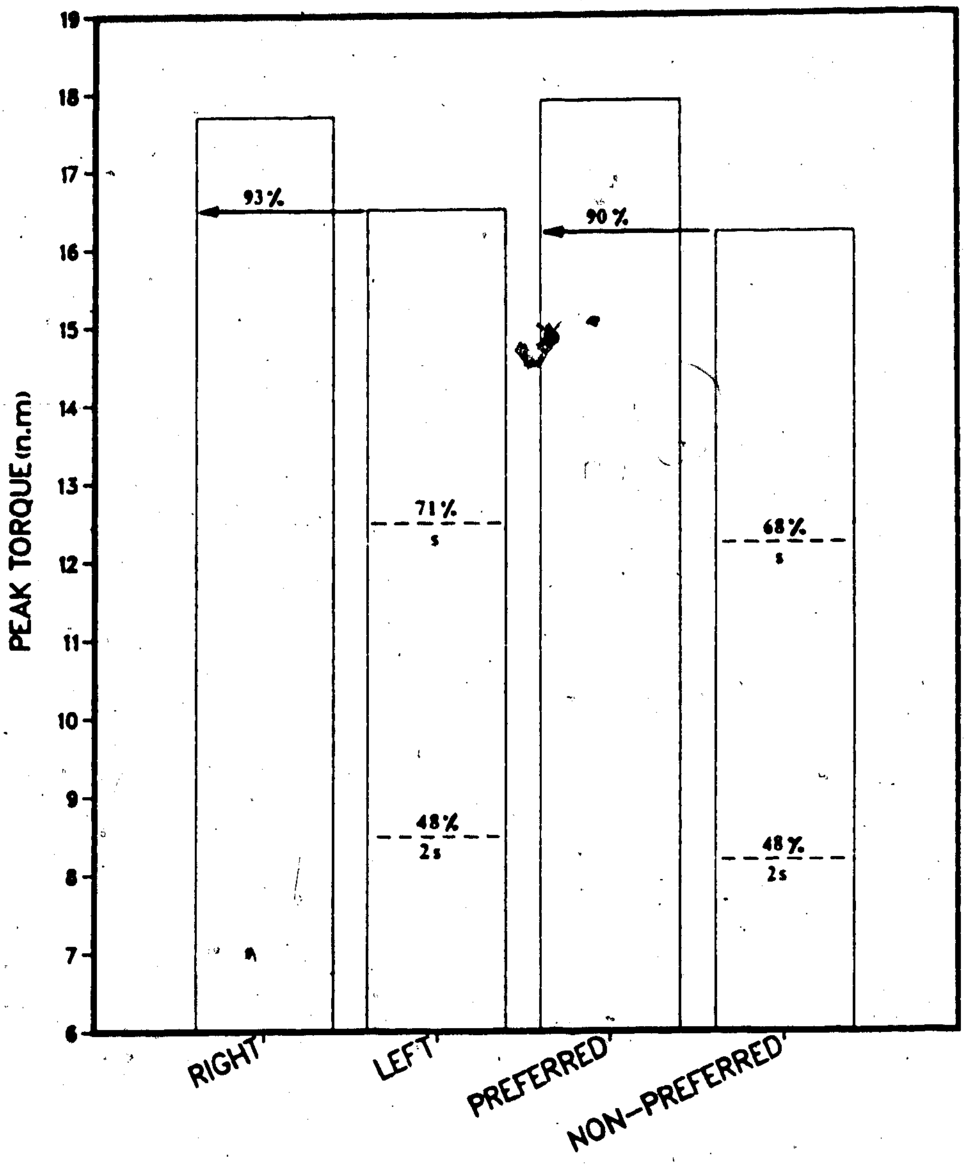

Figure 4.4 Normal relationships in university aged females between the shoulder external rotator peak torque production capacity, the percentage difference of right to left, and preferred to non-preferred arm.

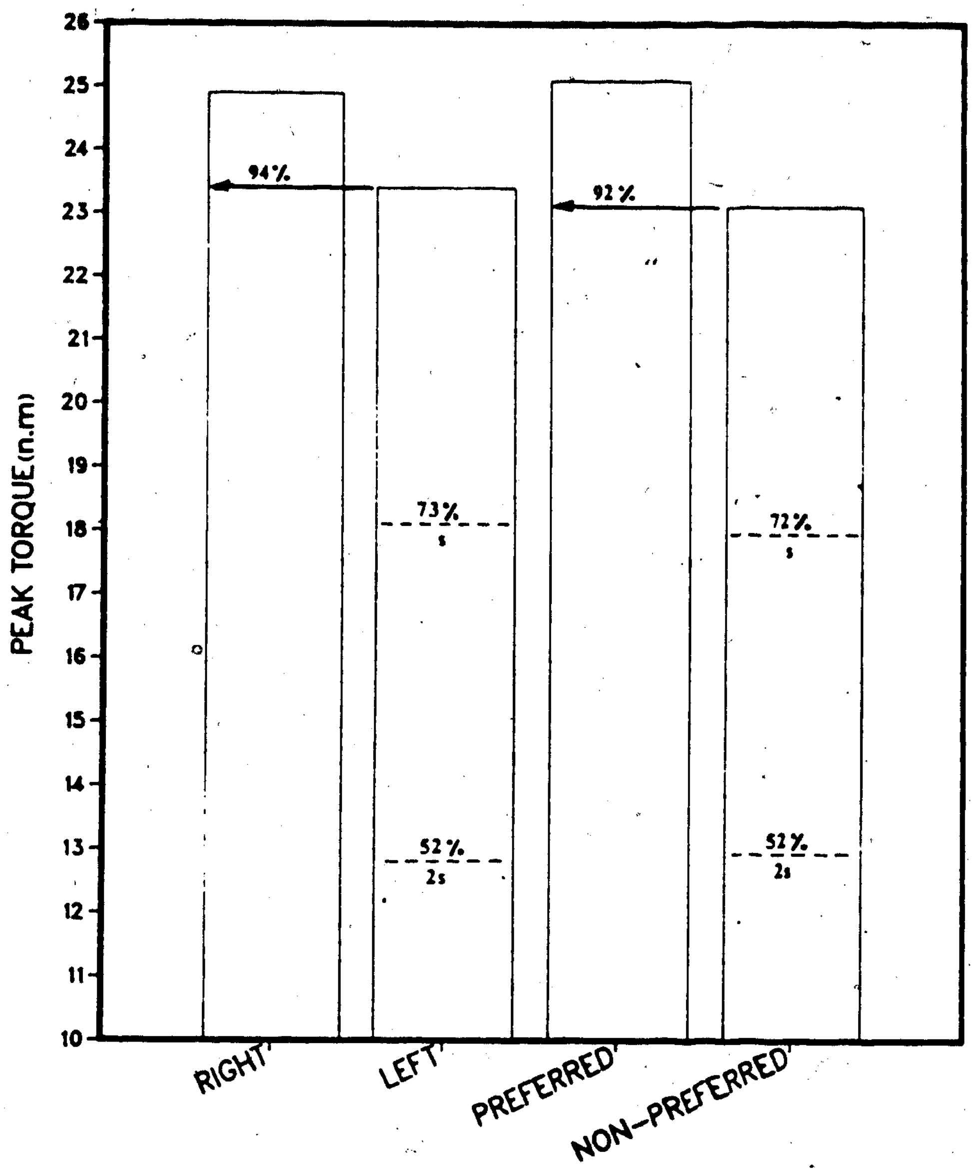

Figure 4.5 Normal relationships in university aged females between the elbow flexor peak torque production capacity; the percentage difference of right to left, and preferred to non-preferred arm.

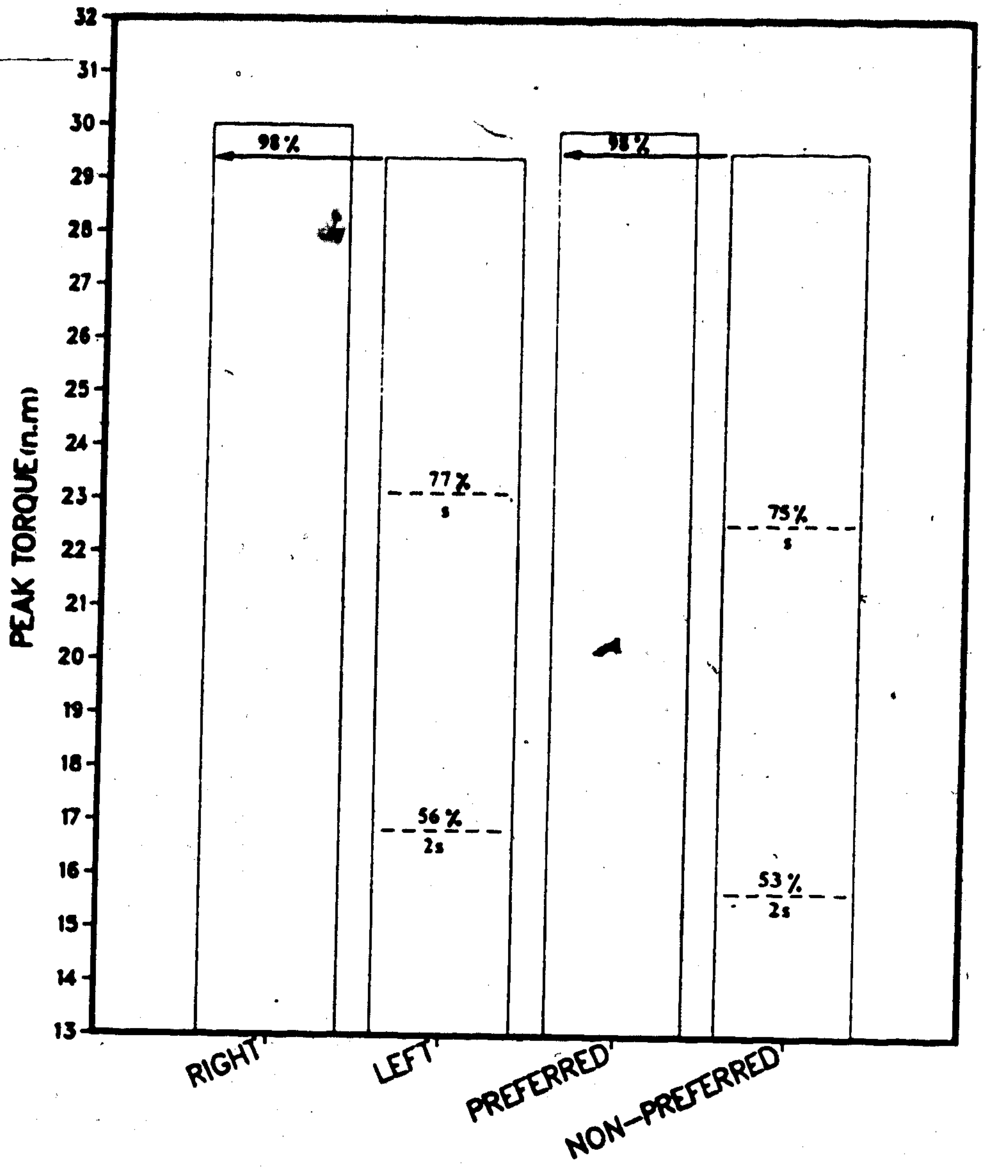

Figure 4.6 Normal relationships in university-aged females between the elbow extensor peak torque production capacity; the percentage difference of right to left, and preferred to non-preferred arm.

suggest that in lower extremity comparisons imbalance becomes a problem, in terms of risk of injury, at one standard deviation below the mean. The normal upper extremity contra-lateral relationships revealed in this study have been presented using Goslin and Charteris' criterion measure of one standard deviation below the mean as an indication of imbalance. The percentage (left of right, and non-preferred of preferred) at two standard deviations is also presented for descriptive purposes.

Figures 4.7, 4.8 and 4.9 display the mean agonist-to-antagonist ratios for the three paired limb movements measured. They are presented in a manner calculated to emphasize the clinical importance of normal agonist-to-antagonist torque producing capabilities of university aged females at 60°/second for shoulder flexion/extension, internal/external rotation, and elbow flexion/extension.

Finally, Tables 4.5, [illegible] and 4.7 summarize the angles at which peak torque was achieved in each of the paired limb movements. When right and left limbs were compared, significant differences were noted between the angles at which peak torque was achieved in the shoulder flexion ($p<0.05$), and the elbow extension ($p<0.01$) measurements. When preferred and non-preferred limbs were compared, significant differences were apparent in the shoulder flexion ($p<0.05$), and the shoulder internal rotation ($p<0.01$) measurements. All other comparisons revealed no significant differences ($p\leq0.05$).

4.2 DISCUSSION

Based upon the results of the statistical analyses, rejection of all null hypotheses (Chapter 1) is warranted at the $p<0.05$ level of significance.

The first null hypothesis, stating that the means of data for peak torque from right and left limb were not significantly different from each other, was rejected on the basis of the differences displayed ($p<0.01$) in all limb movements measured, with the exception of shoulder flexion and elbow extension. Similarly, significant differences ($p<0.01$) in all limb movements measured, with the exception of shoulder flexion and elbow extension, result in the

Table 4.11 ANGLE AT PEAK TORQUE FOR SHOULDER FLEXION/EXTENSION TESTS FOR UNIVERSITY AGED FEMALES AT 60°/SECOND (n = 74)

LIMB	MOVEMENT	ANGLE OF PEAK TORQUE (degrees) ± S.D.
Right	Flexion	†132.8 ± 14.4
	Extension	48.0 ± 17.6
Left	Flexion	†127.4 ± 16.9
	Extension	45.4 ± 18.1
Preferred	Flexion	†132.9 ± 13.9
	Extension	47.9 ± 17.0
Non-preferred	Flexion	†127.3 ± 17.3
	Extension	45.6 ± 18.7

† *Significant difference (P<0.05)*

Table 4.12 ANGLE AT PEAK TORQUE FOR SHOULDER INTERNAL/EXTERNAL ROTATION TESTS FOR UNIVERSITY AGED FEMALES AT 60°/SECOND (n = 74)

LIMB	MOVEMENT	ANGLE OF PEAK TORQUE (degrees) ± S.D.
Right	Int. Rot.	39.0 ± 20.1
	Ext. Rot.	53.7 ± 26.6
Left	Int. Rot.	34.7 ± 19.4
	Ext. rot.	54.6 ± 23.6
Preferred	Int. Rot.	‡40.9 ± 19.4
	Ext. Rot.	52.5 ± 26.1
Non-preferred	Int. Rot.	‡32.8 ± 19.5
	Ext. Rot.	55.7 ± 24.0

‡ *Significant difference ($p<0.01$)*

Table 4.13 ANGLE AT PEAK TORQUE FOR ELBOW FLEXION/EXTENSION TESTS FOR UNIVERSITY AGED FEMALES AT 60°/SECOND (n = 74)

LIMB	MOVEMENT	ANGLE OF PEAK TORQUE (degrees) ± S.D.
Right	Flexion	112.9 ± 15.6
	Extension	‡66.8 ± 14.8
Left	Flexion	113.2 ± 16.0
	Extension	‡59.6 ± 17.2
Preferred	Flexion	113.1 ± 14.6
	Extension	65.0 ± 14.8
Non-preferred	Flexion	113.1 ± 16.9
	Extension	61.4 ± 17.8

‡ *Significant difference (P<0.01)*

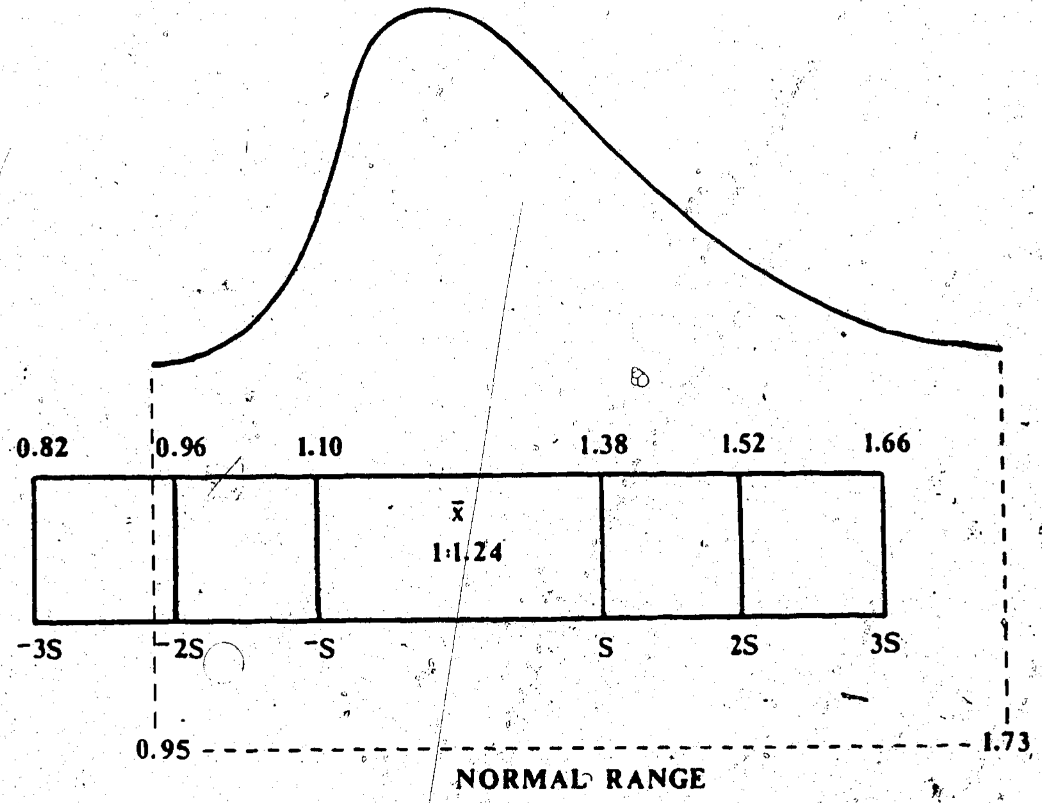

Figure 4.7 The mean shoulder flexor-to-extensor ratio (flexor represented as unity) for 60°/sec. of movement; to show the extent of the normal range of agonist-to-antagonist balance in university aged females.

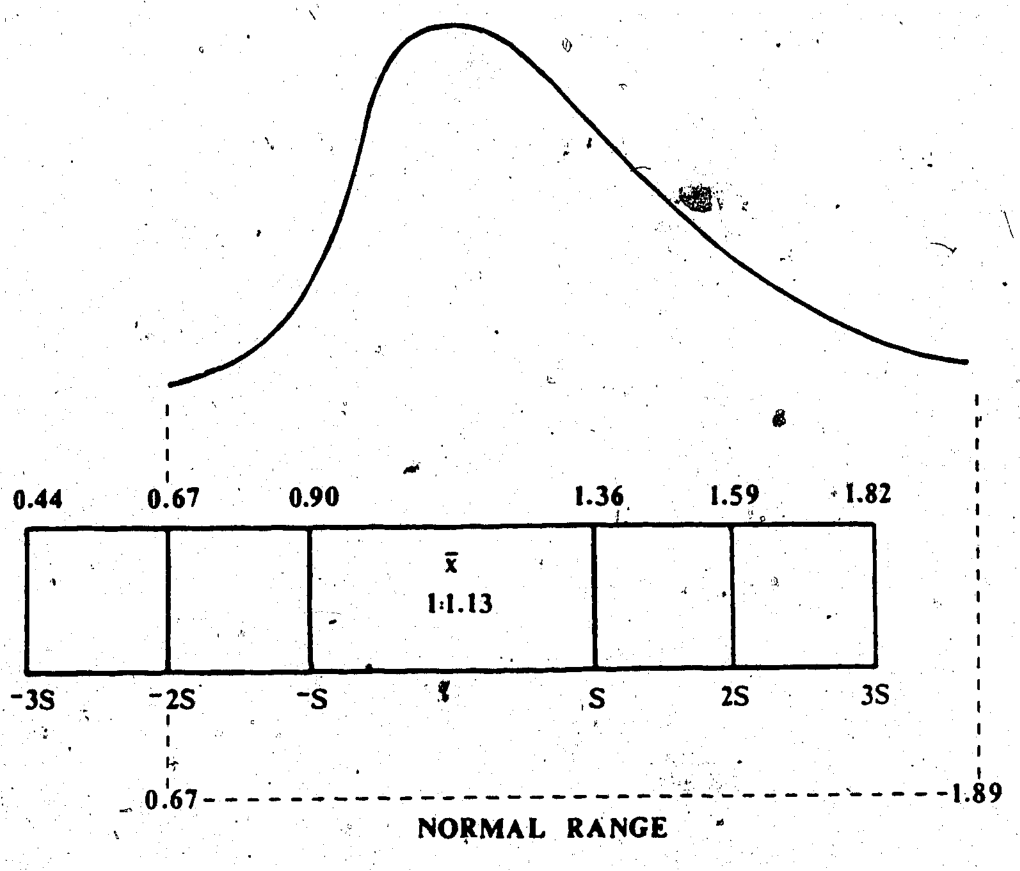

Figure 4.8 The mean shoulder internal-to-external rotator ratio (external rotator represented as unity) for 60°/sec. of movement; to show the extent of the normal range of the agonist-to-antagonist balance in university aged females.

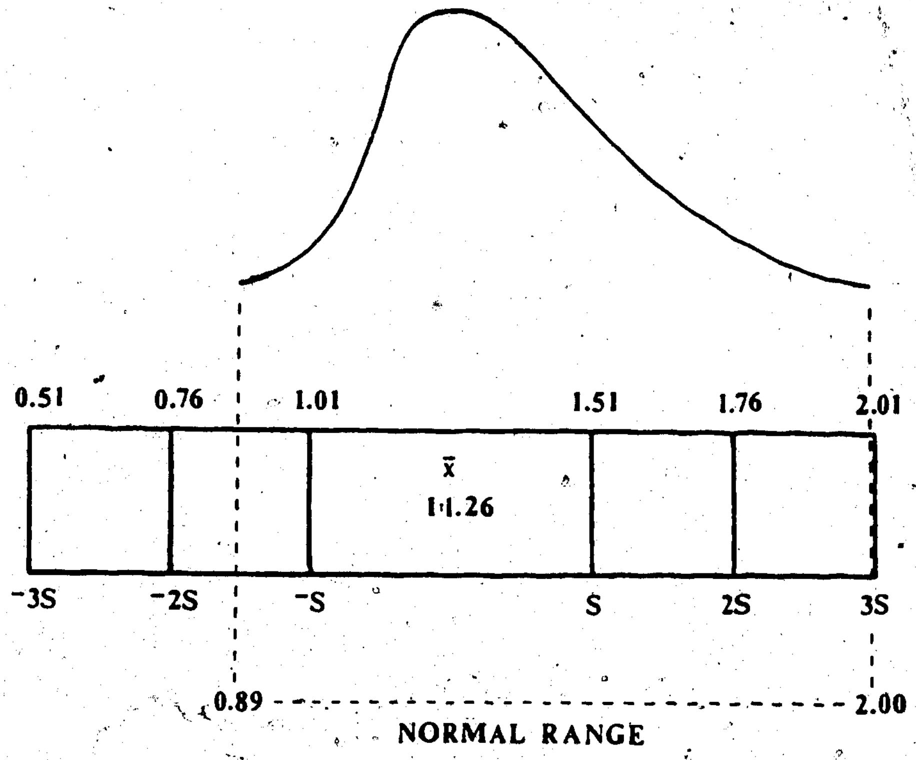

Figure 4.9 The mean elbow flexor-to-extensor ratio (flexor represented as unity) for 60°/sec. of movement; to show the extent of the normal range of the agonist-to-antagonist balance in university aged females.

rejection of the second null hypothesis, stating that the means of data for peak torque from preferred and non-preferred limb were not significantly different from each other.

The two remaining null hypotheses, stating that the means of data for angle of peak torque from right and left limb, and preferred and non-preferred limb, were not significantly different from each other, must also be rejected. The basis of this rejection is the significant differences displayed in shoulder flexion, $p<0.05$ (right to left, and preferred to non-preferred limb); elbow extension, $p<0.01$ (right to left limb); and shoulder internal rotation, $p<0.01$ (preferred to non-preferred limb).

The results of the present study indicate the normal peak torque producing capabilities for university aged females for each of the following limb movements at 60°/second:

1. Shoulder flexion/extension,
2. Shoulder internal/external rotation, and
3. Elbow flexion/extension.

Because of the paucity of literature in upper extremity isokinetic normative data, comparisons are difficult. However, the findings of this study can be considered in light of the work of Davies, *et al* (1980), who evaluated the muscular capabilities of the U.S. National Cross Country Ski Team. He evaluated the female members of the Team at a test velocity of 45°/second and reported the following peak torque values: 1) Shoulder flexion - 22.95 ft.lbs, 2) shoulder extension - 47.70 ft.lbs, 3) elbow flexion - 17.50 ft.lbs, and 4) elbow extension - 27.10 ft.lbs..

Comparisons are difficult because of the different test velocities (45 vs 60°/sec.), and the fact the Davies' subjects ~~are~~ elite athletes and would likely be expected to exhibit greater torque producing capabilities than the normal female. However, the females in the present study exhibited higher peak torque values in shoulder flexion measurements (26.9 vs 22.95 ft.lbs). The skiers were stronger in all other limb movements measured; probably as a result of the specific upper extremity work requirements of cross country skiing. Of most remark, is the high peak torque value achieved by the skiers in the shoulder extension test (47.70 ft.lbs), in relation to the shoulder flexion test (22.95 ft.lbs). This most likely results from the specific poling action, which requires muscular effort during shoulder extension and back extension as the skier seeks to push the body forward. Perhaps the lower "than normal" shoulder flexion scores are a result of the specific extensor mechanism requirements, and the fact that the recovery phase during ski poling is essentially a passive action and relies on elbow flexion and arm momentum, rather than shoulder flexor strength.

The reasons for the significant differences ($p<0.01$) noted in all limb movements measured, between right and left, and preferred and non-preferred limbs in peak torque production capacity, with the exception of shoulder flexion and elbow extension are unclear. It is purely speculation, but it may be said that both of these actions are uncommon neuromuscular movement patterns. Consequently, neither limb has developed superiority in peak torque production capacity. The remaining limb movements are more commonly used; neuromuscular patterns have been developed, and the limb most commonly used for that particular movement pattern has developed a superiority in peak torque production capacity over the contra-lateral limb. As stated, this is purely speculation, and requires formal research in order to verify or negate the argument.

The contra-lateral limb balance that was displayed in all three paired limb movements in this study were within the "normal limits" suggested by other researchers. As previously stated, a contra-lateral limb difference of 10% to 15% is considered to be normal and acceptable for injury-free functioning (Goslin and Charteris, 1979; Davies, 1982). However, beyond this range, the possibility of injury may be higher, and clinicians and therapists should seek to strengthen the weaker limb to the level of the stronger one. This may be particularly true where both arms are used for activity or vocation, for example, gymnasts, hockey players, or golfers. Further research is necessary to correlate the incidence of upper extremity injury and contra-lateral limb imbalance in these types of activity and vocation.

Previous research in lower extremity studies (Osternig, *et al* 1977; Smith, *et al* 1981) has demonstrated the speed-specific ratio of flexor-to-extensor mechanisms. The results of this study describe the normal upper extremity agonist-to-antagonist ratios of university aged females at 60°/second. It is the feeling of this author, and as yet unsubstantiated, that upper extremity agonist-to-antagonist ratios will also display speed-specific relationships. Further investigation is necessary, particularly at the faster test velocities (>60°/sec.) in order to substantiate this argument. In addition, it is the uncorroborated contention of this author, that a relationship may exist between agonist-to-antagonist deviation from normal equilibrium, and subsequent incidence of injury, particularly those involved in competitive sports.

The author of this study proposes that three goals exist in preventative training, and rehabilitation programs:

1. The maintenace or return of normal contra-lateral limb balance.
2. The maintenance or return of normal agonist-to-antagonist muscle balance, and
3. the maintenance or return of average (50th percentile) normal peak torque production capabilities.

The author contends that rehabilitation of the upper extremity is not complete until the following normal ratios at 60°/second have been approximated:

1. Shoulder flexor-to-extensor ratio of 1:1.24 (Fig. 4.7) and the weaker extensors not less than 76% (Fig. 4.2) as strong as those of the contra-lateral limb.
2. Shoulder internal-to-external rotator ratio of 1:1.13 (Fig. 4.8) and the weaker external rotators not less than 68% (Fig. 4.4) as strong as those of the contra-lateral limb.
3. Elbow flexor-to-extensor ratio of 1:1.26 (Fig. 4.9) and the weaker flexors not less than 72% (Fig. 4.5) as strong as those of the contra-lateral limb.

In addition to contra-lateral, and agonist-to-antagonist balance approximating normal values, the third goal of training and rehabilitation programs must also approximate normal average values; that being peak t[illegible]on capacity. Referral to the percentile ranking tables for the appropriate limb m[illegible]4.3, 4.4, 4.6, 4.7, 4.9, 4.10) will provide the clinician or therapist with app[illegible] goals for training or rehabilitation of the upper extremity in university aged females.

The normal values for angles at which peak torque was achieved have been presented (Tables 4.11, 4.12 and 4.13). In all but three limb movements, no significant differences were noted between contra-lateral limbs. The reasons for the significant differences in angle of peak torque for shoulder flexion (right to left and preferred to non-preferred limb); elbow extension (right to left limb); and shoulder internal rotation (preferred to non-preferred limb) remain unclear, but may, in part be due to slight deviations in subject limb positioning as a result of errors in goniometry. Kottke, *et al* (1982), report that even the most experienced therapist must expect differences in the order of ±5° when measuring limb position with a standard goniometer. Further investigation is necessary to determine whether the significant differences reported in this study are real, or whether they are a result of goniometer measurement error.

Those that use isokinetic dynamometry as an evaluation technique, especially clinical practitioners, are well aware of the myriad of test positions and test velocities that may be employed in the assessment of muscular potential. The norms presented here represent only a small portion of the possibilities. In order to establish normative data covering the various combinations of test position, velocity and joint tested, further study is necessary.

Another factor not accounted for in the present normative information is the degenerative effects of aging on muscular tension development. This decrement is estimated to be 20% between the ages of 25 and 60. The largest portion of this decrement occurs from age 45 (Åstrand and Rodahl, 1977). Although this mean strength decrease information can be applied to the present norms to obtain reasonable estimates of isokinetic potential in older subjects, it would seem appropriate to sample youth, middle-aged and older-adult populations to establish norms for these groups.

Finally, these norms have been developed using university aged females, and have been presented as absolute values. Perhaps converting these norms to relative scores (peak torque per kilogram lean body weight) would provide some measure by which males may be successfully rated. However, in the absence of preliminary comparative study to determine the differences, if any, in upper extremity strength between males and females when corrected for lean body weight, that step is mere conjecture. It is the belief of this author that firm normative isokinetic dynamometry data for upper extremity exercises for males would prove beneficial to clinicians, researchers and therapists alike.

5. SUMMARY AND CONCLUSIONS

5.1 PURPOSE

The purpose of this study was threefold: 1) to describe the positioning technique employed for isokinetic evaluation of shoulder flexion/extension, internal/external rotation, and elbow flexion/extension; 2) to present preliminary normative isokinetic dynamometry data for the test positions used in the assessment of the shoulder and elbow joints; and 3) to determine the significance of any difference noted between right and left limb, and preferred and non-preferred limb in peak torque production capacity, and angle of peak torque.

5.2 SUBJECTS

The sample consisted of seventy-four informed and consenting female volunteers between the ages of 18 and 22. Subjects were university residence students from various faculties, who were randomly selected, and were identified as being in good health and having no known pathologic condition nor previous surgery of either of the upper extremities.

5.3 PROCEDURES

The subjects were tested on a Cybex II isokinetic dynamometer at a speed of 60°/second and damp setting of 2. Peak muscle torque, and angle of peak torque were measured in three supine paired tests: 1) shoulder flexion/extension, 2) shoulder internal/external rotation, and 3) elbow flexion/extension.

Student's *t*-tests were applied to determine the significance of any differences noted between the means of data from right and left, and preferred and non-preferred limbs. Normative data was compiled into tables of percentile rankings for each limb movement. Histograms illustrating normal contra-lateral limb balance were presented with indications of imbalance at one and two standard deviations below the mean. Finally, the normal agonist-to-antagonist ratios were presented in a manner calculated to show the range of normal ratios, with indications of the ratio values at two and three standard deviations above and below the mean.

5.4 RESULTS

An examination of the data indicated significant differences ($p<0.01$) in peak torque production in all limb movements measured, with the exception of shoulder flexion and elbow extension.

Significant differneces were noted in the angles of peak torque for shoulder flexion ($p<0.05$) and elbow extension ($p<0.01$) between right and left limbs. As well, shoulder internal rotation revealed a significant difference ($p<0.01$) in angle of peak torque when preferred and non-preferred limbs were compared.

5.5 CONCLUSIONS

From the results of this study the following conclusions are warranted:

1. That significant differences exist between right and left limb, and preferred and non-preferred limb, in the upper extremity peak torque production capabilities of university aged females at a test velocity of 60°/second, with the exception of shoulder flexion and elbow extension movements.
2. That significant differences exist at a test velocity of 60°/second between right and left limb for the angle at which peak torque is achieved during shoulder flexion and elbow extension movements. And, that a significant difference exists at the same test velocity between the preferred and non-preferred limbs for the angle at which peak torque is achieved during shoulder internal rotation movement.

5.6 RECOMMENDATIONS

The results of the present study have established preliminary normative isokinetic dynamometry data for three upper extremity movements in university aged females at a test velocity of 60°/second. The results are intended for use in clinical settings where, to date, very little information has been available to assist clinicians and therapists in the tasks of preventative strength training and rehabilitation. The following recommendations are presented in hopes that further inquiry will be stimulated in this area.

1. Replication of the present study to increase the size of the data base, and to substantiate the significant differences noted in peak torque production and angle of peak torque.
2. The development of normative isokinetic dynamometry data which includes measurements of muscular strength, power, endurance, contra-lateral and agonist-to-antagonist ratios, for different age-groups by sex and activity level, under the following different test conditions: Various test positions; various joints tested; and, a variety of test velocities. This may be approached in one of two ways: 1) actually test groups of normal subjects under each of the test conditions, or 2) examine the isokinetic force-velocity relationship at a variety of test speeds and the length-tension relationship in a variety of test positions and subsequently apply the relationships to the norms for the different age, sex and activity groups.
3. Investigation to determine optimum isokinetic testing and rehabilitation velocities for various joints, particularly in relation to joint pathology and/or injury.
4. Studies which correlate injury with isokinetic muscular potential in an attempt to define the extent of normal muscular balance, and the point at which the risk of injury is increased.
5. Investigation to determine whether speed-specific relationships in agonist-to-antagonist muscle group ratios of the upper extremity exist, particularly at faster test velocities.
6. Studies to show the degree of decrement, if any, in isokinetic muscular potential with age.

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APPENDICES

APPENDIX A

SUBJECTS BY FACULTY

Table 5.1 SUBJECTS BY FACULTY

FACULTY	NUMBER
Nursing	27
Arts	14
Science	12
Education	6
Physical Education and Recreation	5
Home Economics	4
Rehabilitation Medicine	2
Dentistry	2
Engineering	1
Library Science	1
TOTAL	74

APPENDIX B

CYBEX II TORQUE CHANNEL CALIBRATION

CYBEX II TORQUE CHANNEL CALIBRATION

It is important that the calibration procedure be followed in the order as indicated below:

1. Zero the recorder to resting signal of the dynamometer.
   - a. Set damping control at 2, chart speed at 5 mm/sec., and speed selector at 30°/sec. Make sure there is no load on the dynamometer.
   - b. Set ft.lbs scale on 180 and zero the recorder stylus on baseline using the zero adjust knob for torque channel.
   - c. Switch ft.lbs scale to 30.
   - d. If stylus deflects from the baseline, adjust the zero null potentiometer on the side of the recorder with calibration screwdriver to zero stylus on chart baseline.
   - [illegible] Repeat steps 2 to 4 until stylus deflects less than half of a minor division when switching back and forth between 180 and 30 ft.lbs scales.
2. Calibrate each torque channel range scale.
   - a. Set torque channel to ft.lbs scale to be calibrated (in this case 180), set damping control at 2.
   - b. Set speed selector at 30°/sec. and ensure there is no load on the dynamometer. Adjust stylus to zero baseline using the torque channel zero adjust knob.
   - c. Insert calibration T-bar into long input adaptor and set input arm length at setting B.
   - d. Add 32.5 lbs of weight to the T-bar.
   - e. Set chart speed to 5 mm/sec.
   - f. Lift the weighted T-bar to a vertical position above the dynamometer. Push the weighted arm forward gently to engage the iskonetic resistance before letting go so that the arm falls smoothly until it contacts the floor.
   - g. Check the torque reading on the chart recording. The peak value for the 180 ft.lbs scale should reach 5 major divisions above the baseline.
   - h. If the chart recording does not agree with this value, adjust the potentiometer for the

180 ft.lbs scale with the calibration screwdriver.

i. Once the torque value is correct, re-check twice to ensure reading is consistent.

APPENDIX C

CYBEX II POSITION ANGLE CHANNEL CALIBRATION

CYBEX II POSITION ANGLE CHANNEL CALIBRATION

There are two degree scale settings (150° and 300°). Calibrating either one calibrates the other as well. Since most joint patterns have less than 150° range of motion, the 150° scale is the most often calibrated. This brings the accuracy of the 150° scale to ±1.5° (±1%) while the 300° scale accuracy is ±6° (±2%).

When greater accuracy for movement patterns larger than 150° is desired, calibrate the 300° scale directly. This achieves ±3° (±1%) accuracy for the 300°scale; accuracy of the 150° scale decreases to ±3° (±2%).

To calibrate the Position Angle Channel, use the following procedure:

1. With the recorder power on, set degree scale to 150 or 300 as explained above.
2. Set chart speed to 5 mm/sec.
3. Set input direction to clockwise (cw).
4. While depressing the zero test button, use the position angle zero adjust knob to adjust the stylus to zero baseline. Release zero test button.
5. Adjust position angle channel stylus to zero baseline by turning goniometer dial on the dynamometer clockwise. Note, stylus may jump off the scale at one point in the goniometer range - this is normal.
6. Re-check steps 4 and 5 until the stylus does not deviate from zero baseline when zero test button is pressed or released.
7. Using the white line under the goniometer as an index mark, rotate the dial clockwise precisely 300°. If the stylus traces a line exactly on the top line of the position angle chart, no adjustment is necessary. If the stylus lies above or below the top line, repeat steps 4 to 7 to verify the reading. If adjustment is necessary, proceed with step 8.
8. Locate the degree calibration screw on the recorder panel. Using a 7/16" wrench, slightly loosen the locking nut that secures the screw. With a standard screwdriver, turn the screw to move the stylus line precisely to the top line on the position angle chart. Using the screwdriver to hold the screw to the adjusted position, snug down the locking nut. Recheck

calibration by repeating steps 4 to 7.

APPENDIX D

CYBEX II SPEED SELECTOR CALIBRATION

CY[illegible]EED SELECTOR CALIBRATION

Caution: The fo[illegible] procedure requires making internal adjustments to the speed selector while it is in an [illegible]ng condition. Be extremely careful about the location of the fan, which is less visible [illegible] operating, and ensure the location of the internal speed selector potentiometer (R-77).

1. Switch speed selector on.
2. Attach adjustable arm with push-button (set at shortest length), locking collar with thumbscrew, and handgrip.
3. Adjust speed to 180°/sec.
4. Using a stopwatch, determine the time necessary to complete exactly 15 revolutions of the accessory arm (in either direction). Keep the dynamometer torque gauge needle above zero for the entire timing duration. Complete at least one full revolution before you start timing. This will ensure you have reached the set speed and are meeting resistance when the timing begins.
5. Calculate the actual RPM: Divide 900 by the number of seconds it takes to complete 15 revolutions. The result is the actual RPM of the input shaft.
6. If the actual RPM is 30 (±0.3), the tachometer is reading correctly and requires no adjustment. If the actual RPM is less than 29.7 or greater than 30.3, repeat the timing and calculation procedures to check for human error. If repeating the procedures confirms an incorrect tachometer reading, an adjustment must be made inside the speed selector.
7. With the speed selector switch off, remove the top panel from the speed selector.
8. Refer to the Cybex II documentation to locate potentiometer R-77.
9. Switch speed selector on. The tachometer should return to 30 RPM as previously set. If it does not, readjust.
10. Using the insulated calibration screwdriver, turn the white screw in potentiometer R-77 to bring the tachometer needle to a reading that matches your calculated actual RPM (step 5).

11. Repeat steps 4, 5 and 6. If you have performed all procedures correctly, your calculated actual RPM should fall within the acceptable ±0.3 RPM tolerance.
12. Switch speed selector off. Replace top panel and secure.

APPENDIX E

INFORMED CONSENT FORM

The University of Alberta

Department of Physical Education and Sports Studies

INFORMED CONSENT FORM FOR INVESTIGATIVE STUDY:
PRELIMINARY ISOKINETIC DYNAMOMETRY DATA FOR CLINICAL USE IN UPPER EXTREMITY CASES IN FEMALES

Outline of procedures (retained by the Subject).

The concept of isokinetic exercise was developed in the early 1960's by J.J. Perrine and was first reported by Hislop and Perrine in 1967. Since then, isokinetic exercise has been used in clinical settings as a therapeutic modality, as a training and testing device for athletes, and as a method of scientific investigation of the relationships between force and velocity, and muscle agonist, antagonist action.

Much of the work has been concentrated in determining the relative efficacy of isometric, isotonic and isokinetic training for muscular strength and power development. A review of the isokinetic literature reveals three basic deficiencies. The first is a lack of investigation into the effects of isokinetic exercises with respect to the upper extremity. Second, the prevalent lack of standardization of subject position during isokinetic evaluation. And thirdly, although relative comparisons have been made, very little firm isokinetic normative data exists for the use of clinical practioners as well as research workers. Moffroid and her colleagues have established the reliability and validity of the Cybex II isokinetic device for the measurement of torque, work and power, and presented some preliminary norms. Goslin and Charteris (1979), and Davies (1982), have presented preliminary normative data for clinical use in lower extremity cases Molnar and Alexander (1971), have suggested that the establishment of isokinetic normative data would benefit in the assessment of muscular strength, and aid practioners in the rehabilitative process following injury.

The study in which you are being asked to participate will measure the force (torque) in three paired tests of both arms. Two shoulder, and one elbow test will be administered, all in the supine position. You will be asked to work against a resistance arm by use of a handgrip. You will be asked to exert as much force as possible in both directions, and 5 warm-up/practice attempts will be made prior to each measured test.

The tests follow standard protocol and are considered very safe. As a result of the high muscular contraction forces involved there exists a slight possibility of muscular soreness after the exercise session. However, this should be absent or minimal, in most cases, and, if experienced, should be similar to that experienced during and after routine workouts. The possibility of 'pulling' or straining a muscle is minimal and has not been reported in the literature to date.

The total time for testing will be approximately 30 - 45 minutes and you are asked to participate in only one testing session. In the event of questions please feel free to contact Ian Pike (432-5503) or Dr. S.W. Mendryk, (432-3566). You have the right to withdraw from participation at any time.

The University of Alberta

Department of Physical Education and Sports Studies

INFORMED CONSENT FORM FOR INVESTIGATIVE STUDY:
PRELIMINARY ISOKINETIC DYNAMOMETRY DATA FOR CLINICAL USE IN UPPER EXTREMITY CASES IN FEMALES

Subject Concent(retained by investigator)

I, (name), do hereby agree to participate as a subject in the study entitled, "Preliminary Isokinetic Dynamometry Data for Clinical Use in Upper Extremity Cases in Females," conducted by Mr Ian Pike. The nature of this study has been explained to me and I understand the potential risks involved. I do not suffer at present, nor have I ever suffered, any serious elbow or shoulder injury which could interfere with, or be affected by participation in this study. I have been advised that I may withdraw from this study at any time.

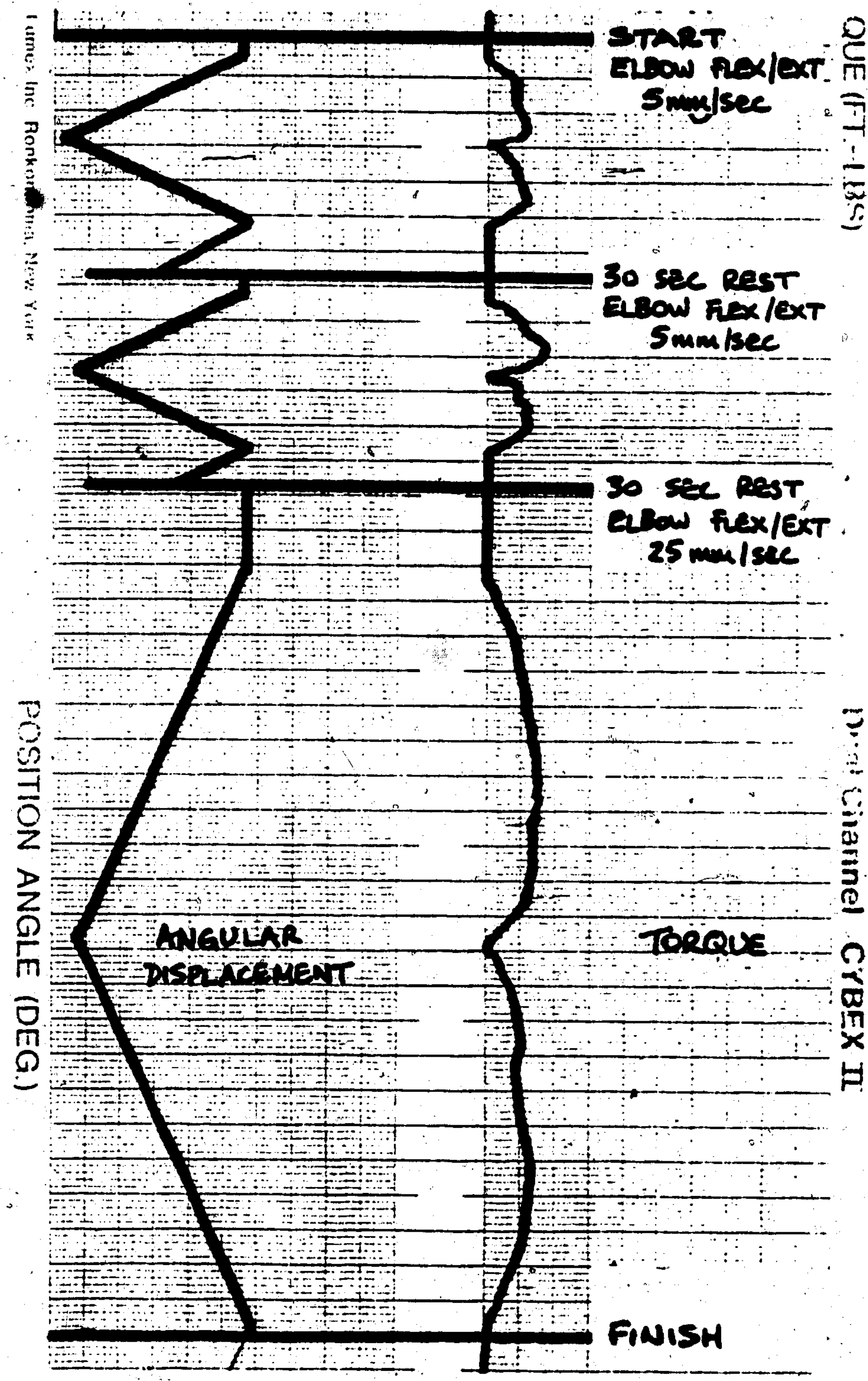
Signed Date

Address Phone

APPENDIX F

CYBEX II RECORDING CHART

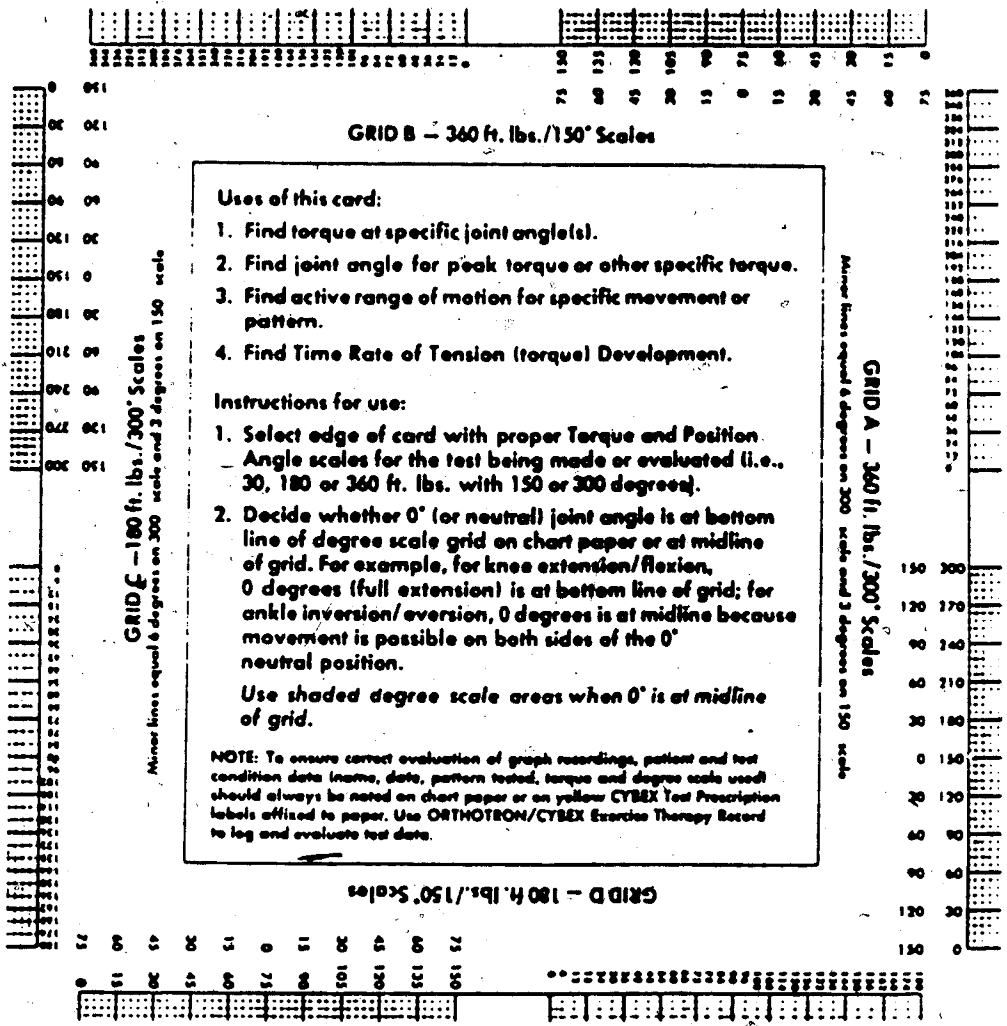
CYBEX II RECORDING CHART



APPENDIX G

CYBEX II CHART DATA CARD

CYBEX II CHART DATA CARD



Uses of this card:

1. Find torque at specific joint angle(s).
2. Find joint angle for peak torque or other specific torque.
3. Find active range of motion for specific movement or pattern.
4. Find Time Rate of Tension (torque) Development.

Instructions for use:

1. Select edge of card with proper Torque and Position Angle scales for the test being made or evaluated (i.e., 30, 180 or 360 ft. lbs. with 150 or 300 degrees).
2. Decide whether 0° (or neutral) joint angle is at bottom line of degree scale grid on chart paper or at midline of grid. For example, for knee extension/flexion, 0 degrees (full extension) is at bottom line of grid; for ankle inversion/eversion, 0 degrees is at midline because movement is possible on both sides of the 0° neutral position.

   Use shaded degree scale areas when 0° is at midline of grid.

NOTE: To ensure correct evaluation of graph recordings, patient and test condition data (name, date, pattern tested, torque and degree scale used) should always be noted on chart paper or on yellow CYBEX Test Prescription labels affixed to paper. Use ORTHOTRON/CYBEX Exercise Therapy Record to log and evaluate test data.