AN ELECTROMYOGRAPHIC INVESTIGATION OF THE INDIVIDUAL RECRUITMENT OF THE QUADRICEPS MUSCLES DURING ISOMETRIC CONTRACTION OF THE KNEE EXTENSORS IN DIFFERENT PATTERNS OF MOVEMENT.

by

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B.sc. (P.T.), Université de Montréal, 1971.

A THESIS SUBMITTED IN PARTIAL FULFILMENT OF

THE REQUIREMENTS FOR THE DEGREE OF

MASTER OF SCIENCE (KINESIOLOGY)

in the Department

of

Kinesiology

SIMON FRASER UNIVERSITY

September, 1974.

APPROVAL

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DEGREE: Master of Science (Kinesiology)

TITLE OF THESIS: AN ELECTROMYOGRAPHIC INVESTIGATION OF THE INDIVIDUAL RECRUITMENT OF THE QUADRICEPS MUSCLES DURING ISOMETRIC CONTRACTION OF THE KNEE EXTENSORS IN DIFFERENT PATTERNS OF MOVEMENT.

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Title of Thesis/Dissertation:

An electromyographic investigation of the individual recruitment of the quadriceps muscles during isometric contraction of the knee extensors in different patterns of movement.

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March 15, 1975.

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ABSTRACT

Many physical therapists have adopted the existing theories of neuromuscular facilitation and their wide variety of applications to meet the needs of individual patients and to search for ideal techniques of muscular re-education. However, it would seem justifiable to undertake thorough investigations of theories and techniques in order to establish the validity of their use for treatment with patients. This investigation must include both a survey of all literature pertinent to the subject and research conducted in a scientific manner. As a first step in this investigation the author has studied the work of Kabat and reviewed the conflicting reports of evidence from previous research concerning the effects of patterning and other facilitation procedures. The focus of the present literature review is on the lower limb in general and the quadriceps muscles in particular; following this a study investigating the effects of some patterns of movement including two patterns of proprioceptive neuromuscular facilitation is presented. These resisted contractions of selected muscle groups are known to be employed to facilitate recruitment in the quadriceps muscles and according to some therapists they act more specifically, depending on the pattern used, on particular components of the quadriceps. Seven normal healthy subjects volunteered for the experiment which lasted for eight weeks and which comprised nine periods of training and five periods of electromyographic investigation. The results suggest that the use of patterning on the lower limb to produce facilitation gives variable influences on the three investigated components (vastus

lateralis, vastus medialis, rectus femoris) of the quadriceps. No "universality" or "inborn" characteristic was evident. Neither was any training or learning effect demonstrated according to the criteria of learning used in this study. Nevertheless, the functional anatomy of these three components has once more been verified. In comparing the results obtained with those produced by previous investigators, particular reference was made to the use of patterning and facilitation in the muscular rehabilitation of orthopaedic cases.

ACKNOWLEDGEMENTS

The author wishes to express his grateful appreciation to the following people who have been the source that made this work possible: Eric W. Banister, for his patience and attention, during my initiation as a graduate student, to developing the skill of scientific analysis; to John M. Montgomery, for his assistance and encouragement toward the pursuit of my interest, and for having helped me so much on the statistical analysis of the present work; to Arthur E. Chapman, for all the time he has devoted in teaching me the basics of research methods, and for his ever constant guidance, as an adviser, throughout this work; to Sue Fife, whose criticism and recommendations have enhanced considerably the final presentation of this study.

Also many thanks to the other faculty members and graduate student friends whose spirit and enthusiasm for study and research, as a team, have taught me so much.

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CHAPTER I

INTRODUCTION

Physiotherapists, and those involved in the field of physiology as applied to the musculo-skeletal system, have worked for many years to find ideal techniques of muscular reeducation. Lenman (1959a) wrote: "If exercise is indicated it is important to know the most effective method of carrying it out". Lawrence, Meyer and Mathews (1962) also stated: "In fact the determination of specific effects to be obtained by various types of exercise, as well as optimum conditions for the development and maintenance of these effects, is of utmost importance if exercise is to be administered to the highest degree of usefulness and efficiency".

While numerous theories have been developed as a guide to those involved in technique of muscular reeducation, little direct experimental evidence has been produced to support the application of these theories.

The purpose of this study was to examine the individual recruitment of three muscles of the quadriceps group during the application of various forms of manual resistance to extension of the knee-joint. Integrated electromyographic activity (I.E.M.G.) was chosen as the criterion of recruitment and its relationship to the total extensor torque about the knee-joint was investigated under certain specific conditions of muscular contraction.

It is hoped that the results of this investigation will provide information on muscular function which will be applicable to those involved in the process of Physical Therapy.

CHAPTER II

REVIEW OF LITERATURE

A. Introduction

The following literature review has four main purposes: to demonstrate the historical development of favoured techniques of muscular reeducation whilst discussing some conflicting research evidence in support of an ideal technique; to examine a particular theory of muscular reeducation; to examine the activity of a specific group of muscles (quadriceps); and to suggest some directions of research which may prove profitable to those involved in the field of Physiotherapy.

B. Historical Development and Conflict of Results

As a result of this search for the "ideal" technique, many authors have devoted much attention to the themes of "isotonic" and "isometric" exercise and a great deal of literature has been written on these subjects. Yet anyone who reviews this mass of literature can only find frustration due to the conflicting results which appear. The conflicts remain, the ideal universal technique of reeducation has not been found and one of the possible reasons for this state of affairs has been suggested by Gravel (1972). This author concludes that many ideas are accepted on a subjective rather than objective basis in clinical practice.

This acceptance appears to be the result of a lack of understanding due to the technical and scientific complications inherent in many of the reports.

C. Patterning and Facilitation

More recently, the theories on muscular reeducation have been directed toward a different approach to exercise therapy. Gardner (1969) supports this different approach when she stated: "Man is born with already built-in nerve circuits designed to produced specific, coordinated patterns of alternating or synchronous muscle response". As a result of many such similar statements the concepts of "patterning", "mass movement" and "overflow" gained favour with many therapists as the technique named Proprioceptive Neuromuscular Facilitation (P.N.F.) (Knott and Voss, 1968). Armed with this new weapon against muscular weakness, many physiotherapists felt in an extremely strong position. Many of the new ideas were based upon sound neurophysiological theories presented by Kabat (1947, 1950a, 1950b, 1952a, 1952b, 1965), his co-workers (Levine and Kabat, 1952a, 1952b, 1953; Kabat and Knott, 1953; Voss and Knott, 1954; Kabat, McLeod and Holt, 1959a, 1959b; Knott, 1967) and others (Partridge, 1954; Awad and Kottke, 1964; Coleman 1969; Smith, 1970) while conflicting evidence was found in the results of other research (Kruse and Mathews, 1958; Panin, Lindenauer, Weiss et al., 1961; Kroll, 1965a, 1965b). The new theories and their resulting practical applications appear to have been successful in treating neurological disorders (Kabat, 1950a; Kabat, McLeod and Holt, 1959a) but not universally so (Stern, McDowell, Miller et al., 1970; Quin, 1971). Morever, there was an attempt to apply the technique of P.N.F. to orthopaedic cases and Voss (1967) stated: "This divergence of concepts becomes important in that Kabat's ideas have been centered on treatment of paralysis, whereas Knott's and mine have been extended to that of an approach to therapeutic exercise". Some references (Voss, Knott and Kabat, 1953; Ault, 1960; Ionta, 1960; Knott and Mead, 1960; Knott and Barufaldi, 1961; Knott, 1964; Piercy, 1973) support such an application to non neurological conditions. For the therapist, these techniques are quite attractive in themselves due to the fact that they attempt, with some scientific logic, to use everything that can help from evolutional theories, reflexes, maximal stimulation and resistance in possibly isometric, isotonic and perhaps even isokinetic form of contractions.

In fact this idea of facilitating contraction of a muscle by overflow, through the use of a pattern, seems quite useful if it is to be used in cases such as the one presented by Wolf, Majora and Gonen (1971). They reported lack of muscular activity of the Vastii in some orthopaedic cases treated with a plaster cast, while the rectus femoris muscle showed some electrical activity (E.M.G.). Hallen and Lindhal (1967) produced similar inhibitory effects on the vastus medialis muscle through experimental anaesthetic procedures. In such cases patterning could be a means of reinforcing the inhibited Vastii. This is based upon the existence of a cross-transfer effect (contralateral segment) and it is possible that a similar ipsilateral effect could demonstrate the existence of overflow. As suggested by McDonald (1971): "Overflow should not be confused with cross education... overflow refers to electromyographic evidence of action potentials in the contralateral limb, whereas cross education refers specifically to evidence of strength increase in a contralateral limb". Overflow to the ipsilateral limb should also be considered (Gellhorn, 1947; Loofbourrow and Gellhorn, 1948; Waterland and Munson, 1964).

Even though few studies have been done on the effects of patterns of movement, many therapists use the technique extensively (Piercy, 1973; Atkinson, 1973; Todd, 1973). As a proponent of P.N.F. Todd (1973) wrote: "Proprioceptive neuromuscular facilitation techniques can be more efficient and more effective and therefore less time consuming than conservative forms of exercise and treatment". Nevertheless, if one examines the literature, no immediate demonstration of this can be found with regard to the application of the principles suggested by the School of patterning and mass movement. Salter (1957) made a statement that is still relevant today: "Kabat claims good results from the practice of these principles of exercise, but gives no quantitative details in support of his claim". More recently Stern et al. (1970) stated: "Neither the proponents nor the physical therapists who employ these treatment modalities have made a serious attempt to evaluate their effectiveness in controlled studies".

Different authors have presented results of research work on patterning with (Basmajian, 1967; Vele, Bazala, Prazak et al., 1967; Snyder and Forward, 1972) or without (McCloy, 1946; Wheathley and Jahnke, 1951; Gough and Ladley, 1961; Bos and Blosser, 1970) mention of the technique now known as P.N.F. Nevertheless no complete agreement can be found in this work regarding both the effects of a pattern of movement on specific muscles and the reproducibility of the results.

While some authors support the theoretical background of Kabat's technique (Knowlton, 1954; Harris, 1970, 1971) others believe that it is less recommendable on a practical basis when its effectiveness is compared to its complexity of utilization. It is considered by some that the time taken to learn the skill of applying P.N.F. far outweighs its usefulness (Basmajian, 1967, 1971), and that it cannot pretend to attain more efficiency as compared to other conservative forms of treatment (Stern et al., 1970; Quin, 1971; Caillet, 1971).

D. The Theories of Kabat on the Technique of Neuromuscular Facilitation

In his introduction to patterning Kabat (1952a) mentioned that a considerably greater motor response can be attained when employing facilitation techniques in addition to resistance as compared with maximal resistance alone. His best example of demonstrating the effectiveness of the use of patterning with maximal resistance is the case of the "zero" muscle (Kabat, 1952a). He reported that either in poliomyelitis or upper motor neuron lesions, the zero muscle will present a response with the use of facilitating techniques, but no response with voluntary effort in free motion with or without maximal resistance. He stated: "For example, a peroneal muscle which failed to respond at all in attempted isolated free motion or against resistance, definitely contracted with the application of stretch and a mass movement pattern of extension and abduction of the hip against resistance (Kabat, 1952a)". Such observation led Kabat to conclude that with facilitation techniques the level of excitation of the anterior horn cells was raised above threshold, with the resulting muscle response. He also added (Kabat, 1952a): "An increased response above that obtained by resistance alone can also be demonstrated from application of additional facilitating mechanism in muscles only partially paralysed and even in normal muscles". Such a quotation suggests that facilitation, and more specifically irradiation, can be obtained by resisted contraction of some muscle groups in subjects without neurological disorders with resulting increase in muscular activity.

Kabat and Knott (1953) justified the use of Neuromuscular Facilitation by the observation that a voluntary movement is never performed by one single muscle. They elicited further support for this especially by referring extensively to Gelhorn, Twitchell, Hellebrandt, Gesel, Loofbourrow and other neurophysiologists. On the same theme, Jackson (1931) as mentioned by Kabat (1965), stated: "Nervous centers know nothing of muscles, they only know of movement". Inman, Saunders and Abbot (1952), again as mentioned by Kabat (1952a), reinforced the importance of patterns of motion for muscle reeducation by stating: "There is, for example, no such thing as a prime mover, as ordinarily understood. There are only patterns of action".

Kabat (1965) also pointed out that when maximal resistance is used in a given activity, the contraction is far from limited to a single muscle, but it is spread to other muscle through a process called "irradiation". Hirt (1967) reported that this phenomenon is described in the work of Sherrington (1961) as the latter observed a spread of excitation when using increasing intensity during electrical stimulation of the plantar skin of the dog. Kabat, as quoted by Hirt (1967) used the term "irradiation" ... "for the comparable phenomenon, the spread of a mass movement pattern with increasing resistance to voluntary movement".

After having explained irradiation with the example of the flexion reflex of the lower extremity Kabat (1965) added: "Irradiation is not haphazard but spread in a specific pattern of muscular contraction". He also believed as did his followers, that a similar process occured in voluntary motion in man. The application is then obvious, by means of irradiation one can facilitate one motion through another voluntary maximally resisted motion.

Kabat (1965), gave a more detailed explanation of the technique by describing the "diagonal-spiral patterns". His complete definition was: "...pattern of voluntary motion which includes in the one motion, at a number of joints simultaneously, three components: flexion or extension, abduction or adduction, and external or internal rotation". These patterns are now widely used. Attempts were also made to describe normal motion in terms of patterns (Levine and Kabat, 1952b). Other workers used the term "congruent set" to describe articular patterns of the femoral shaft involving extension, abduction and medial rotation, and flexion, adduction and lateral rotation (MacConaill and Basmajian, 1969). These authors refer the reader to normal walking for the verification of these patterns as inherent human qualities.

As a concluding justification for mass movement patterns, Kabat (1965) stated: "All voluntary motion begins and ends in a posture, which is based on activity of many reflexes... It should be understood that the C.N.S. is a highly integrated mechanism, in which reflexes and voluntary motion, far from being isolated phenomena, are closely interrelated". Different authors have based similar techniques of treatment on a nearly identical philosophy, and these are Fay (Fay, 1946a, 1946b, 1954a, 1954b, 1955, 1958; Page, 1967; Wolf, 1968), Bobath (Bobath, 1959, 1960, 1963; Bobath and Bobath, 1964; Bobath and Cotton, 1965; Semans, 1967), Brunnstrom (Brunnstrom, 1956, 1970; Perry, 1967), and Rood (Stockmeyer, 1967; Goff, 1969). The acceptance of the above as a law of development and voluntary motion seem to be for Kabat and others the key to understanding movement and efficiency in therapeutic exercise.

Hirt (1967) commented upon the work of Kabat as follows: "Through the use of proprioceptive facilitation of voluntary movement, Kabat identified the natural design of movements. He identified the components, not as anatomical units, but as members of a physiological patternship... He took therapeutic exercise out of the cardinal planes by introducing spiral and diagonal composite movements, adding thereby, a third dimension to therapeutic exercise". This statement illustrates the acceptance of Kabat's theory by many involved in the field of Rehabilitation.

As a result of articles such as the one from which this statement has been taken, many therapists are convinced that the use of mass pattern movement is supported by precisely demonstrated scientific principles. Such acceptance is open to much discussion (Basmajian, 1967; Stern _et al_., 1970) and no extensive scientific demonstration of the effects of patterns now used as suggested by Knott and Voss (1968) could be found in the literature. While studying and practicing all the patterns suggested by Knott and Voss (1968) one is bound to question the validity of all of them, as originally developed by both Kabat and Knott.

E. Functional Anatomy of the Quadriceps and its Relationship to Patterning

Activity of the quadriceps muscle has been investigated during many specific tasks (Brunnstrom, 1966; Rasch and Burke, 1967; Basmajian, 1967; Kelley, 1971). From the results of some of this work, two schools of thought have been formed, one defending the synchrony (Brewerton, 1955; Duchenne, 1959; Pocock, 1963; Close, 1964; Bos and Blosser, 1970; Jackson and Merrifield, 1972) and the other the asynchrony (Wheatley and Jahnke, 1951; Basmajian, 1967; MacConaill and Basmajian, 1969; Basmajian, Harden and Renegos, 1972) between the separate muscular components of the quadriceps femoris. Basmajian (1967) stresses the fact that the rectus femoris is a biarticular muscle which has to act as a flexor of the hip as well as an extensor of the knee. Nevertheless, little is said to explain the asynchrony of the vastii when it is present. In fact, many years ago, McCloy (1946) demonstrated different roles of the rectus femoris and vastus lateralis (considering the vastus lateralis representative of the three vastii) during extension or flexion of the hip. Such evidence at least suggests consideration of the quadriceps as different muscles, each of which could have a different response depending on the movement performed. Consequently the question of overflow from one muscle to another in a variety of movements or patterns warrants investigation. Such an hypothesis could be reinforced by the fact that some anatomical peculiarities have been shown regarding the vastus medialis and rectus femoris muscles (Markee, Logue, Williams et al., 1955; Barnett, 1958; Lieb and Perry, 1971; Perry, 1972).

Close (1964) reported that in the sitting position electromyographic evidence indicates that each of the vastus muscles contributes an identical proportion of its maximal force of extension of the knee. For the rectus femoris, however, he noted that the bulk of electrical activity appears in the latter part of the extension of the knee. With the subject in the supine position, the rectus femoris activity more closely reflected the activity of the vastii. Pocock (1963), Jackson and Merrifield (1972) found no difference as to the effect of position on the activity of the rectus femoris.

Pocock (1963) used the E.M.G. to investigate the effect of some rehabilitation techniques on the quadriceps muscles. He found that with and without resistance during extension of the knee, the muscles act as a unit, i.e. they begin and end their activity all together. This supports Duchenne's theory on the unity of action of these muscles (Duchenne, 1959). The same findings were also reported for the straight leg raising exercise.

Basmajian (1967), MacConaill and Basmajian (1969) are in agreement with Wheatley and Jahnke (1951), that during resisted extension of the knee, the various parts of the quadriceps come into action at different phases of the movement.

Brewerton (1955), Hallen and Lindahl (1967), Lieb and Perry (1971) and Perry (1972), have demonstrated that the activity of the vastus medialis is not confined to the last few degrees of extension but that it produces force throughout the full range of extension in conjunction with the other components. Basmajian (1967, 1970, 1972) supported this but added more precise evidence on the independence of action of this muscle as compared with the three other components, while performing some specific tasks.

Basmajian (1967) also found that this asynchrony between the separate muscles of the quadriceps occurs during the movement of rising from the sitting to the standing position. The vastus medialis was found to be retarded and less active than the rectus femoris and the vastus lateralis.

F. Patterning

Wheatley and Jahnke (1951) stated that there exists a greater activity in the vastus medialis muscle when the knee is held in extension with the hip joint flexed and the knee joint (leg) laterally rotated. Similarly, there is a greater activity of the vastus lateralis when the knee is held in extension with the hip joint flexed and the knee joint (leg) medially rotated.

Bos and Blosser (1970), in an evaluation of some isometric rehabilitation techniques of the quadriceps reported findings that were in agreement with those of Wheatley and Jahnke (1951). The effects of the rotation of the leg were as follows: with external rotation occuring in adduction, an increase in the electrical activity was recorded in the vastus medialis; when internal rotation occured in abduction an increase in the electrical activity was recorded in the vastus lateralis. It must be added that the results of this investigation (Bos and Blosser, 1970) have also supported those of Close (1964) and Pocock (1963) for the similarity or synchronization of the action of the three major components considered.

Basmajian (1967) reported an unpublished study in which he employed the technique of electromyography to investigate "some of the rehabilitation techniques currently being used by physiotherapists with the purpose of producing facilitation effects". Some of his major findings are as follows: Augmented activity of the quadriceps was found in only half of his subjects when movements of the toes were allowed. In those where augmentation occured, flexion in some and extension of the toes in others was effective. Associated foot and ankle movements were "somewhat" more effective. This was true for most but not all the subjects. Furthermore, there were no "clear-cut" differences between the effects of the following associated movements: dorsi-flexion, plantar-flexion, inversion and eversion of the foot. Gough and Ladley (1961) have shown dorsi-flexion to be the most efficient for the quadriceps as a group and the vastus medialis in particular. Basmajian (1967) stated that "medial or lateral rotation of the hip joint performed simultaneously with contraction of the quadriceps had essentially no effect on the E.M.G. activity of quadriceps". This is in desagreement with Vele et al. (1967) who gave credit to the rotation for production of facilitation through patterns. Basmajian (1967) also noted: "not only did simultaneous hip flexion fail to augment the amount of activity in the quadriceps in most subjects, but it even decreased it in some". Gough and Ladley (1961), and Allington et al. (1966) have demonstrated the same effect when referring to the straight leg raising exercise (S.L.R.). This is in agreement with one pilot study of the author of this study.

Finally, with regard to facilitation in straight leg raising, Pocock (1963) noted that the activity was increased if the subjects were instructed to "set" the quadriceps before lifting the limb. Dorsi-flexion as well as plantar-flexion of the foot were also reported to increase the action potential amplitude during their exercises.

G. Directions of Research

In the light of the preceding comments concerning the questionable nature of universal use of patterning and P.N.F., the author suggests that research should be directed to answering the following questions:

- What is the relative activity of a given muscle under a given pattern?

- Is there overflow produced more specifically in one muscle by the use of a specific pattern?
- Are the effects of patterning "universal", i.e. the same on different people?
- Is there a learning process related to recruitment of muscular activity with time?

H. The Use of Electromyography

To assess the degree of recruitment in an individual muscle working in a pattern of movement, the technique of electromyography may be used as has been done by Wheatley and Jahnke (1951); Brewerton (1955); Gough and Ladley (1961); Pocock (1963); Close (1964); Allington, Baxter, Koepke et al. (1966); Basmajian (1967); Hallen and Lindahl (1967); Bos and Blosser (1970); Lieb and Perry (1971); Snyder and Forward (1972); Basmajian, Harden and Regenos (1972); Jackson and Merrifield (1972).

Under specific conditions the Integrated Electromyogram (I.E.M.G.) yields much more easily interpretable data than the untreated electromyogram. Provided that the conditions of the experiment remain constant with respect to both the placement of electrodes and the physiological state of the muscle, the I.E.M.G. may be used as an index of tension in a muscle voluntarily contracted under isometric conditions as suggested by different authors (Bayer and Flechtenmayer, 1950; Inman, Ralston, Saunders et al., 1952; Lippold, 1952; Chapman and Troup, 1969).

A linear relationship has been found in human muscles between the I.E.M.G. and an externally applied force using surface electrodes during static (isometric) contraction (Lippold, 1952; Bigland and Lippold, 1954; Lenman, 1959b; Eason, 1960; Liberson, Dondey and Asa, 1962; Poudrier and Knowlton, 1964; Asmussen, Poulsen and Rasmussenn, 1965; DeVries, 1968;

Chapman and Troup, 1969). In ten experiments involving the gastrocnemius muscles of different subjects, Lippold (1952) obtained coefficients of correlation of 0.93 to 0.99 for the linear relationship (I.E.M.G.-Force).

It is on the basis of this relationship that I.E.M.G. has been used as a criterion of degree of recruitment of a muscle. This in turn has been based upon the assumption that greater I.E.M.G. activity represents the activity of greater numbers of motor units, in which case it can be stated that a given muscle is being activated by a greater amount and therefore is producing a greater force. In other words: "The linear relationship between isometric tension and electrical activity of voluntary muscle makes it clear that the integrated electromyogram provides a quantitative measure of the level of exitation in a muscle" (Lenman, 1969).

In a discussion on the type of electrode to be used, O'Connell and Gardner (1963) stated that whether one is interested in either the duration or amount of activity in the muscle as a whole, surface electrodes may be used. The location, size and other characteristics relevant to a logical placement of electrodes are of course to be considered. This is supported by Pocock (1963) for investigation of the quadriceps muscle. Komi and Buskirk (1970) compared the quality of reproducibility of E.M.G. of the wire and surface electrodes and concluded: "The results suggest that the surface electrode technique can be utilized reliably in long term studies where E.M.G. recording are repeated at intervals of several days".

CHAPTER III

MATERIAL, METHODS AND PROCEDURES

Both electromyographic activity (E.M.G.) and integrated electromyographic activity (I.E.M.G.) were recorded from the vastus lateralis (V.L.), vastus medialis (V.M.) and rectus femoris (R.F.) muscles, along with the torque produced during extension of the knee joint.

Subjects underwent three work tasks (W.T.1, W.T.2, W.T.3) during which the E.M.G. from each muscle was recorded. The first task, W.T.1, involved the development of varying amounts of extensor torque about the knee joint with the joint in 180 degree of extension. The second task, W.T.2, required maximal voluntary contraction of the extensor muscles while the experimenter applied manual resistance to the foot in a number of different directions. The third task, W.T.3, was identical to the first except that the knee was maintained at an angle of 160 degree of extension, the thigh being elevated and supported and the weight-pan fixed to the floor.

Electromyographic activity (E.M.G.), integrated electromyographic activity (I.E.M.G.) and force were recorded using surface electrodes, an electromyograph, an integrator, and a force transducer. These recordings were made during five recording sessions for each subject performing W.T.1 and W.T.2 consecutively. The first four sessions were separated by three training periods which replicated W.T.2. Similar recordings were performed during the two sessions per subject of W.T.3.

A. Material

Seven healthy uninjured male students (N=7) volunteered as subjects. Their ages, weights, statures and "d" values (see Methods) are given in table I. These subjects participated in W.T.1 and W.T.2 for a period of eight consecutive weeks.

Three different subjects undertook W.T.3 over a period of two weeks. Their ages, weights, statures and "d" values (see Methods) are given in table II.

All these subjects were partially involved in recreational activities although the effect of the activities could not be assessed.

B. Methods

i. Experimental postures adopted by the subject

a. Work task 1 (W.T.1)

All experimental and training sessions were performed with the subjects lying supine on a treatment table. The approximate axis of the knee joint was placed coincidental with the end of the table and an adjustable stool supported the heel of the subject, thus allowing 150 degrees of extension of the knee. The foreleg of the non-experimental leg was allowed to hang vertically over the edge of the table.

A force-transducer was used to register the vertical force produced during the development of extensor torque about the knee. It was attached at the upper end to the proximal premalleolar level by a padded strap and a weight pan was suspended from the lower end. The weight pan lay on the floor directly below the attachment to the leg of the subject, and it had a detachable connection to the transducer to allow the weights carried to be varied (see figure 1).

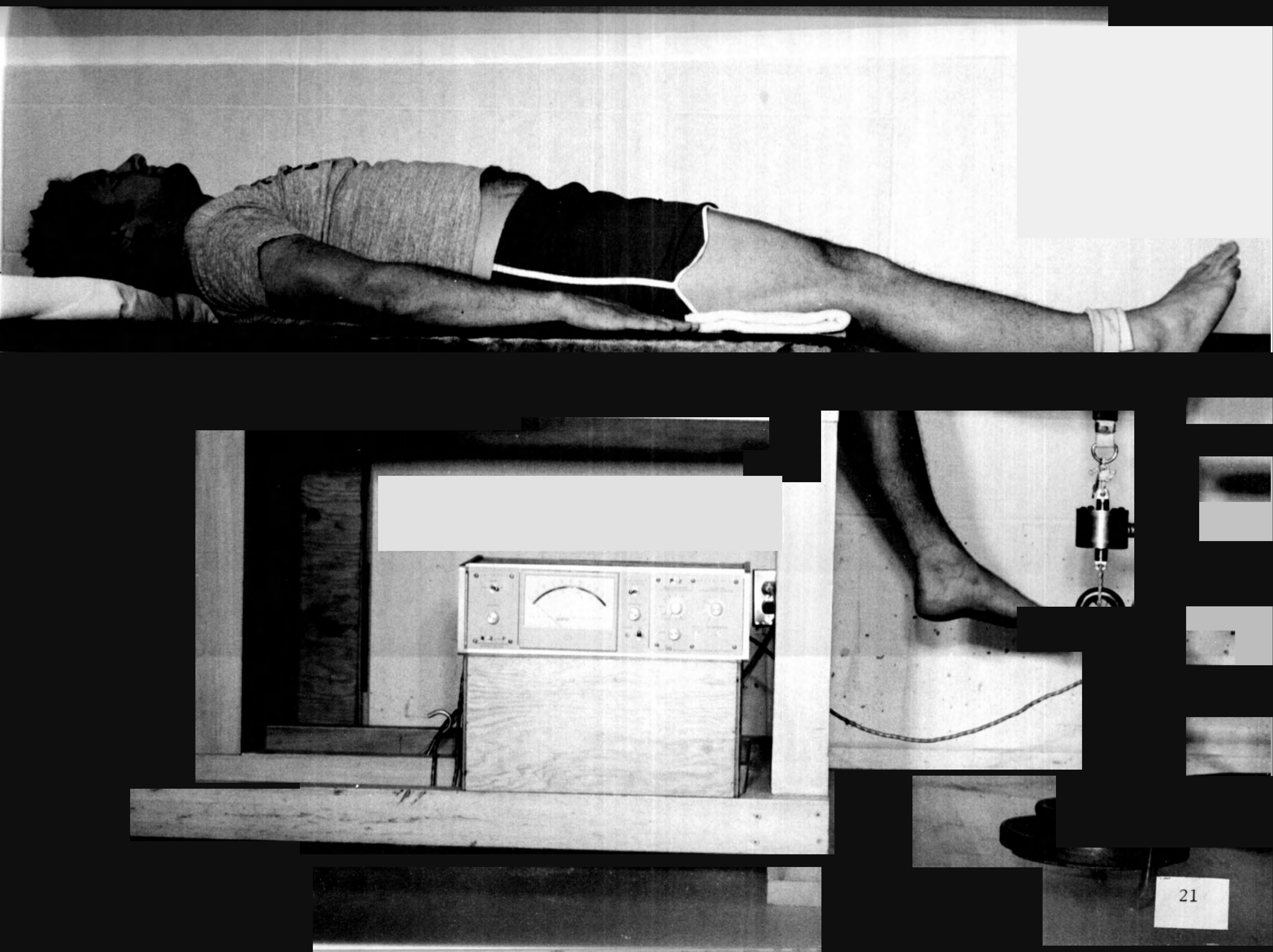
TABLE I: The age, weight, stature and "d" value for each subject involved in W.T.1 and W.T.2.

Subject no.	Age	Weight (kg.)	Stature (mm.)	d (cm.)
1	22	75.75	1820	34.0
2	25	81.20	1825	36.0
3	21	75.15	1721	34.5
4	22	73.80	1797	32.5
5	21	85.35	1812	37.0
6	23	83.00	1794	36.0
7	20	68.00	1733	33.0

TABLE II: The age, weight, stature and "d" value for each subject involved in W.T.3.

Subject no.	Age	Weight (kg.)	Stature (mm.)	d (cm.)
1	20	82.20	1850	38
2	24	71.10	1631	33
3	26	58.75	1662	33

Figure 1: The posture used for supporting the load by contraction of the quadriceps during W.T.1. The force-transducer is shown suspended from the shin with the weight-pan below it. The stool allowed the subject to rest the leg between contractions.



b. Work task 2 (W.T.2)

In W.T.2 no force-transducer was used. The subject lay supine and the whole of the experimental leg, apart from the heel, was supported on the table and manual resistance was applied to the foot by the experimenter (see figures 2 and 3). A variety of verbal commands were given to the subject by the experimenter who was placed at the end of the table (see Procedures). When the subject reached maximal effort a technician operated the recording equipment by means of which E.M.G. and I.E.M.G. were recorded.

c. Work task 3 (W.T.3)

The subject lay supine with the thigh supported by a pad situated at the end of the table. The foreleg was maintained horizontal with the heel resting on a stool allowing approximately 160 degree of extension at the knee as measured with a goniometer. The force-transducer was fixed, as for W.T.1, at the proximal pre-malleolar level and attached to an immovable weight placed on the floor vertically below the subject's leg. Different percentages of maximal effort were performed during which the E.M.G., I.E.M.G. and the output from the force-transducer were recorded.

ii. Apparatus used in the measurement of force

a. The force-transducer

The force-transducer used was a Daytronic model 300-D comprising three modules: Module 1 was a type 70 Differential transformer input module. The transducer conditioning selector was set on "B", and the range Selector on "2" (thousandths of an inch full scale). Module 2, was a type P Galvanometer driver output module, with a meter which al-

Figure 2: The posture of the subject and position of the experimenter as used in W.T.2.

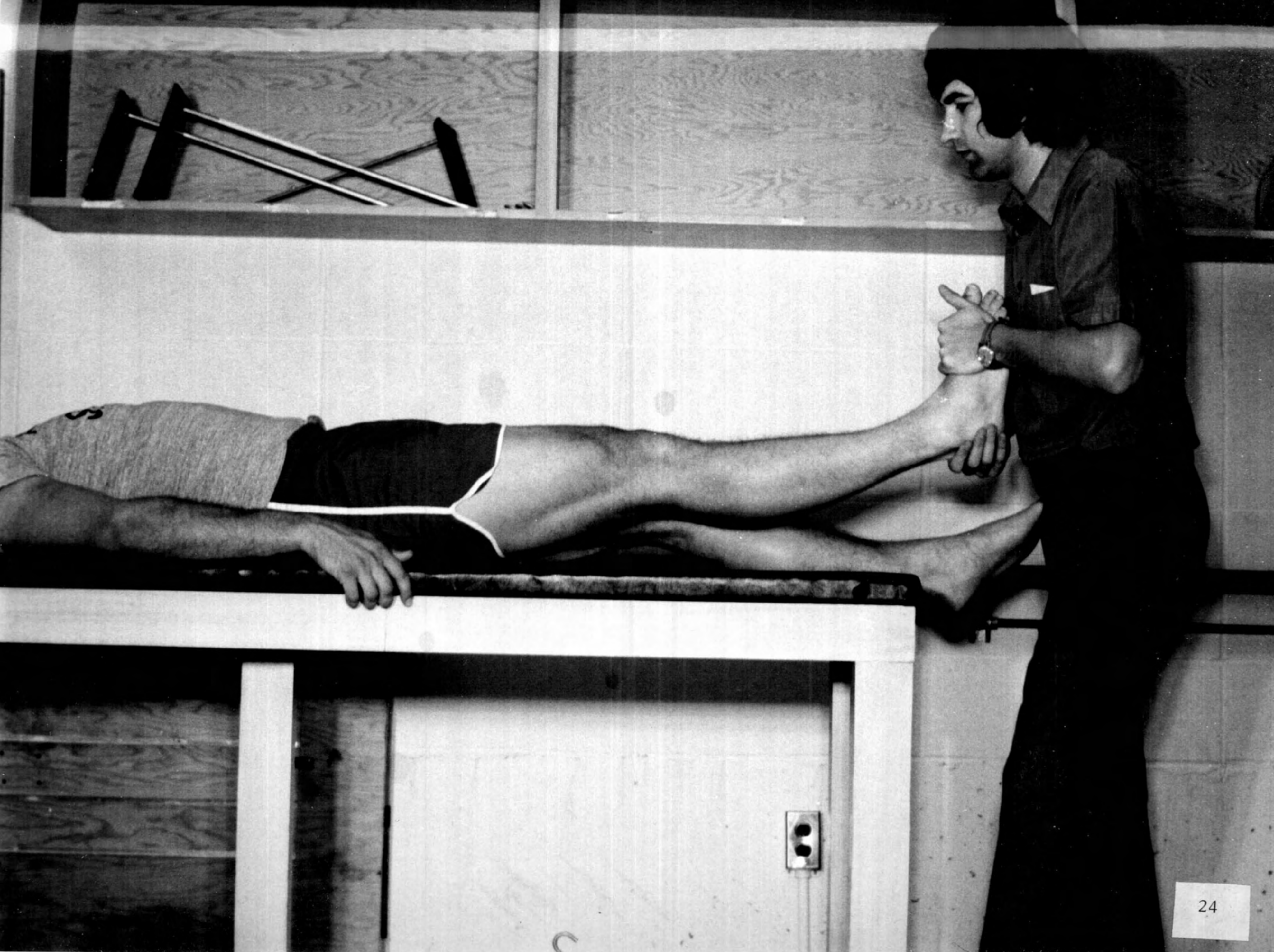

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Figure 3: The position of the hands when applying manual resistance as used in W.T.2

lowed visual monitoring of the force applied. Module 3, was the transducer amplifier indicator.

This force-transducer system was coupled with a galvanometer* having a flat frequency response from 0 to 3000 Hz, situated within a Bell-Howell Ultra-Violet recorder (see oscillograph recorder). The deflection obtained on oscillograph paper was proportional to the force applied to the transducer.

b. Calibration of the force-transducer

The force-transducer was calibrated by suspending weights from the weight-pan. No detectable deviation from linearity was observed in the relationship between force applied to the force-transducer and deflection obtained on the galvanometer. Consequently any error inherent in the system could neither be measured nor accounted for.

iii. Apparatus used in the recording of electromyographic activity

A modular electromyographic system** with two plug-in modules was used to amplify the electrical signals from two muscles, vastus lateralis and vastus medialis. The electromyographic activity from the rectus femoris was recorded by means of a Integrating Bioelectric Monitor***.

During a recording session the amplified output from the vastus lateralis muscle was integrated by means of an integrator****. At the

* Type 7-326, manufactured by Bell-Howell.

** Type T.E.4, manufactured by Teca Corp., White Plains, N.Y.

*** Type 100, manufactured by Newport laboratories, Newport Beach, California.

**** Type I-6, manufactured by Teca Corp., White Plains, N.Y.

termination of each experimental session the E.M.G. from vastus medialis was played into the integrator to obtain the corresponding I.E.M.G. for this muscle. The Newport Integrating Bioelectric Monitor allowed direct recording of the I.E.M.G. from rectus femoris during the experimental session.

Both E.M.G. and I.E.M.G. from each muscle were recorded either on the U/V recorder paper or by means of a Hewlett Packard F/M tape recorder (see procedures and circuits for recording and play back) and an oscilloscope was used to display the E.M.G. from all three muscles.

a. The oscilloscope

While recording, the oscilloscope displayed the electromyographic activity from the three muscles, with a sweep duration of 50 ms. Simultaneously the I.E.M.G. activity of channel one (V.L.) was displayed.

b. The amplifiers

Two E.M.G. amplifiers* were used for recording the E.M.G. from the V.L. and V.M. These AA6 systems have a pre-amplifier which was placed close to the subject to reduce lead capacity and interference problems. The filter control was placed at a band width from 1.0 Hz to 3 KHz (3 db points).

The choice of gains of the amplifier varied between subject from 2 KmV. to 500 mV. / division (2 K, 1 K, 500). The amplification of the activity of the rectus femoris muscle was executed with an Integrating Bioelectric Monitor (see Newport Bioelectric Integrating Monitor).

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* Type AA6, manufactured by Teca Corp., White Plains, N.Y.

c. The integrators

To obtain a quantitative measure of the E.M.G., electrical integration was obtained with one I-6 (Teca Corp.) integrator which gave a sawtooth output. The frequency of the sawtooth wave provided a measurement of the voltage-time integral of the input waveform. This I-6 integrator was a module suited for the T.E.4 modular electromyographic system, and thus served for the integration of the V.L. and V.M. muscles (see section iv, a and b).

Electrical integration by means of a square wave output was given by the Integrating Bioelectric Monitor (see section iii, d) for the rectus femoris.

d. The Newport Integrating Bioelectric Monitor

The rectus femoris muscle was coupled to an Integrating Bioelectric Monitor in which a choice of gains of 100, 10, 1.0, and 0.1 mV./division was available. A selector offered different choices of High pass frequencies (100, 300, 1 K, 3 K, 10 KHz) and of Low pass frequencies (.01, 0.1, 1.0, 10, 100 Hz). A bandwidth of 1.0 Hz to 3 KHz (3 db points) was choosen to avoid the problem of interference which occured during movement of the leads of the electrodes. This bandwidth was kept constant throughout the experiment.

e. The electrodes

Electromyographic recordings were made from the three muscles through the use of three sets of silver/silver Chloride surface electrodes*, five millimeters in diameters and a lead, 93 cm. in length, was

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* Manufactured by I.M.I., Newport Beach, California.

used for each set of electrodes to facilitate manipulation of the leg of the subject. Random noise was reduced by grounding the screening of the leads. Low Chloride Gel* was used as electrode jelly between the skin and the electrodes.

After each experiment the electrodes were removed and cleaned with water and a soft paper-cloth.

A silver plate, 5 cm. by 3 cm. was used as ground for the V.L. and V.M. muscles. Before application it was covered with electrode jelly, connected to the ground terminal of a pre-amplifier and fixed to the subject with a velcro strap (see procedures).

A silver/silver Chloride surface electrode of the type used for recording the E.M.G. was used as a ground electrode for the rectus femoris muscle and it was connected to the ground input of the Newport device.

f. Calibration of the integrators

The I-6 integrator was calibrated prior to the experiment, and it was verified that a linear response existed between planimetric assessments of the voltage-time integral of the square-wave input signal to the amplifier and the number of resets per second of the integrator. Such a linearity was found for the following gains of the amplifiers: 5 K, 2 K, 1 K, 500, 200. The other possible gains were not investigated, and as expected the 2 K, 1 K, and 500 mV. gains only were used throughout the experimental work.

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* I.M.I. Low Chloride Gel, manufactured by I.M.I., Newport Beach, California.

A similar calibration was also performed on the Newport Integrating Bioelectric Monitor. The following gains were investigated: 100, 10, 1.0, 0.1 mV. The gain of 10 mV. was choosen to be used constantly as it provided the most stable desired linear relationship.

g. The oscillograph

The amplifications, integrations and output from the force-transducer were recorded on U/V sensitive paper* by means of an oscillograph**. Timing marks were set at one second intervals with a paper speed of 4 cm./sec.

h. The tape recorder

A tape recorder*** was used to store some of the recordings (amplification of the vastus medialis muscle, and the integrated value from the rectus femoris muscle) on magnetic tape**** which was replayed at the end of the experiment.

i. The generator

A Hewlett-Packard, 3310A Function generator was used after each experiment to pass a square wave (1 mV. peak to peak) signal into the Integrating Bioelectric Monitor for the purpose of calibration.

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* Type DP1, SPM, 217822, manufactured by Bell & Howell Co., Vancouver

** Type 5-127 Recorder Oscillograph, manufactured by Bell & Howell Co., Vancouver.

*** Type 3960 Instrumentation Recorder, manufactured by Hewlett-Packard, Toronto.

**** Type DP15, manufactured by Philips, Toronto.

iv. Circuits used for recording and retrieval of data

a. Recording

Each plug-in module of the T.E.4 system had two switch positions. Position 'AMP' allowed use of the amplification system and position 'EXT' (External) allowed a signal to be passed to the oscilloscope without being treated by the amplification unit.

The electromyographic signals of the V.L. and V.M. muscles were recorded through the two AA6 (Teca Corp.) amplifiers switched on 'AMP' and situated respectively in channel 1 and 2 of the modular system. Their recordings appeared on channel 1 and 2 of the oscillograph recorder.

The I-6 integrator, situated in channel 5 of the modular system, gave simultaneous integration of channel 1, i.e. of the V.L. muscle. Its recording appeared on channel 5 of the oscillograph (see figure 4).

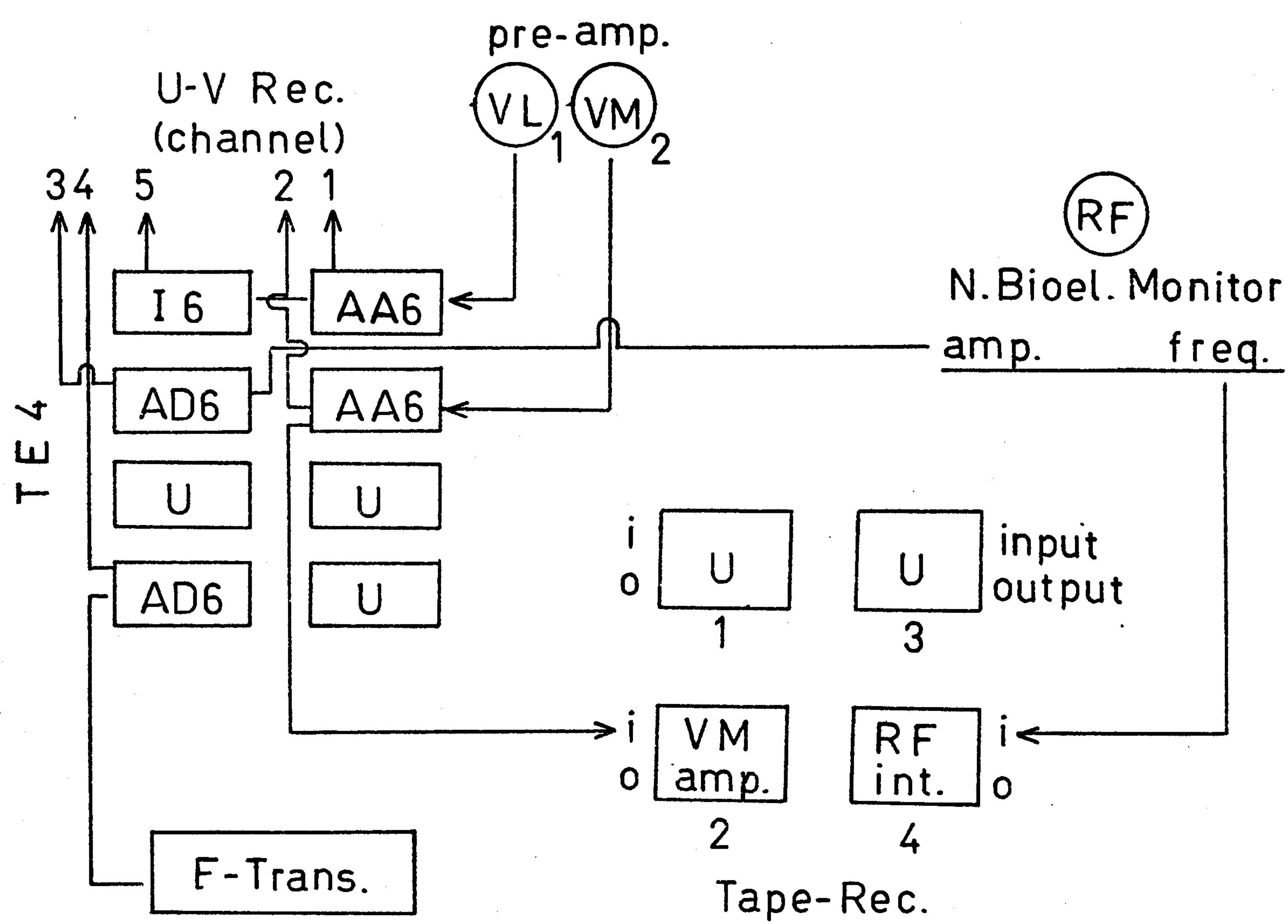
The E.M.G. of channel 2 (V.M.) was stored on tape for further used.

The amplification signal of the R.F. muscle was passed via channel 6 of the modular system by using the 'EXT' switch position of an AD6 amplifier (Teca Corp.). The frequency signal (I.E.M.G.) of this muscle was stored on tape for further use.

The output from the force-transducer (for W.T.1) was passed through the external circuit ('EXT') of a AD6 amplifier situated in channel 8 of the modular system, and it was recorded on channel 4 of the oscillograph recorder.

Channel 3, 4 and 7 of the modular system were not used and a board containing a U-shaped printed circuit was placed in each of these to insure the continuity of the circuit of the system.

Figure 4: Diagram of the recording circuits including the T.E.4 modular amplifiers, Integrators and pre-amplifiers system, the Newport Bioelectric Monitor, and the F/M Tape Recorder. (The symbol 'U' represents an unused channel).


pre-amp.
VL
1
VM
2
U-V Rec.
(channel)
3 4 5 2 1
RF
N. Bioel. Monitor
amp.
freq.
I 6
AA6
AD6
AA6
TE 4
U
U
AD6
U
i
o
U
1
U
3
input
output
i
o
VM
amp.
2
RF
int.
i
o
4
F-Trans.
Tape-Rec.

b. Retrieval

As the I.E.M.G. of the V.M. and of the R.F. muscles were not recorded on oscillograph paper, it was then necessary to obtain these recordings to complete the data.

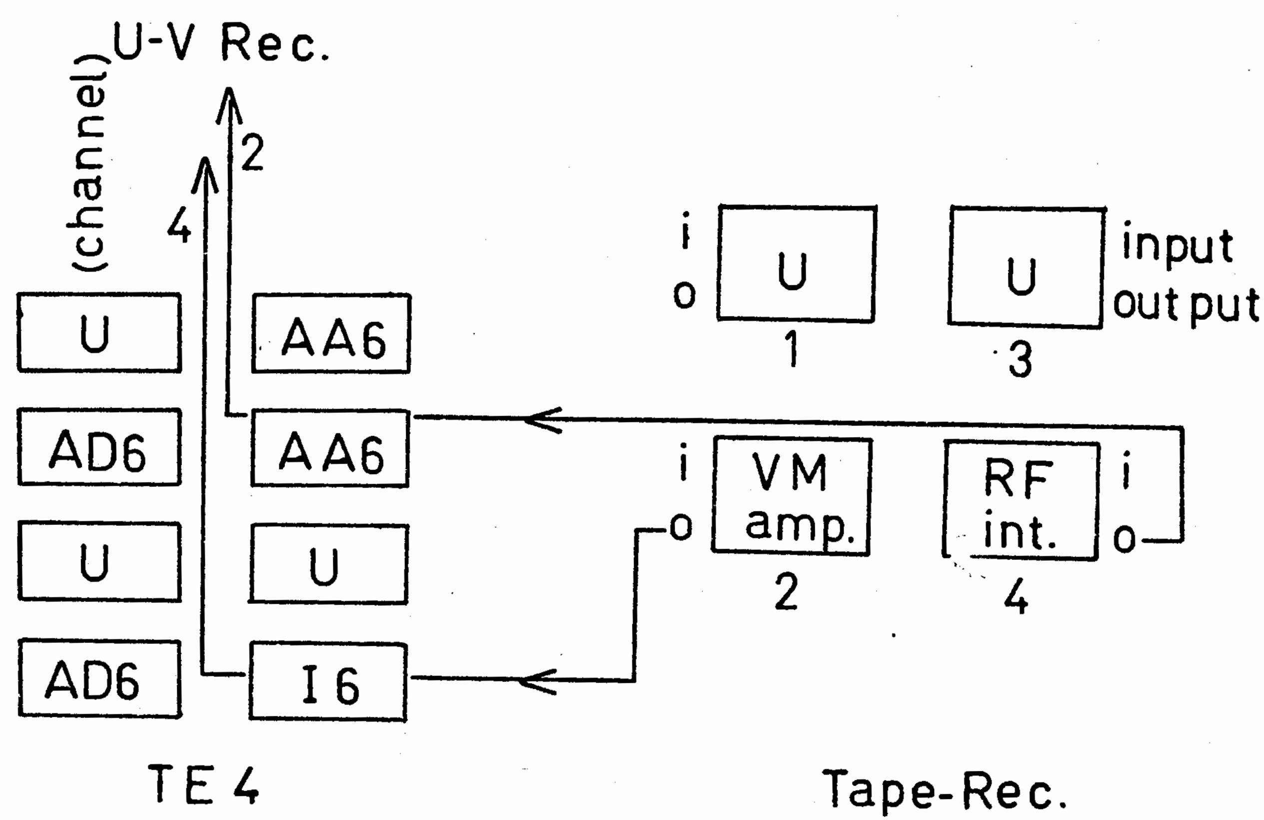
The frequency signal (I.E.M.G. in the form of a square wave signal) given by the Newport Integrating Bioelectric Monitor had been stored on tape. This recording was then passed through the AA6 amplifier of channel 2 swithched on 'EXT', and the data was collected on channel 2 of the oscillograph recorder.

As the E.M.G. of the V.M. muscle was stored on tape it was possible to obtain its I.E.M.G. by passing this stored E.M.G. through the I-6 integrator. For that purpose, the I-6 integrator was placed in channel 4 of the modular system and the recording was obtained on channel 4 of the oscillograph. The U-shaped circuit previously fixed in channel 4 was transfered into channel 5 which was not being used.

The recording of the I.E.M.G. of the V.M. and R.F. muscles was done simultaneously. The AA6 amplifier of channel 1 and the AD6 amplifiers of channel 6 and 8 were switched off. The integrator was still switched on. Finally the three printed circuits were placed in channels 3, 5 and 7 (see figure 5).

When the circuit was reorganized for the play-back procedure the tape recorder was started and recordings on the tape were passed into the circuit. The I.E.M.G. were displayed on the oscilloscope screen and it was possible for the experimenter to record on oscillograph paper a minimum of three seconds of each signal, including the calibration signals.

Figure 5: Diagram of the 'retrieval procedure' including the F/M Tape Recorder and the T.E.4 modular amplifier and integrator.


U-V Rec.
(channel)
2
4
U
AA6
AD6
AA6
U
U
AD6
I 6
TE 4
i
o
U
1
U
3
input
output
i
o
VM
amp.
2
RF
int.
4
i
o
Tape-Rec.

At the end of the procedure, the oscillograph paper contained the E.M.G. and the I.E.M.G. of each muscle under investigation, the resets of the calibration signals and the deflection from the force-transducer for W.T.1.

C. Procedures

i. Preparation, application and choice of site of the electrodes

Prior to the preparation of the skin, the electrodes were prepared according to following procedures.

Each electrode was fixed horizontally in a hole carved into a wooden board. An adhesive ring (a sticker adhesive on both side) was fixed to each electrode, permitting the latter to be stuck to the skin. The electrodes were then filled with jelly and immediately before their application they were inspected to ensure the presence of a small convexity of the surface of jelly. Any superfluous jelly was taken off with a razor blade and if a lack of jelly was evident, more was added to the electrodes until the required quantity was achieved.

The sites for application of the electrodes were chosen on the basis of trials performed during a pilot study. During the pilot study marks were placed at various points on the skin covering the three muscles under investigation. Subjects were requested to sustain maximal contractions of these muscles in a supine posture with the whole body fully supported on the table. Distances were measured between the marks and a reference mark on the skin over the tibial tuberosity. The thigh was then set at 30 degrees of hip flexion and these measurements were repeated. No significant differences were obtained between distances measured in either posture for those marks over the most prominant part of the belly of the muscles. Furthermore, this part of the belly of the muscle did not appear to change its relationship to the mark on the skin. It was therefore concluded that this amount of hip flexion would have no effect upon the relationship between the placement of electrodes and the fibres underlying the electrodes.

At the beginning of the first session, before the preparation of the skin, the subject was asked to perform a contraction of the quadriceps muscles (right leg). Through visual inspection and palpation the investigator chose the sites (as described in methods) and placed two dots of china ink, each dot being situated three centimeters apart longitudinally. This was easily done for the vastus medialis and vastus lateralis muscles, the bulk of each of these muscles being easily seen and palpated (Bos and Blosser, 1970). When this was not the case for the rectus femoris muscle, extension of knee was resisted by the investigator at the ankle level with one hand, having previously placed one arm under the subject's knee, at a fulcrum. As the bulk of the R.F. became more apparent, the site could be choosen for placement of the electrodes.

The ground electrode used for the V.L. and V.M. muscles was placed on the same leg, on the antero-medial part of the tibia, under the tibial spinous process (tubercle of the tibia), where a bony surface is very evident.

The surface electrode used as ground electrode for the R.F. muscle connected to the Integrating Bioelectric Monitor, was placed medially to the set of recording electrodes, all three forming an equilateral triangle.

Because the use of surface electrodes requires careful preparation of the electrode site (the skin having a high level of impedance), a constant technique was used, according to Kelley (1971).

The hair was shaved with a razor on a region wide enough to allow application of the electrodes. An alcohol solution was then applied to the area for the purpose of removing surface oils. To remove some of the epidermal cells, abrasion of the skin was performed with the help of a fine grade sandpaper. Some electrode jelly was then rubbed into the prepared area, with a toothbrush to ensure a low impedance of the skin. Finally, the surface of the skin was cleaned with a paper-cloth to take off the excess of jelly.

Each set of electrodes were applied to the chosen area of the skin, the distance between electrodes being three centimeters. The leads, near their attachment to the electrodes, were fixed to the skin with adhesive tape to prevent noise associated with movement of the leads.

The ground electrode (plate) was covered with jelly and fixed to its site with a velcro strap, the skin area having been cleaned with an alcohol solution.

ii. Pre-recording routine

After the electrodes had been placed and connected to their respective amplifiers, the oscilloscope screen was examined to check for the existence of electrical noise. If some noise appeared due to a malfunctioning of one set of electrodes, they were removed, the skin was cleaned, and the procedure for the preparation of electrodes was repeated.

The subject was then asked to perform a maximal isometric contraction of his quadriceps muscles. The gains for amplifiers 1 and 2 (V.L., V.M.) were then selected so that the maximal amplitude of the signal reproduced on the screen of the oscilloscope was kept within four divisions for each of these muscles. As stated previously the gain for the rectus femoris muscle was kept constant at a value of 10 mV./div. for each subject on all sessions. The gains chosen on the first session for the V.L. and V.M. muscles were then kept constant for each subject during the other recording sessions.

The integrator was then set a zero level with the subject at rest. This procedure was aided by examination of the integrated activity on the screen of the oscilloscope. A recording of the zero activity was taking for a minimum of three seconds.

The subject was then placed in position as described in Methods, with the force-transducer fixed and the weight-pan loaded for a maximal contraction to be performed. The subject was then asked to perform a maximal contraction against the load plus manual pressure on the weight-pan by the experimenter. At this time, the force-transducer amplifier indicator was set at a level which allowed approximately 90% of the full deflection of the recording galvanometer.

The distance between the articular line of the knee joint and the center line of the strap of the force-transducer was measured for each subject and maintained constant for all experimental sessions. This measure was registered as "d" and was latter used to calculate the extensor torque produce by the contraction of the quadriceps during W.T.1 and W.T.3 (see tables I and II).

iii. Testing sessions

a. Work task 1 (W.T.1)

At the completion of the pre-recording routine, E.M.G. recordings were made during the separate muscular contractions in the order described in table III. This sequence was done once for each session of investigation.

The movement, while lifting the loads, consisted in an extension of the knee joint to the 180 degrees position. The E.M.G. recording was made for a minimum of three seconds when the load became stationary. The subject was asked to avoid the straight leg raising movement, thus avoiding hip flexion, and to maintain the load steady. Between lifts, a minimal interval of sixty seconds of rest was allowed with insistance from the investigator on muscular relaxation.

Work task 1 (W.T.1) was performed with the aim of evaluating the relationship between the E.M.G. obtained from any one muscle and the total extensor torque produced.

b. Work task 2 (W.T.2)

After having performed W.T.1, the subject was freed from his attachment to the force-transducer and asked to lie supine on the table with only the heel projecting over the end. At this point, a minimum of three minutes of rest was allowed.

Seven maximal contractions of the quadriceps muscles were then performed as described in table IV.

The following general procedure was kept constant for all subjects through the whole session of W.T.2 recording:

<u>TABLE III</u>: Different conditions of isometric contractions of the quadriceps recorded under W.T.1. The extension was performed at 180 degrees and recorded for a minimum of three seconds in conditions of steady weight holding.

- Leg at rest (E.M.G. recording)
- Extension of the leg alone (nothing attached to it)
- Rest (minimum of 60 seconds)
- Extension of the leg with a weight of 6.94 kg.
- Rest (minimum of 60 seconds)
- Extension of the leg with a weight of 11.34 kg.
- Rest (minimum of 60 seconds)
- Extension of the leg with a weight of 19.14 kg.
- Rest (minimum of 60 seconds)
- Extension of the leg with a weight of 24.54 kg.
- Rest (minimum of 60 seconds)
- Holding in extension, knee locked with maximal resistance applied by the investigator by pressing on the weight-pan.

TABLE IV: Patterns of muscular contractions performed during W.T.2. Patterns number V and VII are known as being two P.N.F. patterns, taken from Knott and Voss (1968).

I)	Maximum isometric contraction of the quadriceps muscle
II)	As I, plus extension of the toes and dorsi-flexion of the foot
III)	As II, with dorsi-flexion being resisted manually
IV)	Extension of the toes, dorsi-flexion of the foot, hip flexion and lateral rotation of the leg, under manual resistance
V)	Extension of the toes, dorsi-flexion and inversion of the foot, hip flexion, lateral rotation and adduction of the leg, under manual resistance
VI)	Extension of the toes, dorsi-flexion of the foot, hip flexion and medial rotation of the leg, under manual resistance
VII)	Extension of the toes, dorsi-flexion and eversion of the foot, hip flexion, medial rotation and abduction of the leg, under manual resistance

- The subject was told the pattern to perform. Each pattern was explained to him prior to the performance

- The subject performed the pattern required against minimal resistance given by the investigator

- with the subject being at rest, the command "go" was given to the technician who started the FM-tape recorder

- the different commands were given to the subject so that he produced the pattern progressively as a whole movement and not as a succession of different movements. The resistance was increased by the investigator who gave the command "maximum" during the time of recording. The subject was then stimulated to maintain the contraction for a minimum of three seconds through maximal resistance and with loud verbal stimulation.

- after these three seconds of recording the subject was given the command "stop", always after the technician had stopped the recording apparatus (both tape and oscillograph simultaneously)

- a minimum of sixty seconds was allowed for rest before performing the next pattern

- when flexion of the hip was included in the pattern, it was limited to a 30 degrees elevation of the leg by the investigator

- when either medial or lateral rotation, and either abduction or adduction were included in the pattern, just a very limited amount of movement was allowed by the investigator.

During the contraction, the subject was not allowed to grip the under side of the table as this had resulted in the following problems in a preliminary study:

- Lifting of one hip on one side which had the effect of limiting the control of the investigator during rotation, hip flexion, and either abduction or adduction

- this manoeuvre could also lead to rolling of the skin over the muscle which would change the site of the electrodes over the muscles under investigation.

Nevertheless, subjects were allowed to place their hands flat on the side of the table, thus allowing the possibility of some kind of stabilization generally used in overflow stimulation.

The following specific instructions were given to the subject during the execution of the seven separate patterns.

Pattern 1

The subject was asked to "set" his quadriceps and to perform a maximal isometric contraction at the command "maximum" given by the investigator.

Command: set your quadriceps,
pull on your patella,
maximum, hold it...

Pattern 2

The subject was asked to extend his toes, perform a dorsi-flexion, and set his quadriceps muscles. Maximal dorsi-flexion was expected with maximal isometric contraction of the quadriceps muscles.

Command: bring your toes and foot up towards you,
pull on your patella,
maximum, hold it...

Pattern 3

The subject repeated the same procedure as for pattern 2, except that a maximal resistance was applied by the investigator against the dorsi-flexion. The subject was reminded not to flex his knee, nor his hip, and to concentrate on his maximal isometric contraction of the quadriceps.

The resistance was applied directly against the dorsal part of the foot with the left hand of the experimenter pulling towards him, his other hand holding the heel, in a grip manner from below.

Command: bring your toes and foot up towards you,
pull on your patella,
maximum, hold it...

Pattern 4

The subject repeated the same procedure as for 2, and followed with a hip flexion, giving a 30 degrees elevation of the leg. Finally this was followed by a lateral rotation of the leg, while concentrating on keeping the knee locked.

Hip flexion as well as dorsi-flexion were resisted by the left hand of the investigator placed on the dorsal surface of the foot. Rotation of the leg was resisted with his other hand holding the heel from below, in a grip position.

Prior to the recording, during the practice movement, it was emphasized that neither abduction, adduction, inversion nor eversion were to be performed. This requirement was also taken into consideration by the investigator, so that appropriate resistance would be used in a way which would neither confuse the subject nor stimulate other movements.

Command: pull your toes and ankle up towards you,
lift your leg,
turn your knee outward,
maximum, hold it...

Pattern 5

This pattern was included as being similar to the previous one and also as a P.N.F. pattern taken from Knott and Voss (1968).

The subject was asked to perform extension of the toes, dorsi-flexion with inversion of the foot, followed by hip flexion, lateral rotation of the leg and adduction.

It was understood that the knee had to be kept locked at all times, with no hip elevation (lifting) allowed. Nervertheless, elevation of the head and shoulders was permitted.

Command: pull your toes and ankle inwards and up towards you,
lift your leg,
turn your knee outward,
kick up and across inside,
maximum, hold it...

The investigator's left hand placed on the medio-dorsal face of the foot resisted the dorsi-flexion and inversion, as well as the hip flexion and adduction. The right hand, surrounding the heel from below in a grip position, resisted lateral rotation.

Pattern 6

Pattern 6 was primarily concerned with medial rotation as was pattern 4 with lateral rotation.

Subjects were asked to perform extension of the toes with dorsi-flexion of the foot followed by hip flexion and medial rotation of the leg.

Due to the fact that few subjects had a tendency to perform inversion with medial rotation, at the very beginning of the experimental work, more attention had to be placed on the separation of these two movements.

Dorsi-flexion and hip flexion were resisted by placing the left hand of the investigator on the dorsal surface of the foot. The medial rotation was resisted with the other hand surrounding the heel in a grip position.

Command: pull your toes and ankle up towards you,
lift your leg,
and turn your knee inward,
maximum, hold it...

Pattern 7

This pattern was presented to the subject as similar to, but more complex than pattern 6. It was another P.N.F. pattern taken from Knott and Voss (1968).

The subject was asked to perform extension of the toes, dorsi-flexion, eversion of the foot followed by hip flexion, medial rotation of the leg and abduction.

The investigator resisted the dorsi-flexion, eversion, hip flexion and abduction with his left hand placed on the latero-dorsal surface of the foot. Medial rotation was resisted with the right hand surrounding the heel in a grip position.

Command: pull your toes and ankle up and outwards,
lift your leg,
turn your knee inward,
and kick up across and outside,
maximum, hold it...

The sites of manual contacts for sensory stimulation and resistance are different from those proposed by Knott and Voss (1968) as far as the two P.N.F. patterns involved are concerned. This was due to the fact that the three sets of skin electrodes on the thigh precluded the suggested ideal hand placement. After a few trials in a pilot study using hand placements of Knott and Voss (1968), a high level of electrical noise was produced due to manipulation of the skin. Thus, the sites used were chosen to permit sufficient control by the investigator without interfering with the electromyographic recordings.

c. Work task 3 (W.T.3)

The purpose of W.T.3 was to replicate W.T.1 although on this occasion the knee was partially flexed in a position of 160 degrees of extension (180 degrees represents full extension).

This experiment was performed to verify results of W.T.1 as the behavior of each component through W.T.1 may have been confounded by the position of a locked-knee or complete extension.

Subjects were asked to extend the knee at different percentages (e.g. 0, 25, 50, 75, 100%) of maximal voluntary contraction. Sixteen recordings at different percentages of force were made on three subjects (N=3) on each of two occasions.

The compliance of the attachment of the force-transducer allowed only a very small movement of extension.

The commands were: - pull up to X%, - hold it... (while recording), - rest.

By visual examination of the output from the force-transducer the investigator was in a position to indicate the level of contraction required.

A minimum of thirty seconds of rest was allowed between each contraction and the levels of contraction requested were selected randomly.

Emphasis on knee extension was made with insistance that the subject avoided hip elevation and straight leg raising.

The same procedures as for W.T.1 were followed regarding the apparatus and recording of data.

iv. Calibration during the testing session

After the final muscular contraction the subject was freed from electrode attachments and calibration of both the E.M.G. apparatus and the force-transducer was performed.

A generator was used to pass a one mV. (peak to peak) square wave into the Newport Integrating Bioelectric Monitor for the purpose of calibration. Since the two AA6 modules had internal calibration signal generators, it was possible to record the calibration signals from the three amplifiers.

A weight of 24.54 kg. was attached to the weight-pan of the force-transducer. While the force-transducer was held horizontally the tape recorder was started and when it reached a constant speed the oscillograph recorder was started for data recording. After one or two seconds of recording with the force-transducer held horizontally, it was then placed in the vertical plane and the weight lifted for approximately three seconds.

During the calibration procedure, a paper speed of 2 cm./sec. was used.

v. Training sessions (W.T.2)

Nine training periods which did not include recording, were performed by each subject during W.T.2 as follows:

- three sessions following the first session of investigation,
- three sessions following the second session of investigation,
- three sessions following the third session of investigation.

Each session lasted for a period of ten to fifteen minutes and consecutive sessions were separated by either one or two days depending upon the availability of the subjects.

The purpose of training was to ensure that each subject learned each task so that they could perform it easily in as short a time as possible.

The seven contractions or patterns required for W.T.2 were performed by subjects for a minimum of five to seven repetitions during each session. The same commands, use of resistance and stimulation as described previously were used by the investigator. Each pattern was well described and practiced in terms of what to do and what not to do. It was insured that each subject knew how to perform each pattern properly as required. The aim of the study was revealed to the subjects at the end of the experimental work only.

D. Accuracy of the Results

The accuracy of the values of the torque (kg.cm.) produced and the electrical activity (mV.) registered depended upon such factors as the reproduction of the subject's posture, calibration of the force-transducer and electromyograph, and reproduction of the position of the electrodes.

i. Reproduction of posture

The postures previously described regarding each work task were meticulously repeated and kept constant. No change of procedures occured through the experimental work and no piece of equipment was either changed or modified.

ii. Reproduction of the position of electrodes

Before taking off the electrodes after the first investigation period, their contours were marked with china ink. The subject was then asked to retrace over these marks daily if necessary.

Because a few subjects forgot that procedure at the beginning of the experiment, it was necessary to trace them again for the following session. This was nevertheless an easy task as the area was well shown by the shaved zone.

iii. Reproduction of the site of the force-transducer

The distance "d" taken at the first session of investigation, gave a reference point for placement of the force-transducer for the following sessions. This insured the consistency of the lever-arm used for each subject.

E. Method of Analysis

i. Preliminary graphical analysis of the data

After each testing session data were in the form of tracings on U/V sensitive oscillograph paper. Displacement of the trace produced by the galvanometer which was coupled to the force-transducer, was recorded in millimeters. Values of I.E.M.G. were obtained by counting the number of resets (peaks on the sawtooth recording) in one second.

Digital values obtained from analysis of the recordings were placed on a data sheet (figure 6) and converted to values in their respective units by reference to calibration graphs. Initially the number of resets per second produced by the input of 0 mV. and 1 mV., was recorded for each of the three amplifiers. The deflection produced by the application of a known weight to the force-transducer was also recorded.

Figure 6: Data sheet used for W.T.1 and W.T.2 showing values that were used for drawing the Force-Transducer calibration graph, E.M.G. calibration graphs, torque/volts curves (3), and a Histogram of volts/patterns for each muscle

DATA SHEET

Name__________ No._____ Session #________ Date__________

A) Force-Transducer Calibration: Load:________ kg. Deflection:________ mm.

B) Force-Transducer Calibration graph:

Torque	Deflection
leg______ kg.cm.	______ mm.
weight______ kg.cm.	______ mm.
leg + Wt______ kg.cm.	______ mm.

C) E.M.G. Calibration graph:

Cal. in			Resets
V.L.	0 mV.	:	______
	1 mV.	:	______
V.M.	0 mV.	:	______
	1 mV.	:	______
R.F.	0 mV.	:	______
	1 mV.	:	______

D) Torque/volts curves in kg. cm./mV. (W.T.1):

Torque	E.M.G.- Resets & Volts						F-Transd. Deflec. mm.
	V.L.		V.M.		R.F.		
	R	V	R	V	R	V	
Leg at rest							
Leg only							
Wt 1 X d							
Wt 2 X d							
Wt 3 X d							
Wt 4 X d							
Wt 5 X d							

E) Histogram of Volts/patterns (W.T.2):

Pattern	E.M.G.- Resets & Volts					
	V.L.		V.M.		R.F.	
	R	V	R	V	R	V
Wt 5 X d (W.T.1)						
I						
II						
III						
IV						
V						
VI						
VII						

Data from W.T.1 were obtained by measuring the deflection of the oscillograph trace from the force-transducer in a region where it was steady for at least one second. I.E.M.G. values were obtained for each muscle from the same region of the trace. The same procedure was used when analysing the recordings of W.T.3.

For W.T.2, I.E.M.G. values were obtained from a region of the trace when a maximal spike count occured for one second duration.

At this time the data sheet contained all the information necessary in digital form to construct the following:

- a calibration graph of the relationship between the total extensor torque produced about the knee joint and the deflection of the trace from the force-transducer (figure 7),
- a calibration graph for each channel of E.M.G. of the relationship between input voltage to the amplifier and number of resets of the integrator (figure 7),
- a graph of the relationship between integrated output voltage from each muscle and the total torque developed about the knee joint (figure 9),
- a histogram of the integrated output voltage from each muscle for each pattern used in W.T.2 (figure 8).

a. <u>Relationship between extensor torque and output from the force-transducer</u>

The total extensor torque produced was the sum of the torque applied to the limb by suspension of a weight from it and the torque due to the mass of the leg. The graph was constructed in the following manner.

Figure 7: Calibration graphs for the Force-Transducer, and I.E.M.G. for each muscle (see text).

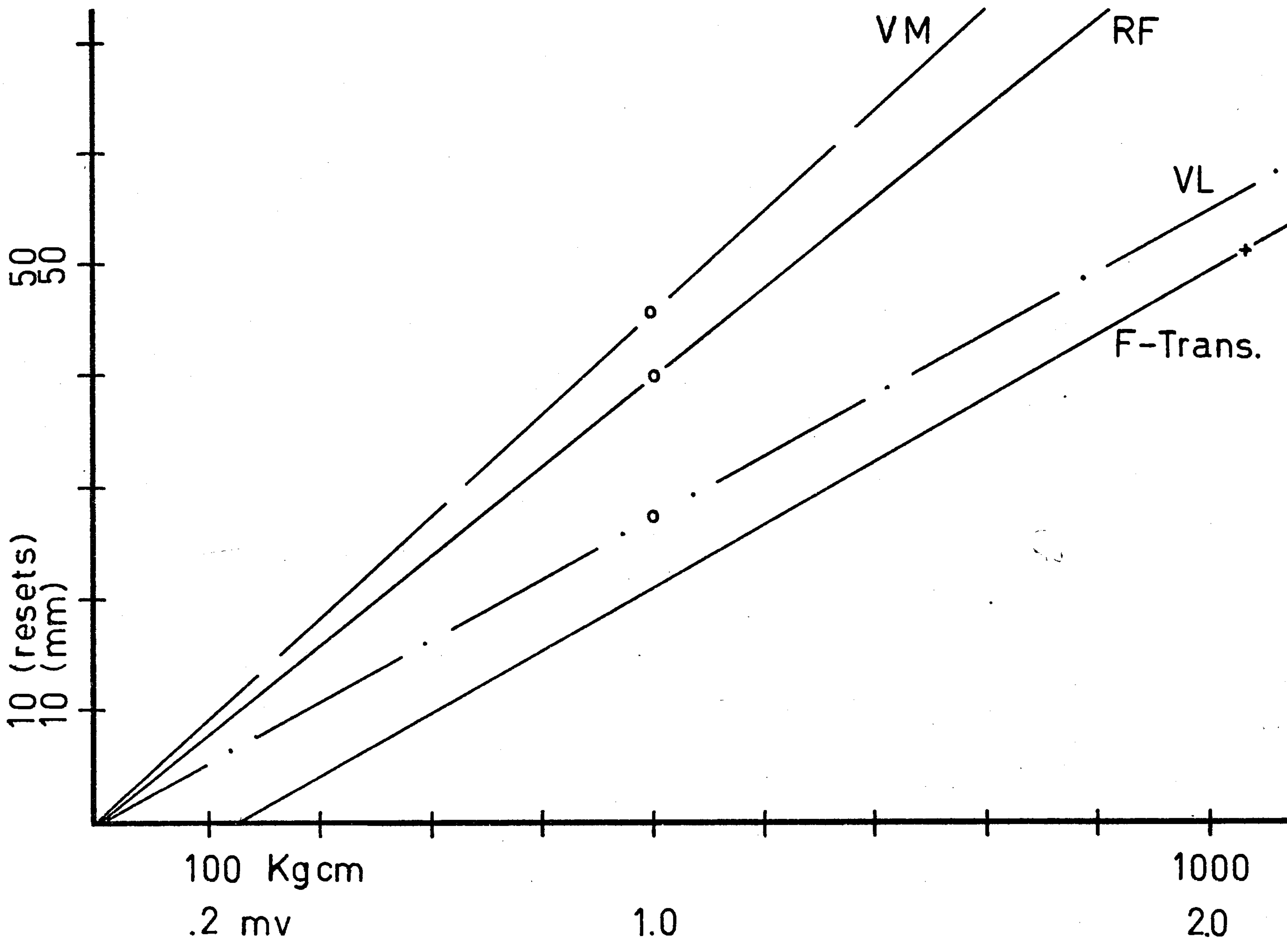
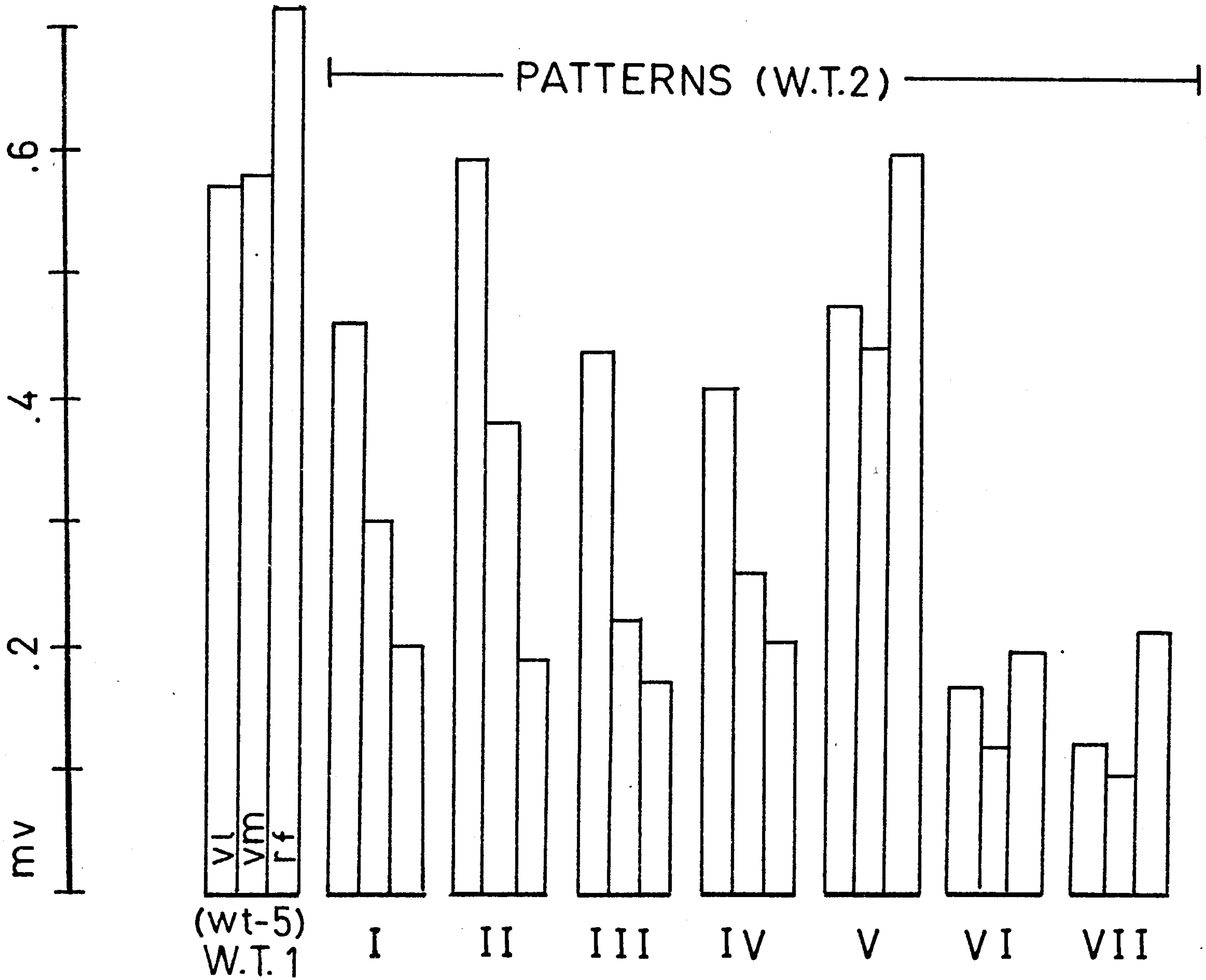

VM
RF
VL
F-Trans.
50
50
10 (resets)
10 (mm)
100 Kgcm
.2 mv
1.0
1000
2.0

Figure 8: Histogram of the integrated output voltage from each muscle, from each pattern used in W.T.2. (Example taken from one subject, one recording session).


mv
.2
.4
.6
vl
vm
rf
(wt-5)
W.T. 1
PATTERNS (W.T.2)
I
II
III
IV
V
VI
VII

The torque produced when lifting the leg from the stool without application of a load was calculated from the following formula (Dempster, 1955).

leg alone: $T = \frac{6.2}{100} M \times \frac{13.7}{100} S$

leg+ wt: $T = \frac{6.2}{100} \times \frac{13.7}{100} \times M \times S + wt \times d.$

M = Subject's mass
S = Subject's stature

Thus the value "T" obtained corresponded with zero deflection of the trace from the force-transducer. The second point chosen was the value of the torque produced by the leg lifting a weight of 24.54 kg. at a given distance from the knee joint. A "Calibration line" was then drawn passing through these two points.

Thus it was possible to find the values of the torque produced for each deflection obtained from the trace produced by the force-transducer. These values were finally recorded on the data sheet and kept for further use.

b. <u>Electromyographic calibration</u>

As the gain of three amplifiers and integrator combinations were maintained within their limits of linearity between input-voltage and integrated output it was possible to construct and use an E.M.G. calibration graph for the I.E.M.G. of each muscle investigated.

An input of 0 mV. produced either zero or a small number of resets and 1 mV. input produced a much larger number of resets. A line plotted through these two coordinates gave the E.M.G. calibration curve for an amplifier-integrator combination.

Therefore the number of resets produced by each muscle during any contraction could be converted into a value in volts.

c. Relationships between torque and electromyographic activity

The values of both deflection and I.E.M.G. resets obtained from W.T.1 and W.T.3 were converted into units of torque and mV. respectively by using the appropriate calibration graphs.

These converted values were used to construct a graph of the E.M.G. produced by each muscle against total torque developed about the knee joint for a range or torques from the zero to maximum.

d. Histogram of I.E.M.G. obtained with each pattern

The number of resets per second produced by each muscle during W.T.2 were converted into millivolts. A histogram was then constructed of the voltage obtained from each muscle during the execution of a given pattern. Pattern number one on the abcissa represents the respective voltage of each muscle while performing the maximal extension movement of W.T.1. The seven other sets (2 to 8) represent the output voltage from each muscle during each pattern of W.T.2. Such histograms were for immediate visual examination and as a guide to the statistical analysis.

ii. Statistical analysis

Following preliminary analysis of the data, appropriate statistical treatments were applied to the results of the following work tasks.

a. Work task 1 (W.T.1)

For each value of torque developed about the knee joint there were three values of I.E.M.G. obtained, one from each muscle.

The Pearson product-moment coefficient of correlation (r) (Guilford, 1965) was used to assess the degree of correlation between the I.E.M.G. of any two of the three muscles. Thus three coefficients of correlation were obtained, one for each pair of muscles (V.M.-V.L.; V.M.-R.F.; V.L.-R.F.).

b. <u>Work task 2 (W.T.2)</u>

Using the information obtained from the previous manipulation of data (use of the histrograms in preliminary analysis), the analysis was completed by means of:

- an analysis of variance (Kirk, 1968) was implemented as a Two-way analysis of variance with block effects (Decus program library, Focal 8-124, Analysis of variance package, W.D. Ronald, Canadian Dept. of Agriculture, Vancouver, B.C., March 25, 1970),
- Scheffe's contrast between means (Decus program library, Focal 8-16, Scheffe's contrast between means, M.J. McKeown, Chicago Lying-In Hospital, University of Chicago).

An analysis of variance was performed for each muscle under investigation in order to test the change in I.E.M.G. with respect to sessions and patterns (Kirk, 1968). This "Two-way analysis of variance with block effects" was performed using the ratios of (see Discussion):

$$\frac{\text{value in mV. of one muscle in one pattern}}{\text{value in mV. of same muscle during the max. contraction from W.T.1}}$$

The fraction shown above was used in an attempt to normalize the I.E.M.G. DeVries (1968) has indicated that reproducible absolute level of I.E.M.G. can be obtained during the production of a given muscular force with both repeated application of the electrodes and repeated experimental sessions. However, this repeatability can only be assumed if such factors as the impedence of tissues are maintained at a constant level. In ordre to avoid the necessity of measuring impedence, it was decided that the I.E.M.G. obtained during standard loading of the quadriceps should be used as a reference with which the remaining I.E.M.G. values could be compared. It was felt tha loading the leg, both with weights and application of force by the experimenter (see wt 5 in W.T.1) represented the greatest possible stress on the quadriceps muscles in full extension of the knee. Consequently it was assumed that maximal values of I.E.M.G. were likely to be obtained during this manoeuvre for all subjects on all sessions of recording. The raw values of I.E.M.G. from which the ratio was calculated are tabulated in appendix 1.

This treatment was applied to each I.E.M.G. from each muscle for the five sessions of investigation performed.

The "mean", "variance" and "S.D." of the I.E.M.G. from each pattern, pooled over all sessions, were given consecutively for the seven patterns executed. The F-ratio was tested for significance at an alpha level of .05.

When a significant difference between group means was found by the analysis of variance, a Scheffe's contrast between means (Kirk, 1968) was performed to investigate more thoroughly the source of the difference.

This test revealed the significance of the difference between I.E.M.G. ratios obtained on given patterns for each subject separately, each value for a pattern being the mean of the pooled values of all I.E.M.G. results for a given pattern on all sessions.

c. Work task 3 (W.T.3)

During W.T.3 a total of sixteen coordinates of voltage (mV.) against torque (kg. cm.) were produced for the three muscles under investigation. The data was analysed by means of:

- a correlation coefficient (Guilford, 1965),
- curve fitting.

The coefficient of correlation was performed in a similar manner to that applied to W.T.1. However, three coefficients of correlation were obtained for each pair of muscles (V.M.-V.L.; V.M.-R.F.; V.L.-R.F.). The first coefficient of correlation was obtained from eight pairs of values of I.E.M.G. representing the eight lowest torques produced. The I.E.M.G. values from the highest eight torques were similarly investigated, and the final coefficient of correlation was obtained from the full sixteen pairs of points representing the full range of muscular contraction.

A curve fitting procedure was performed to assess the suitability of fitting either a linear or a quadratic equation to the relation between I.E.M.G. and torque. The formula presenting the smallest "mean square deviation" was choosen as offering the best fit (8 K Focal program, 1969).

CHAPTER IV

RESULTS

A. Work Task 1 (W.T.1)

Inspection of the correlation coefficients (r) obtained from the I.E.M.G. of pairs of muscles showed clearly that the activity of no pair of muscles was any better correlated than that of any other pair. Table V indicates that a high correlation is generally found for each pair with only twelve out of one hundred and five correlations below 0.811 which is significant at a level of confidence of 0.05. The mean values (r) pooled across subjects and sessions again indicate that no pair of muscles was any better correlated than any other pair of muscles.

Figure 9 shows a typical I.E.M.G. - Torque relationship for each muscle under investigation (one subject on one session).

B. Work Task 2 (W.T.2)

The main purpose of this study was to compare the effectiveness of different manipulative patterns on the lower limb in terms of muscle recruitment of the quadriceps components.

For a specific muscle on any particular session of recording the I.E.M.G. from all subjects was pooled; the means and S.D. were then calculated (tables VI, VII, and VIII) and plotted for each session (N=5) and each pattern (N=7) as shown in figures 10, 11 and 12. For any particular muscle, the I.E.M.G. from all subjects and all patterns was pooled; the means and standard errors (S.E.) were calculated (table IX) and then plotted against sessions of recording as shown in figure 13.

TABLE V: Work Task 1: Correlation coefficients of I.E.M.G. (mV.) between each pair of muscles for each session (N=5) and each subject (N=7), plus the mean value for each pair pooled across subjects and sessions. P<0.05 when r>0.811 and P<0.01 when r>0.918.

Subject no.		V.M.:V.L.	V.M.:R.F.	V.L.:R.F.
1	session 1	.885	.817	.980
	session 2	.858	.844	.983
	session 3	.885	.974	.812
	session 4	.806	.978	.775
	session 5	.910	.913	.977
2	session 1	.909	.981	.898
	session 2	.969	.941	.969
	session 3	.754	.939	.843
	session 4	.901	.973	.860
	session 5	.935	.986	.906
3	session 1	.904	.796	.946
	session 2	.792	.947	.757
	session 3	.940	.959	.824
	session 4	.921	.894	.773
	session 5	.864	.931	.724
4	session 1	.968	.987	.948
	session 2	.938	.881	.948
	session 3	.558	.959	.468
	session 4	.996	.966	.944
	session 5	.987	.987	.984
5	session 1	.988	.980	.971
	session 2	.930	.981	.973
	session 3	.970	.992	.987
	session 4	.853	.992	.879
	session 5	.964	.993	.931
6	session 1	.898	.922	.908
	session 2	.663	.840	.929
	session 3	.957	.895	.777
	session 4	.909	.988	.868
	session 5	.875	.926	.829
7	session 1	.983	.976	.954
	session 2	.913	.864	.880
	session 3	.920	.927	.804
	session 4	.975	.964	.976
	session 5	.715	.773	.926
		$\bar{\bar{X}}$ .891	$\bar{\bar{X}}$ .933	$\bar{\bar{X}}$ .980

Figure 9: The relationship between I.E.M.G.(mV.) and total torque obtained (Torque in kg.cm.) during W.T.1 from one subject on one recording session.

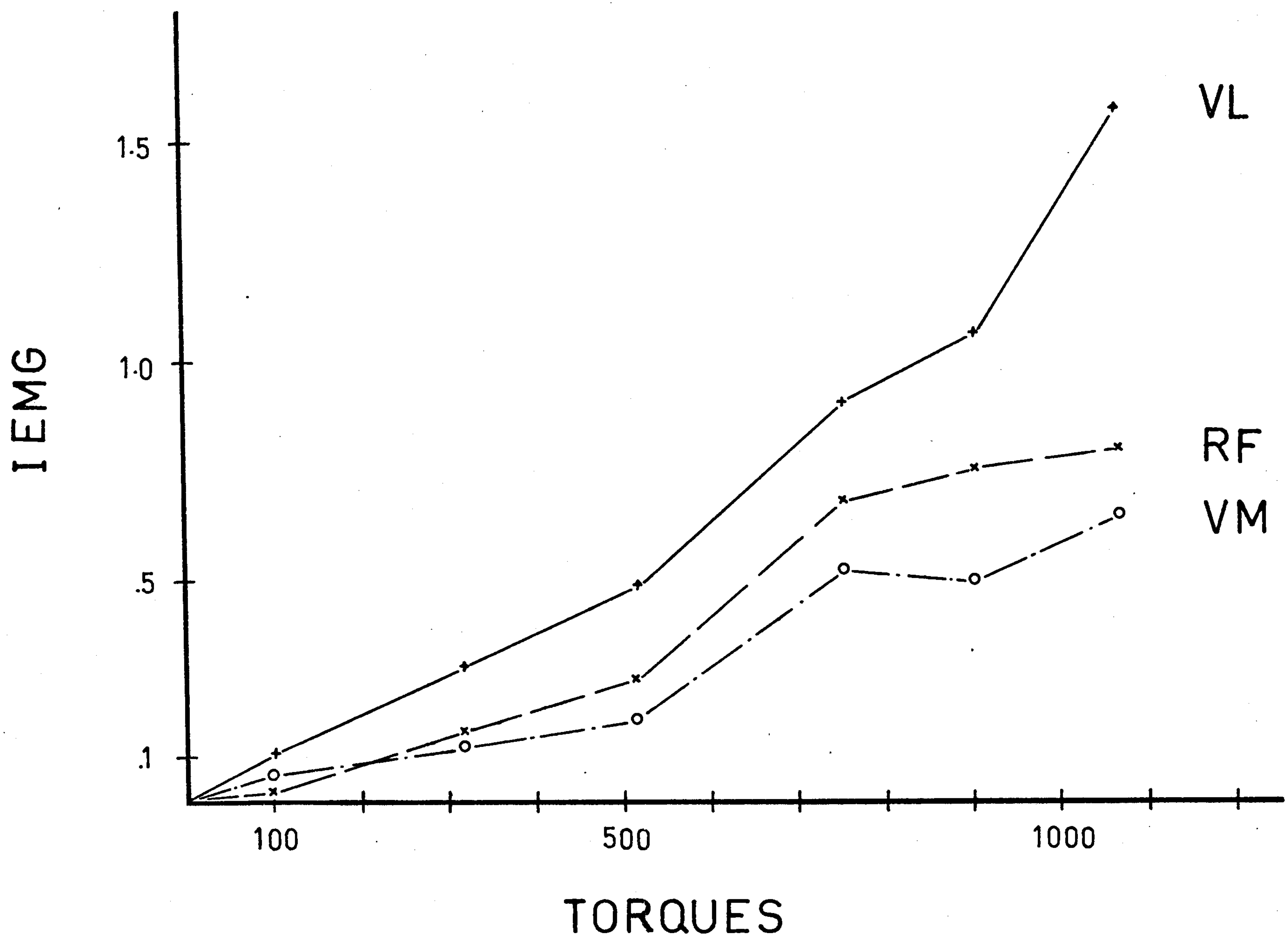
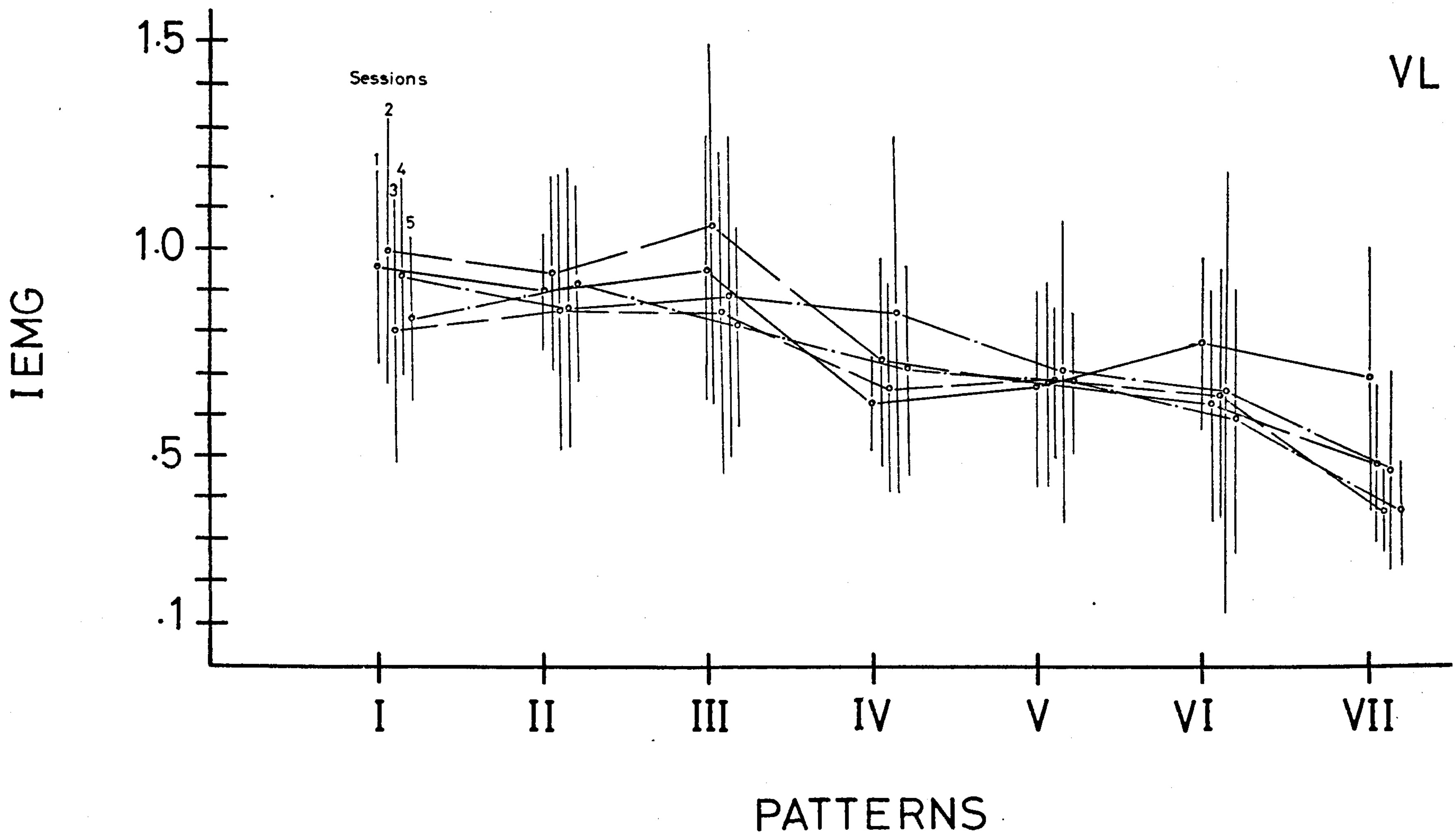

IEMG
1.5
1.0
.5
.1
100
500
1000
TORQUES
VL
RF
VM

TABLE VI: Means of the I.E.M.G. ratios from V.L. muscle of all subjects for sessions by patterns, with standard deviation (S.D.).

Session No	I	II	III	IV	V	VI	VII
	Means of I.E.M.G. ratios for sessions by patterns (V.L.)						
1	0.973	.904	.947	.626	.671	.782	.692
2	1.036	.904	1.054	.722	.670	.620	.479
3	0.802	.844	.845	.671	.683	.641	.362
4	0.960	.860	.896	.834	.690	.660	.468
5	0.830	.921	.821	.720	.687	.607	.389
	Standard Deviation for session by patterns						
1	.242	.154	.331	.116	.241	.210	.319
2	.389	.247	.444	.249	.253	.288	.184
3	.378	.339	.384	.267	.181	.314	.103
4	.249	.343	.393	.429	.383	.545	.261
5	.197	.244	.248	.254	.171	.333	.120
Pattern No	I	II	III	IV	V	VI	VII

Figure 10: The means of the I.E.M.G. ratios from V.L. muscle of all subjects, showing the change between sessions and patterns. Vertical bars represent the standard deviation (S.D.) between subjects.



VL
Sessions
1
2
3
4
5
1.5
1.0
.5
.1
IEMG
I
II
III
IV
V
VI
VII
PATTERNS

TABLE VII: Means of the I.E.M.G. ratios from V.M. muscle of all subjects for sessions by patterns, with standard deviation (S.D.).

Session No	I	II	III	IV	V	VI	VII
Means of I.E.M.G. ratios for sessions by patterns (V.M.)							
1	0.581	.739	.733	.620	.612	.765	.583
2	0.969	.864	.925	.924	.794	.777	.559
3	0.883	.948	.886	.797	.769	.682	.538
4	0.938	.704	.797	.726	.619	.676	.438
5	0.840	.894	.652	.687	.725	.602	.482
Standard Deviation for sessions by patterns							
1	.251	.203	.274	.169	.278	.325	.291
2	.397	.331	.363	.248	.340	.332	.214
3	.307	.294	.335	.355	.247	.222	.233
4	.291	.219	.313	.337	.206	.277	.148
5	.283	.280	.284	.202	.181	.247	.174
Pattern No	I	II	III	IV	V	VI	VII

Figure 11: The means of the I.E.M.G. ratios from V.M. muscle of all subjects, showing the change between sessions and patterns. Vertical bars represent the standard deviation (S.D.) between subjects.

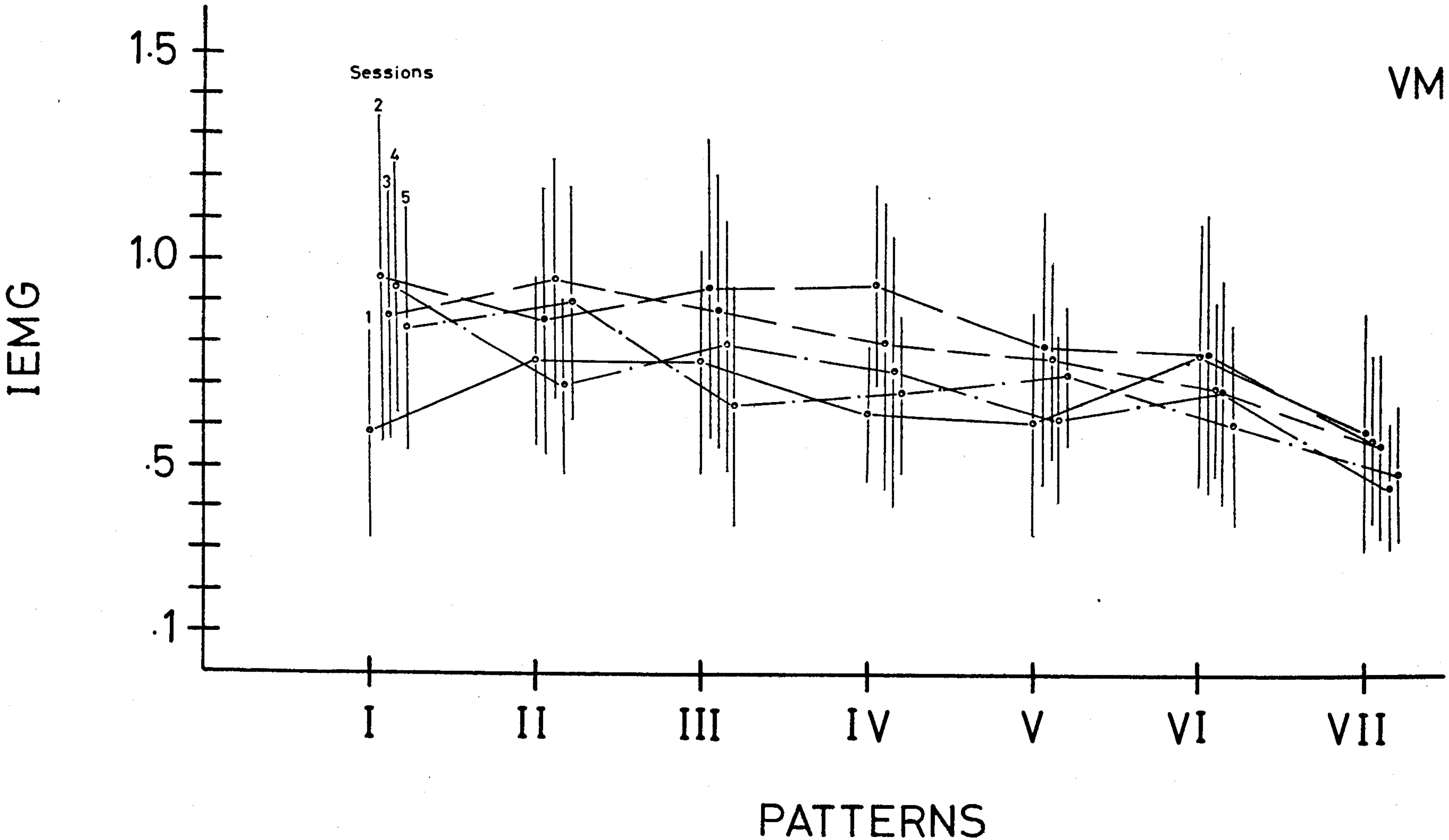

VM
Sessions
1
2
3
4
5
1.5
1.0
.5
.1
IEMG
I
II
III
IV
V
VI
VII
PATTERNS

TABLE VIII: Means of the I.E.M.G. ratios from R.F. muscle of all subjects for sessions by patterns, with standard deviation (S.D.).

Session No	I	II	III	IV	V	VI	VII
Means of I.E.M.G. ratios for sessions by patterns (R.F.)							
1	.326	.426	.496	.590	.680	.417	.532
2	.389	.325	.391	.721	.662	.481	.580
3	.398	.391	.521	.763	.700	.438	.516
4	.464	.348	.543	.737	.676	.459	.548
5	.480	.393	.470	.597	.759	.555	.635
Standard Deviation for sessions by patterns							
1	.210	.159	.224	.260	.218	.191	.230
2	.078	.072	.237	.259	.203	.122	.280
3	.161	.131	.410	.249	.204	.177	.183
4	.177	.170	.269	.295	.240	.243	.252
5	.198	.194	.232	.215	.184	.264	.217
Pattern No	I	II	III	IV	V	VI	VII

Figure 12: The means of the I.E.M.G. ratios from R.F. muscle of all subjects, showing the change between sessions and patterns. Vertical bars represent the standard deviation (S.D.) between subjects.

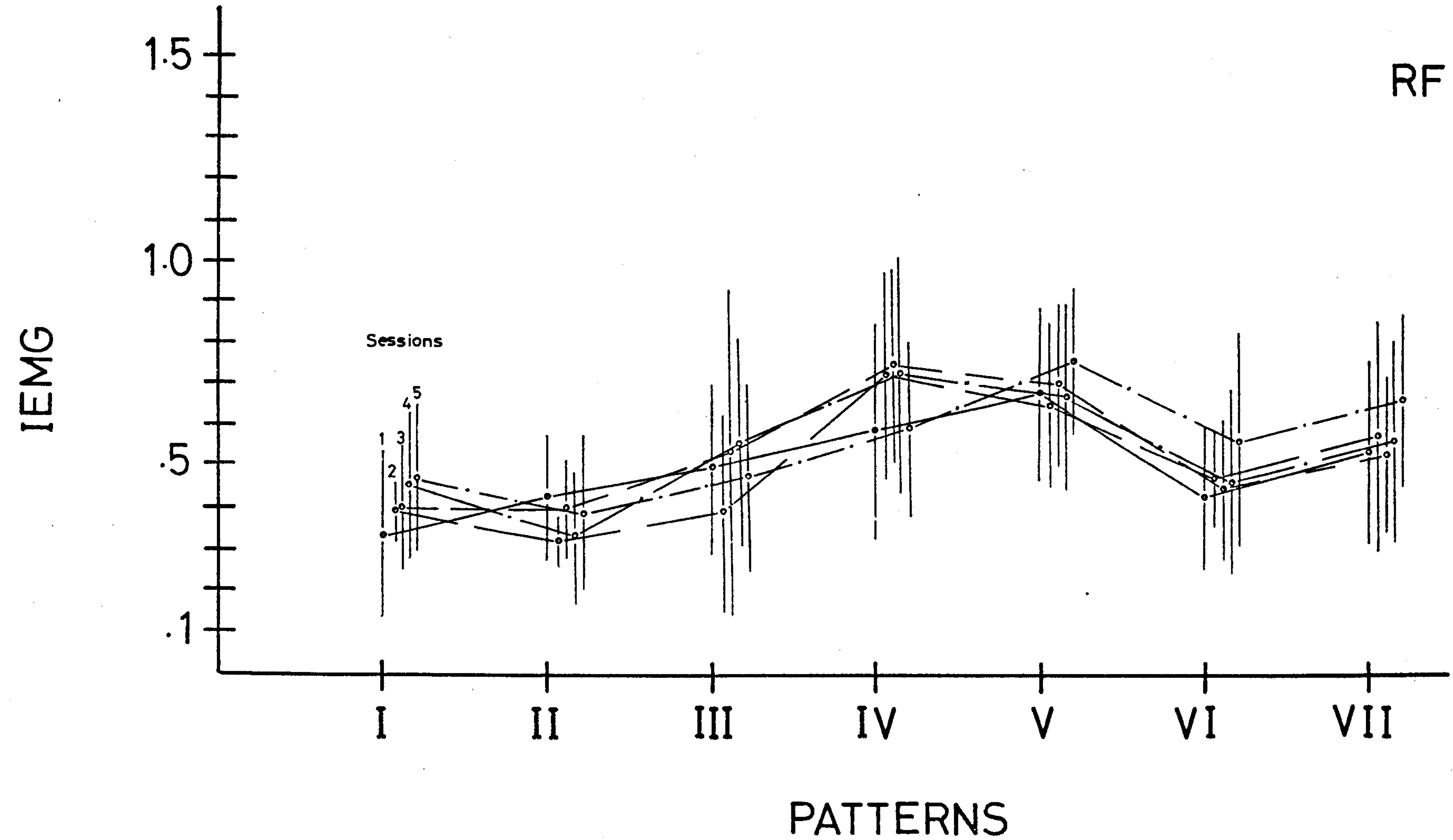
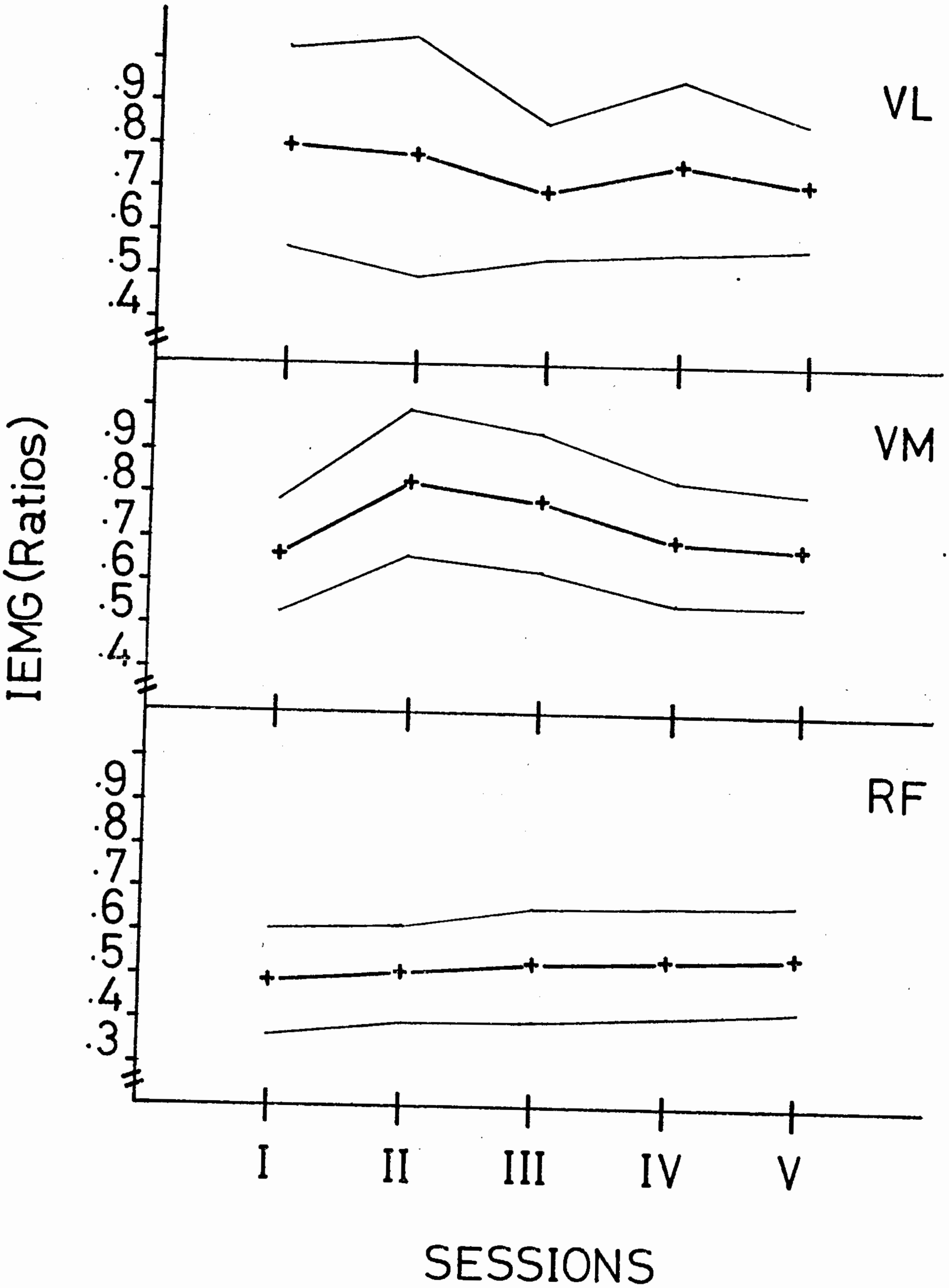

RF
IEMG
1.5
1.0
.5
.1
Sessions
1
2
3
4
5
I
II
III
IV
V
VI
VII
PATTERNS

TABLE IX: Means of I.E.M.G. ratios with standard error (S.E.) for training sessions pooled across subjects and patterns, respectively for V.L., V.M. and R.F.

Muscle	Means of I.E.M.G. ratios for sessions with S.E.				
V.L.	.800 (.137)	.789 (.184)	.693 (.168)	.767 (.207)	.711 (.142)
V.M.	.662 (.135)	.830 (.174)	.786 (.158)	.700 (.149)	.697 (.136)
R.F.	.495 (.120)	.507 (.120)	.533 (.134)	.539 (.134)	.555 (.122)
Session	1	2	3	4	5

Figure 13: I.E.M.G. ratios mean (thick line) S.E. (thin lines) for each muscle on each session.


IEMG (Ratios)
VL
VM
RF
.9
.8
.7
.6
.5
.4
.3
I
II
III
IV
V
SESSIONS

For a given muscle the I.E.M.G. from all subjects and all sessions was pooled; the means and S.E. were calculated (table X) and then plotted against patterns as shown in Figure 14.

From Figure 14, it can be seen that the tendency for V.M. and V.L. is not to behave differently in the first three patterns used when the data from all subjects is pooled.

This suggests that 'dorsi-flexion' (Pattern II) and 'manually resisted dorsi-flexion' (Pattern III) did not appear to produce 'irradiation-fixator action' (Piercy, 1973). To support this suggestion, no significant difference at the 0.05 level of confidence was found between the I.E.M.G. ratios obtained from any two of these three patterns (table XII).

Resisted dorsi-flexion, nevertheless, gave a slight increase of the I.E.M.G. activity of the R.F. muscle as may be seen in figure 12 where the results from each session are plotted separately. Subjects reacted quite differently to the manipulation of Pattern III as may be seen in figure 15, and only subject 7 presents a significant increase ($P<0.05$) from patterns I and II to pattern III.

Pattern IV introduced flexion of the hip with external or lateral rotation of the leg. A somewhat important decrease of activity (significant in subjects 2 and 7 at the 0.05 level) is noted in V.L. and there is a tendency for V.M. to decrease but not significantly (figure 14) for all subjects except for subject 7 (table XII).

A significant ($P<0.05$) increase in I.E.M.G. activity of the R.F. muscle was produced for four subjects (figure 14 and table XII). Some variations between subjects may be seen in figure 15.

TABLE X: Means of I.E.M.G. ratios with standard error (S.E.) for patterns pooled across subjects and sessions respectively for V.L., V.M. and R.F.

Muscle	I	II	III	IV	V	VI	VII
Means for levels of patterns							
V.L.	.920	.894	.913	.715	.680	.662	.478
V.M.	.842	.830	.799	.751	.704	.700	.520
R.F.	.411	.377	.484	.681	.695	.470	.562
Standard Error (S.E.)							
V.L.	.128	.113	.153	.118	.105	.147	.099
V.M.	.138	.116	.135	.118	.108	.118	.091
R.F.	.073	.063	.117	.109	.087	.086	.097
Pattern No	I	II	III	IV	V	VI	VII

Figure 14: I.E.M.G. ratios mean (thick line) S.E. (thin lines) for each muscle on each pattern.

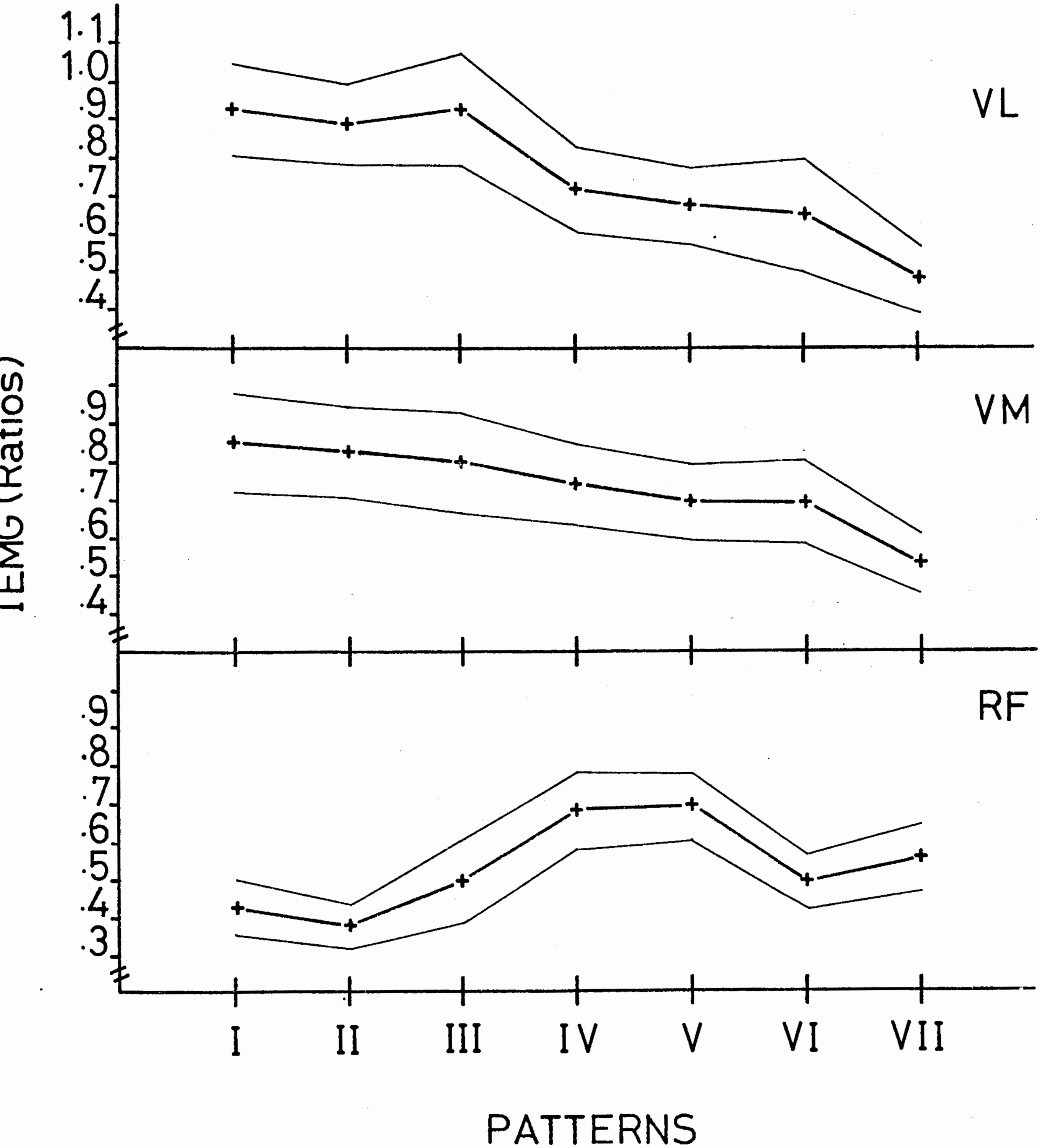

IEMG (Ratios)
1.1
1.0
.9
.8
.7
.6
.5
.4
VL
.9
.8
.7
.6
.5
.4
VM
.9
.8
.7
.6
.5
.4
.3
RF
I
II
III
IV
V
VI
VII
PATTERNS

Figure 15: The means for each subject and each muscle of the I.E.M.G. ratios obtained on all sessions plotted against patterns showing standard deviation (S.D.) as vertical bars.

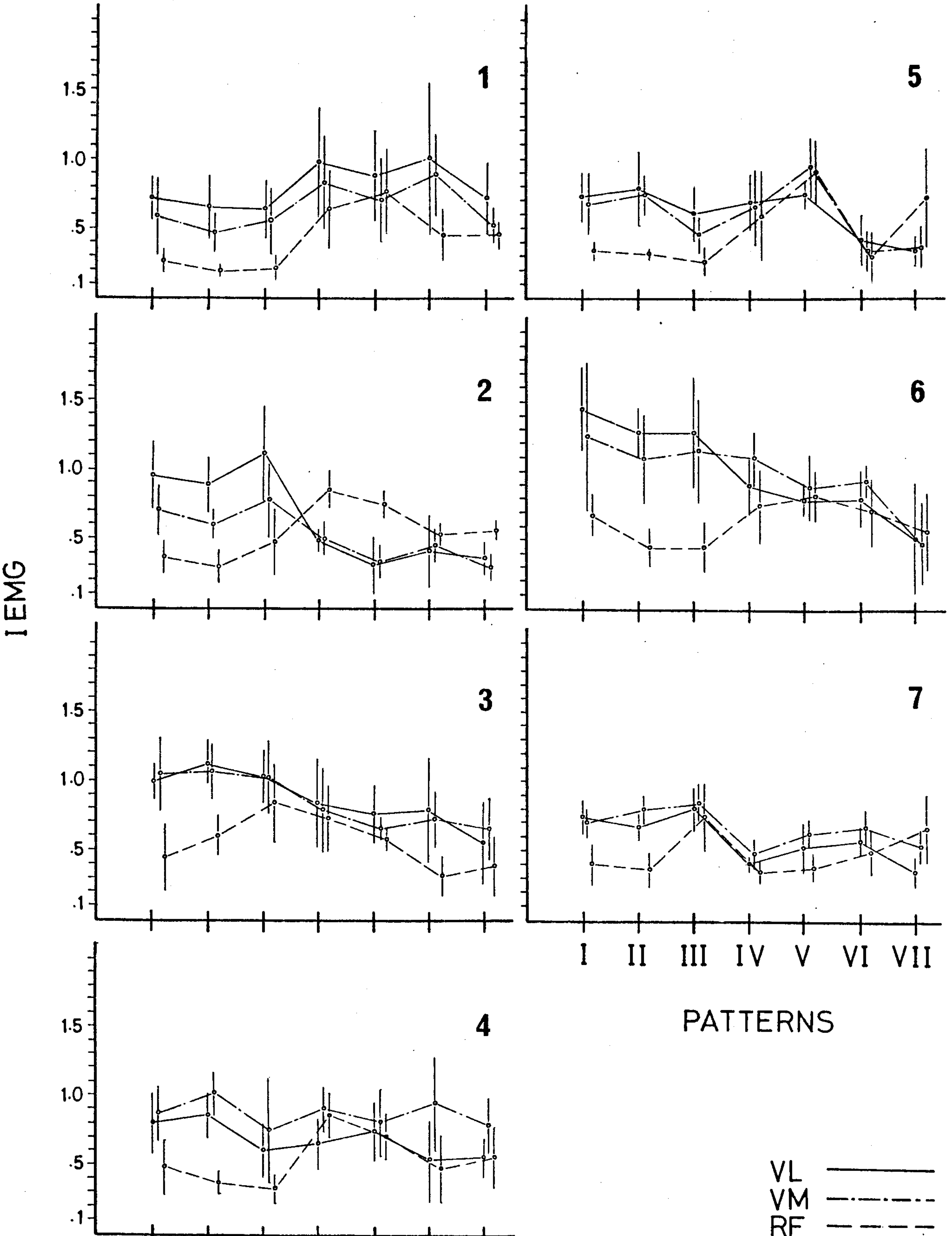

1
2
3
4
5
6
7
1.5
1.0
.5
.1
I EMG
I II III IV V VI VII
PATTERNS
VL
VM
RF

TABLE XI

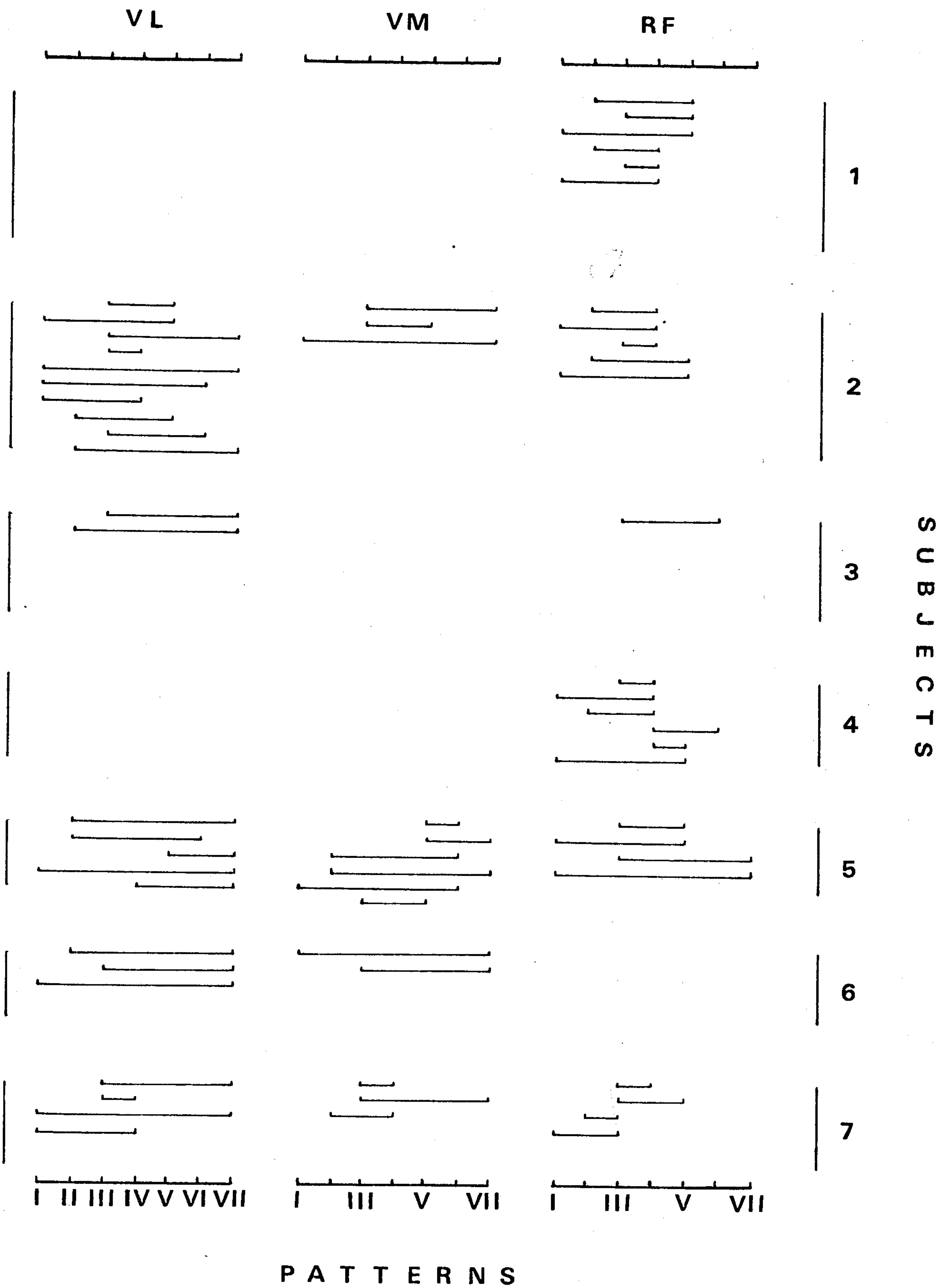
Within subject analysis of variance of I.E.M.G. ratios with block effects. The level of significance of each muscle is given for each subject with patterns (N=7) and sessions (N=5) pooled.

	SUBJECTS						
	1	2	3	4	5	6	7
V.L.	2.13*	13.69***	5.97***	2.65**	7.78***	7.44***	8.35***
V.M.	4.55***	6.47***	3.50**	1.05	12.21***	4.73***	7.32***
R.F.	13.46***	9.44***	4.22***	11.94***	11.19***	3.21**	5.66***

* Significant .10
** Significant .05
*** Significant .01

TABLE XII

Scheffe's analysis representing the combinations of pattern means witch are significantly different, for each subject, each muscle. A bar between any two patterns indicates a difference at the .05 level of significance.


VL
VM
RF
1
2
3
4
5
6
7
SUBJECTS
I II III IV V VI VII
I III V VII
I III V VII
PATTERNS

Pattern V which introduced an adduction component or diagonal characteristic together with dorsi-flexion and inversion of the foot, hip flexion and lateral rotation of the leg did not produce any significant effect (figure 14) compared with pattern IV. Nevertheless subject 4 presented a significant increase ($P<0.05$) in activity of the R.F. as compared to pattern IV.

Pattern VI which introduced medial or internal rotation, also failed to produce any improved muscular recruitment (figure 14) compared with patterns V and IV as far as the two vastii are concerned except for subject 5 who presented a significant ($P<0.05$) decrease in V.M. activity as compared to pattern V. Nevertheless a very important decrease of muscular recruitment occured for R.F. muscle (figure 14). This was evident in all but one subject (figure 15). None of the differences between patterns V and VII were significantly different at the 0.05 level of confidence.

Pattern VII produced a decrease in activity of V.M. and V.L., while a small increase was noted in R.F. muscle (figure 14). This seems, to be quite constant, in the individual graphs (figure 15). Nevertheless these changes in muscular activity do not differ significantly at the 0.05 level from the previous pattern (VI) (table XII).

Mean I.E.M.G. values were compared within subjects by a two-way analysis of variance with block effects where patterns (N=7) and sessions (N=5) were pooled. The F-ratios and their levels of significance are shown in table XI.

Table XII shows mean I.E.M.G. ratios between pairs of muscle which were significantly different for each subject and each muscle. Variability within subjects is obviously a determinent point in this study as can be seen in table XII and figure 15.

C. Work Task 3 (W.T.3)

Correlation coefficients shown in Table V indicate that a high level of correlation exists between the activity of pairs of muscles. Table XIII shows that correlations obtained during the eight contractions producing the greatest torques are higher than those obtained during the eight contractions producing the lowest torques. Only six pairs show a correlation below 0.800. Because the amount of data was too small the significant level of these correlations was not studied as it would have been meaningless (Gilford, 1965).

Curve fitting analysis showed that there was no significant preference for either a linear or quadratic fit (see table XIV).

Figure 16 is a typical graph showing the relationship between torque and I.E.M.G. for one subject.

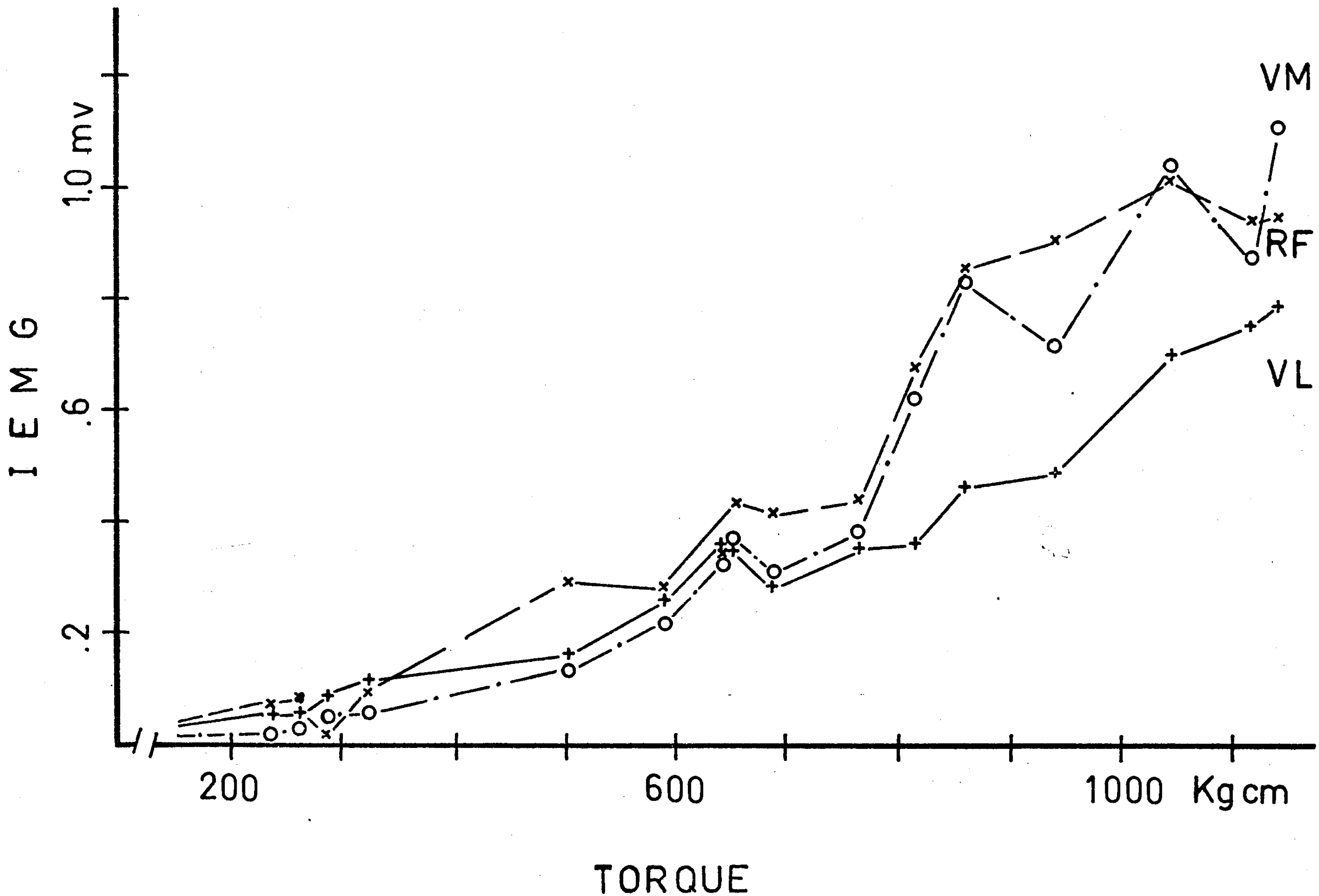
TABLE XIII: Showing the three coefficients of correlations obtained for each pair of muscles (V.M.-V.L.; V.M.-R.F.; V.L.-R.F.). The first "r" was obtained from eight pairs of values of I.E.M.G. representing the eight lowest torques produced; the second "r" is the one of the eight last and highest torques produced; and the third is the "r" obtained from the full sixteen pairs of points representing a full range of muscular contraction from W.T.3. The mean value of "r" within subject for all sessions is shown at the bottom of the table.

Subject	Session	V.M.-V.L.			V.M.-R.F.			V.L.-R.F.		
		1-8	9-16	16 pairs	1-8	9-16	16 pairs	1-8	9-16	16 pairs
1	1	.902	.828	.894	.788	.945	.934	.917	.885	.898
	2	.843	.973	.979	.622	.918	.950	.810	.855	.908
2	1	.735	.951	.957	.872	.989	.991	.832	.966	.972
	2	.878	.951	.964	.807	.886	.983	.942	.943	.962
3	1	.993	.905	.963	.938	.945	.978	.924	.851	.942
	2	.655	.806	.915	.872	.962	.957	.702	.759	.874
	$\bar{X}$	.834	.902	.946	.816	.957	.965	.855	.877	.926

TABLE XIV: Curve fitting analysis showing the mean square deviation for both linear and quadratic equations studied on each muscle, each subject, each session. The lowest value determines the best equation fitting these data.

Subject		1		2		3		
Session		1	2	1	2	1	2	Equation
V.L.		.08	.04	.02	.03	.05	.16	linear
		.04	.04	.02	.03	.03	.10	quadratic
V.M.		.07	.06	.04	.05	.11	.08	linear
		.07	.06	.03	.05	.09	.05	quadratic
R.F.		.05	.07	.01	.07	.09	.07	linear
		.05	.06	.01	.07	.09	.07	quadratic

Figure 16: Typical relationship between I.E.M.G. (mV.) and Torque (kg.cm.), from each muscle during W.T.3 from one subject on one session.



I E M G
1.0 mv
.6
.2
200
600
1000 Kgcm
TORQUE
VM
RF
VL

CHAPTER V

DISCUSSION

A. Work Task 1 (W.T.1)

From the results given in table V it may be seen that there is good correlation (r) between each pair of muscles investigated. This indicates that each muscle followed very closely the behavior of the others and that no particular pairing of muscle activity is better correlated than any other.

On all occasions for each subject at each session approximate linear relationships were obtained between I.E.M.G. and torque and a typical example of this relationship obtained for one subject on one session is shown in figure 9. Although the relationships are not perfectly linear, it may be concluded that they represented scatter about a true linear relationship. It was felt that this assumption was valid for no non-linear trend was observed when all the data obtained from W.T.1 was examined.

To have attempted to define the relationship between I.E.M.G. and torque more explicitly would have extended data collection unreasonably without garantee of greater definity in W.T.1 against the possible hazard of muscular fatigue affecting the data of W.T.2. As the aim of W.T.1 was to investigate a proposed linear relationship between I.E.M.G. and Force, it was felt that the present data were acceptable and that they justified the pursuit of analysis of W.T.2 which was the main purpose of this study. There is no doubt that greater reliance must be placed on the prior investigations reported in the literature on this relationship.

B. Work Task 2 (W.T.2)

Dorsi-flexion of the foot to produce over-flow to the quadriceps muscles gave results which were in agreement with the work of Basmajian (1967). It is obvious that different subjects vary in response to this technique as shown in figure 15. Even with resisted dorsi-flexion no greater recruitment of the two vastii muscles was obtained compared with the previous patterns (I and II) as shown in figure 14. Nevertheless, if over-flow can be produced, it seems to have had its effect on the R.F. muscle which showed increased activity (figure 14) but significantly so in subject 7 only (table XII). Again subjects vary in response to this manoeuvre (figure 15).

The addition of hip flexion seems to produce a negative effect on recruitment of the vastii (figure 14) as previously shown by Basmajian (1967). Only subject 7 presented a significant difference ($P<0.05$) for the three muscles under investigation. Gough and Ladley (1961), and Allington et al. (1966) substantiated this tendency with reference to a straight leg raising exercise. Nevertheless variations from subject to subject is found (figure 15).

Lateral rotation did not prove to have any general effect on V.M. activity which differs from previous investigations (Wheatley and Jahnke, 1951; Bos and Blosser, 1970). From pattern III to IV an overall decreased activity of the V.L. muscle was observed (figure 14) with subjects 2 and 7 showing significant differences ($P<0.05$) (table XII).

A combination of dorsi-flexion and inversion of the foot, flexion of the hip, and adduction and lateral rotation of the leg did not produce any general increase of V.M. muscle activity (figure 14) when compared to pattern III except for subject 5. Nevertheless, subject 2 showed a significant decrease ($P<0.05$) in this comparison. Hip flexion combined with lateral rotation of the leg (pattern IV) produced a very large increase in activity of R.F. muscle which was significant for four subjects. This finding supports the work of Carlsoo and Fohlin (1969) and such an effect may be expected as R.F. muscle is a flexor of the hip. Isolated effects of lateral rotation could not be evaluated due to the complicated nature of the manoeuvre, although Carlsoo and Fohlin (1969) suggest that lateral rotation is insignificant. Unfortunately, the limitations of this study allow no definitive observations on the theory that rotary components are a major factor for increasing muscular recruitment (Vele et al., 1967). The inclusion of inversion of the foot had little if any effect on the vastii muscles and this effect is similar to that observed by Gough and Ladley (1961). Of particular interest is the work of Lesage and LeBars (1970) who have shown a selective augmentation of the activity of R.F. muscle compared to the vastii, while performing adduction of the leg with external rotation of the foot.

Internal rotation (pattern VI) failed to produce any marked increase ($P<0.05$) in the activity of the V.L. muscle (figures 14 and 15) as suggested elsewhere (Wheatley and Jahnke, 1951; Bos and Blosser, 1970); the addition of an abduction component, together with eversion of the foot, etc. (pattern VII) produced further decrease of activity of both V.L. and V.M. in nearly all subjects (figures 14 and 15), and significantly so ($P<0.05$) for 5 subjects when compared to one of the three first patterns. This is clearly in disagreement with other work (Wheatley and Jahnke, 1951).

Eversion of the foot as a component in itwelf does not seem to have any definite positive effect on recruitment.

Internal rotation (pattern VI) seemed to produce a marked but non-significant decrease in activity of the R.F. (figure 14) as compared to pattern V. On the other hand, the addition of abduction (pattern VII) produced an increase in activity of the R.F. in all but one subject, but not significantly as compared to the previous patterns (table XII). This seems to be in accordance with the results of Wheatley and Jahnke (1951) and may be explained by the fact that R.F. is considered to help in abduction of the leg (Basmajian, 1967).

The positive effects of external rotation on R.F. partially support the theory of Vele et al. (1967) who stated that a rotation component is most important in the manipulative patterns and theory proposed by Kabat and Knott (1953). However the present work does not confirm this for internal rotation.

It is doubtful that inversion, eversion and even dorsi-flexion of the foot produced any functional over-flow to the three muscles under investigation.

From table XII it can be noted that pattern VII has presented a significant decrease in activity of the V.L. in five subjects when compared with the results of the first three patterns. The same can be reported for the V.M. where four subjects showed significant decrease in activity ($P<0.05$) as compared to the first three patterns. Five subjects showed significant increases in E.M.G. activity ($P<0.05$) for the R.F. between pattern V and either one of the three first patterns investigated.

It is believed that comparisons can be made for the R.F. muscle between either one of the three first patterns (leg flat on the table) and the four other patterns where the thigh is flexed at 30^{o}. Even though the shortened position of the muscle under thigh flexion may theoretically bring changes in electrical activity (bigger muscular volume under the electrodes), observation and palpation suggest that such an effect would have been minimal. In which case the increase in muscular activity recorded was probably due to the increased load induced by S.L.R. In the case of the vastii muscles, either the lying position or S.L.R. position should not have affected the position of the electrodes over the muscle fibers. Consequently comparisons between the results obtained from the first three patterns and the remaining four patterns are permissible.

As far as the mono-articular muscles (vastii) are concerned, the more complex the task seems to be the less activity seems to be developed by these muscles.

Results obtained from single bi-articular (R.F.) muscle confirm its role in flexing the hip and helping the abduction of the leg. Yet in general, inhibition seems to have been produced by the use of internal rotation of the leg. No clear explanation can be given for this phenomenon at the present time.

The P.N.F. pattern (pattern V) comprised flexion of the hip, adduction and external rotation of the leg plus inversion and dorsi-flexion of the foot with the knee straight. This might be expected to place the same demand on the muscles of the knee as a similar pattern (Knott and Voss, 1968) performed with active extension of the knee. To support such a statement Basmajian (1967), while investigating similar patterns as these stated: "The most effective technique for maximal motor unit activity was having the subject actively perform extension of the knee against resistance - not in a static position but during motion. Nonetheless, in many subjects, static contractions were just as effective - or even more effective - and therefore cannot be categorically condemned". Levine and Kabat (1953) also stated: "Our observations indicate that quantitatively the contractions of muscles isometrically represent the same relationships as they do in isotonic contractions for the particular portion of the range studied". Knott and Voss (1968) concluded that the muscular work at the knee level is executed mainly by the V.M. muscle, the articularis genu and the R.F. (medial portion). The present results demonstrate that V.M. was not recruited in preference to V.L. and it is difficult to understand why Knott and Voss (1968) did not include the vastus intermedius (V.I.) in their observations, at least in the place of the articularis genu since the former demonstrates a specific role in knee extension (Lieb and Perry, 1971; Basmajian _et al_., 1972). The addition of the term "medial portion" for the active part of R.F. muscle seems to be quite a new concept especially after the rejection, by Basmajian (1957, 1967), of theory of distal and proximal bulks (Markee _et al_., 1955). With regard to hip movement, the sartorius muscle may be included in accordance with the statement of MacConaill and Basmajian (1969): "... is active during flexion of the thigh regardless of whether the knee is straight or bent".

The other P.N.F. pattern (pattern VII), which used flexion of the hip, abduction and internal rotation of the leg and eversion of the foot combined with dorsi-flexion with the knee straight, theoretically should require the same muscular work for the muscles crossing the knee as when knee extension movement is included in the pattern. Again Knott and Voss (1968) suggested that the V.I., V.L., R.F. (lateral portion) and the articularis genu should be activated in these patterns. The results of the present study do not confirm the inclusion of V.L. and the exclusion of the V.M.

Of course it is possible to argue the fact that better muscular recruitment can be obtained when the knee joint is fixed over a fulcrum with the leg performing extension against maximal resistance. Nevertheless, the best method for recruitment of the quadriceps muscles is not under investigation here. What is under investigation is the effects of different patterns of movement on the recruitment of the quadriceps. Because the two P.N.F. patterns investigated (knee straight) have the same position as finally reached during the similar patterns involving knee extension (Knott and Voss, 1968), the facilitatory effects may be expected to be similar in that final position.

More investigation should be done to study the effects of maximal resistance offered at different angles of knee extension during performance of these two patterns (V and VII). Comparison should also be made between recruitment produced during a simple maximally resisted knee extension and knee extension maximally resisted while performing P.N.F. patterns V and VII.

Wheaton (1968) studied the gain in strength of quadriceps muscles trained in both a standing and a sitting position which he classified respectively as functional and non-functional exercise positions. He clearly demonstrated that the standing position produced a marked absolute and more rapid increase in strength. Houtz, Lebow and Beyer (1957) had performed similar work and even though their results may not be directly comparable with those of Wheaton (1968) their main conclusion was: "The posture of the subject has a greater effect on the realizable force developed at the knee than does the influence of gravity on the leg, or the stabilization of adjacent parts". Such a statement is interesting in that muscles can behave quite differently depending upon the training position used. While such a statement has its application in this study, it is not new; Rasch and Morehouse (1957) studied the effect of static and dynamic exercises on muscular strength and hypertrophy and noted: "Whereas subjects showed strength gains in the tests when muscles were employed in a familiar way, little or no gain in strength was observed when unfamiliar procedures were employed". More investigation is nevertheless needed to determine whether one is actually testing a real gain in strength and not degree of familiarity with the testing procedure.

For comparison of the present data with previous work, it should be noted that Bos and Blosser (1970) used the standing position and active voluntary isometric contraction only. Wheatly and Jahnke (1951) described interesting data on this topic, but it is not clear when they refer to the V.M. and V.L. muscles if the results obtained from both lying and standing positions were pooled for analysis. Gough and Ladley (1961) used half-lying and lying positions with submaximal effort and produced results which are more in agreement with those presented here in terms of the effects of some patterns of movement on specific muscles.

While Basmajian (1967) presented the results of Wheatley and Jahnke (1951) he seems to have failed to reproduce similar findings consistently in an unpublished experiment with the collaboration of physical therapists, investigating the effects of patterning of the leg on the quadriceps muscles. He even concluded that: "The lesson to be learned by Physiotherapists and rehabilitation specialists from these findings is one of healthy scepticism for many of the dogmatic teachings that bear on the methods of evoking maximal quadriceps activity. Some of our findings appear to confirm dogmas, others flatly contradict them, and still others show that different subjects react in different ways". His findings seem to be very similar to ours, when the exercises in question refer to the exercises and posture used in this study.

Rasch and Morehouse (1957) conclude in their study: "The findings suggest that the higher scores in strength tests resulting from the exercise programs reflected largely the acquisition of skill". After training sessions ranging over a four weeks period, Kroll (1965b) did not find any learning factor as far as facilitation is concerned for contralateral effects in an isometric form of work. Even though Payton and Kelley (1972) have reported acquisition of skill during execution of a simple task we could not offer the same conclusion through our method of analysis for our gross patterns of activity. If a prolonged learning period is needed when using P.N.F. patterns with the aim of recruitment activity in a specific muscle or group of muscles, a loss of time in muscular reeducation may be encountered in such cases were our data are applicable. Consequently, in the field of orthopaedic medicine, other techniques than those used in patterning should be considered seriously for the rehabilitation of the injured quadriceps muscles. Furthermore as the response of individuals to a given technique of patterning appears to vary (figure 15), it may prove more profitable to find and use techniques which give a more predictable degree of recruitment for the larger number of the injured population.

The reason for normalizing the I.E.M.G. by the means of the ratio have been discussed in Methods of analysis. If this manoeuvre is considered valid, the ratio gives a measure of how closely the I.E.M.G. obtained during any pattern changed relative to the 'standard' value of I.E.M.G. Consequently it is possible to investigate any trends in the relative activity which occur with practice and therefore ascribe the results to a process of learning.

In the non-normalized I.E.M.G. data (see appendix 1) there is more variation than in the ratios but there are no obvious trends which would indicate learning (see appendix 3).

C. Work Task 3 (W.T.3)

Similar graphs to figure 9 were plotted from the results of W.T.3 (see figure 16), and again, a similar kind of relationship between Torque and I.E.M.G. was shown as previously in W.T.1. From these results, there were no evidence that the locked knee position may have altered the values of the results of W.T.1. In fact the locked knee position seemed to produce less scatter in the I.E.M.G.-Torque relation then that obtained with the knee set at 160 degrees of flexion.

The table of correlations (r) (table XIII) of I.E.M.G. between different pairs of muscles shows a uniform high correlation. No particular pair of muscles present a significantly higher correlation than any other two pairs in agreement with the data of W.T.1.

The average (mean) correlations given for the eight highest torques show higher correlations than are the average (mean) correlations for the eight lowest torques. The average of the sixteen contractions produced demonstrate a very high level of correlations.

The curve fitting program which studied the mean square deviation for both linear and quadratic equations for each muscle, each subject and each session, shows that there is no significant preference for either linear or quadratic fit (see table XIV).

This is clearly of interest and needs future investigation. However it can be seen that some points which represent the highest levels of torques produced have the tendency to deviate from the linear relationships obtained from the low and mid-range torques. As stated previously, many more points involving many more muscular contractions would be needed to define clearly the nature of the relationship.

CHAPTER VI

CONCLUSIONS

The more complex of the patterns investigated in this study produced variability in recruitment between subjects and could therefore be considered variable in terms of producing over-flow to the three components of the quadriceps muscles under investigation.

The functional anatomy of each component investigated was confirmed in its principle action i.e. the vastii being extensors of the knee, and R.F. being a flexor of the hip, extensor of the knee as well as assisting in abduction of the hip.

No ipsilateral over-flow to the quadriceps could be demonstrated by means of distal (at the foot) and proximal (hip) stimulation during maximal manual resistance and other facilitation mechanisms (voice, etc.). No "universality" or "inborn" characteristics were observed.

No training effect or learning, in terms of muscular recruitment, was observed during regular practice and investigation lasting two months with seven normal healthy subjects, under the criteria used in this study.

Consequently, it is felt that more experimentation should be pursued on the topic of patterning and facilitation. This is justified by the fact that the existing literature on the subject is very contradictory, and that few studies are devoted to this topic in comparison with the popularity of its use in clinical practice.

After many more studies of this type, the field of muscular rehabilitation will be enhanced and many of the practices which are now based upon theory, will be based upon fact.

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APPENDIX

1. Raw data for W.T.1 and W.T.2

2. Raw data for W.T.3

3. Histograms of the raw data

Appendix 1: Raw data for W.T.1 and W.T.2.

DATA SHEET

Name ______ Br. ______ No. 1 Session # 1 Date ______

A) Force-Transducer Calibration: Load: 24.54 kg. Deflection: 52 mm.

B) Force-Transducer Calibration graph:

Torque	Deflection
leg 125.87 kg.cm.	______ mm.
weight 883.44 kg.cm.	______ mm.
leg + Wt 1009.31 kg.cm.	53.5 mm.

C) E.M.G. Calibration graph:

Cal. in			Resets
V.L.	0 mV.	:	0
	1 mV.	:	46
V.M.	0 mV.	:	3
	1 mV.	:	40
R.F.	0 mV.	:	2
	1 mV.	:	44

D) Torque/volts curves in kg. cm./mV. (W.T.1):

Torque	E.M.G.- Resets & Volts V.L.		V.M.		R.F.		F-Transd. Deflec. mm.
	R	V	R	V	R	V	
Leg at rest	-	-	-	-	-	-	0
Leg only	4.0	0.09	9.0	0.16	2.5	0.02	0
Wt 1 X d	10.5	0.23	11.0	0.22	8.2	0.15	15
Wt 2 X d	12.0	0.27	20.5	0.47	12.5	0.25	21.5
Wt 3 X d	21.0	0.46	24.5	0.58	33.0	0.74	41.0
Wt 4 X d	23.5	0.51	24.0	0.57	33.0	0.74	53.5
Wt 5 X d	30.0	0.66	55.0	1.40	39.0	0.89	71.0

E) Histogram of Volts/patterns (W.T.2):

Pattern	E.M.G.- Resets & Volts V.L.		V.M.		R.F.	
	R	V	R	V	R	V
Wt 5 X d (W.T.1)	30.0	0.66	55.0	1.40	39.0	0.89
I	25.0	0.55	14.0	0.30	8.0	0.15
II	24.0	0.53	23.0	0.54	7.0	0.12
III	28.0	0.61	15.0	0.33	6.0	0.10
IV	18.0	0.39	17.0	0.38	8.4	0.16
V	15.0	0.33	12.0	0.27	20.0	0.27
VI	15.0	0.33	23.0	0.54	10.0	0.19
VII	26.0	0.57	19.0	0.43	16.0	0.33

DATA SHEET

Name ____ Da. ____ No. 2 Session # 1 Date ____

A) Force-Transducer Calibration: Load: 24.54 kg. Deflection: 51.5 mm.

B) Force-Transducer Calibration graph:

Torque	Deflection
leg 131.36 kg.cm.	____ mm.
weight 907.98 kg.cm.	____ mm.
leg + Wt 1039.3 kg.cm.	51 mm.

C) E.M.G. Calibration graph:

Cal. in			Resets
V.L.	0 mV.	:	0.6
	1 mV.	:	27
V.M.	0 mV.	:	3
	1 mV.	:	44
R.F.	0 mV.	:	1
	1 mV.	:	48

D) Torque/volts curves in kg. cm./mV. (W.T.1):

Torque	E.M.G.- Resets & Volts						F-Transd. Deflec. mm.
	V.L.		V.M.		R.F.		
	R	V	R	V	R	V	
Leg at rest	-	-	-	-	-	-	0
Leg only	3.0	0.10	4.0	0.01	6.0	0.11	0
Wt 1 X d	13.0	0.47	11.5	0.21	18.0	0.36	16
Wt 2 X d	12.0	0.44	13.0	0.24	19.0	0.38	28
Wt 3 X d	9.5	0.34	20.0	0.42	27.0	0.56	42
Wt 4 X d	18.0	0.66	23.0	0.49	30.5	0.63	51
Wt 5 X d	25.0	0.93	36.0	0.82	38.5	0.80	73

E) Histogram of Volts/patterns (W.T.2):

Pattern	E.M.G.- Resets & Volts					
	V.L.		V.M.		R.F.	
	R	V	R	V	R	V
Wt 5 X d (W.T.1)	25.0	0.93	36.0	0.82	38.5	0.80
I	34.0	1.27	28.0	0.62	22.5	0.46
II	25.0	0.93	25.0	0.54	20.0	0.41
III	41.0	1.53	36.0	0.82	33.0	0.68
IV	15.5	0.56	21.0	0.45	30.0	0.63
V	4.5	0.15	10.5	0.18	31.0	0.64
VI	22.0	0.84	23.0	0.50	16.0	0.32
VII	10.5	0.38	10.5	0.18	18.0	0.37

DATA SHEET

Name Gl. No. 3 Session # 1 Date ______

A) Force-Transducer Calibration: Load: 24.54 kg. Deflection: 57 mm.

B) Force-Transducer Calibration graph:

Torque	Deflection
leg 126.48 kg.cm.	______ mm.
weight 883.44 kg.cm.	______ mm.
leg + Wt 1009.92 kg.cm.	58 mm.

C) E.M.G. Calibration graph:

Cal. in			Resets
V.L.	0 mV.	:	0
	1 mV.	:	21
V.M.	0 mV.	:	0
	1 mV.	:	24
R.F.	0 mV.	:	0
	1 mV.	:	45

D) Torque/volts curves in kg. cm./mV. (W.T.1):

Torque	E.M.G.- Resets & Volts						F-Transd. Deflec. mm.
	V.L.		V.M.		R.F.		
	R	V	R	V	R	V	
Leg at rest	-	-	-	-	-	-	0
Leg only	14.5	0.70	19.0	0.80	8.5	0.19	0
Wt 1 X d	15.5	0.75	19.8	0.83	22.5	0.50	17
Wt 2 X d	19.0	0.91	17.5	0.74	30.0	0.68	29
Wt 3 X d	28.0	1.34	26.0	1.09	42.0	0.94	46
Wt 4 X d	28.2	1.35	32.0	1.34	42.0	0.94	58
Wt 5 X d	29.0	1.39	32.0	1.34	45.0	1.00	74

E) Histogram of Volts/patterns (W.T.2):

Pattern	E.M.G.- Resets & Volts					
	V.L.		V.M.		R.F.	
	R	V	R	V	R	V
Wt 5 X d (W.T.1)	29.0	1.39	32.0	1.34	45.0	1.00
I	33.5	1.60	19.0	0.80	3.8	0.07
II	32.0	1.54	29.0	1.21	20.0	0.45
III	34.5	1.65	32.0	1.34	33.0	0.74
IV	17.6	0.86	22.0	0.92	26.9	0.59
V	21.0	1.24	22.0	0.92	26.0	0.58
VI	32.0	1.54	23.2	0.96	10.8	0.24
VII	28.0	1.34	25.0	1.04	20.0	0.45

D A T A   S H E E T

Name ________ Gr. ________ No. 4 Session # 1 Date ________

A) Force-Transducer Calibration: Load: 24.54 kg. Deflection: 44 mm.

B) Force-Transducer Calibration graph:

Torque		Deflection
leg 100.0 kg.cm.		______ mm.
weight 809.8 kg.cm.		______ mm.
leg + Wt 909.9 kg.cm.		41 mm.

C) E.M.G. Calibration graph:

Cal. in			Resets
V.L.	0 mV.	:	0
	1 mV.	:	21
V.M.	0 mV.	:	0
	1 mV.	:	21
R.F.	0 mV.	:	1
	1 mV.	:	45

D) Torque/volts curves in kg. cm./mV. (W.T.1):

Torque	E.M.G.- Resets & Volts						
	V.L.		V.M.		R.F.		F-Transd. Deflec. mm.
	R	V	R	V	R	V	
Leg at rest	-	-	-	-	-	-	0
Leg only	2.20	0.11	1.00	0.05	2.0	0.01	0
Wt 1 X d	6.50	0.31	2.60	0.13	8.0	0.16	11
Wt 2 X d	7.50	0.50	4.00	0.19	13.0	0.28	21
Wt 3 X d	19.25	0.91	11.00	0.53	31.0	0.69	33
Wt 4 X d	22.50	1.08	10.5	0.51	34.0	0.76	41
Wt 5 X d	32.0	1.58	13.5	0.65	36.0	0.80	49

E) Histogram of Volts/patterns (W.T.2):

Pattern	E.M.G.- Resets & Volts					
	V.L.		V.M.		R.F.	
	R	V	R	V	R	V
Wt 5 X d (W.T.1)	32.0	1.58	13.5	0.65	36.0	0.80
I	26.5	1.25	14.0	0.67	14.5	0.31
II	27.5	1.29	16.0	0.71	19.0	0.41
III	24.0	1.15	14.0	0.67	14.0	0.30
IV	18.5	0.86	10.2	0.48	30.8	0.68
V	28.9	1.36	13.0	0.62	32.0	0.72
VI	33.0	1.58	20.5	0.97	29.0	0.64
VII	23.5	1.12	13.5	0.65	24.5	0.54

DATA SHEET

Name Ji. No. 5 Session # 1 Date ______

A) Force-Transducer Calibration: Load: 24.54 kg. Deflection: 63 mm.

B) Force-Transducer Calibration graph:

Torque	Deflection
leg 109.9 kg.cm.	______ mm.
weight 846.6 kg.cm.	______ mm.
leg + Wt 956.5 kg.cm.	60.5 mm.

C) E.M.G. Calibration graph:

Cal. in			Resets
V.L.	0 mV.	:	0.3
	1 mV.	:	89
V.M.	0 mV.	:	5
	1 mV.	:	80
R.F.	0 mV.	:	0
	1 mV.	:	46

D) Torque/volts curves in kg. cm./mV. (W.T.1):

Torque	E.M.G.- Resets & Volts						F-Transd. Deflec. mm.
	V.L.		V.M.		R.F.		
	R	V	R	V	R	V	
Leg at rest	-	-	-	-	-	-	0
Leg only	11.5	0.13	9.4	0.07	5.5	0.12	0
Wt 1 X d	25.4	0.28	17.5	0.17	11.5	0.25	17.5
Wt 2 X d	37.0	0.41	28.5	0.32	15.0	0.33	32.0
Wt 3 X d	40.0	0.45	31.8	0.37	21.5	0.47	49.0
Wt 4 X d	53.0	0.59	36.8	0.43	22.5	0.49	58.0
Wt 5 X d	54.0	0.61	41.0	0.49	25.0	0.54	68.5

E) Histogram of Volts/patterns (W.T.2):

Pattern	E.M.G.- Resets & Volts					
	V.L.		V.M.		R.F.	
	R	V	R	V	R	V
Wt 5 X d (W.T.1)	54.0	0.60	41.0	0.49	25.0	0.54
I	32.0	0.36	24.8	0.28	7.0	0.15
II	36.0	0.40	30.0	0.34	8.0	0.18
III	38.0	0.43	24.0	0.27	11.0	0.24
IV	47.0	0.53	33.5	0.39	23.0	0.50
V	39.5	0.44	37.0	0.44	23.3	0.51
VI	39.0	0.43	25.0	0.28	9.0	0.20
VII	27.5	0.31	23.0	0.25	25.5	0.55

DATA SHEET

Name ______ Ra. ______ No. 6 Session # 1 Date ______

A) Force-Transducer Calibration: Load: 24.54 kg. Deflection: 63 mm.

B) Force-Transducer Calibration graph:

Torque	Deflection
leg 112.65 kg.cm.	______ mm.
weight 797.55 kg.cm.	______ mm.
leg + Wt 910.20 kg.cm.	64 mm.

C) E.M.G. Calibration graph:

Cal. in			Resets
V.L.	0 mV.	:	0
	1 mV.	:	44
V.M.	0 mV.	:	0
	1 mV.	:	44
R.F.	0 mV.	:	0
	1 mV.	:	45

D) Torque/volts curves in kg. cm./mV. (W.T.1):

Torque	E.M.G.- Resets & Volts						F-Transd. Deflec. mm.
	V.L.		V.M.		R.F.		
	R	V	R	V	R	V	
Leg at rest	-	-	-	-	-	-	0
Leg only	11.0	0.23	10.0	0.22	7.0	0.43	0
Wt 1 X d	26.0	0.54	31.2	0.71	30.5	0.67	18
Wt 2 X d	35.0	0.73	26.0	0.59	32.0	0.71	33
Wt 3 X d	33.0	0.70	33.0	0.75	42.0	0.93	50
Wt 4 X d	33.0	0.70	33.0	0.75	41.0	0.91	64
Wt 5 X d	40.0	0.84	43.5	0.99	44.5	0.99	73

E) Histogram of Volts/patterns (W.T.2):

Pattern	E.M.G.- Resets & Volts					
	V.L.		V.M.		R.F.	
	R	V	R	V	R	V
Wt 5 X d (W.T.1)	40.0	0.84	43.5	0.99	44.5	0.99
I	46.0	0.96	14.0	0.31	30.0	0.66
II	44.0	0.92	29.5	0.67	30.5	0.67
III	32.0	0.67	29.0	0.67	23.0	0.50
IV	26.0	0.55	33.0	0.75	15.0	0.32
V	33.0	0.70	29.0	0.69	34.0	0.75
VI	25.0	0.53	36.0	0.82	26.0	0.57
VII	48.0	1.00	40.0	0.91	22.0	0.48

DATA SHEET

Name ______ Ro. ______ No. 7 Session # 1 Date ______

A) Force-Transducer Calibration: Load: 24.54 kg. Deflection: 70 mm.

B) Force-Transducer Calibration graph:

Torque	Deflection
leg 117.10 kg.cm.	______ mm.
weight 834.4 kg.cm.	______ mm.
leg + Wt 951.5 kg.cm.	73 mm.

C) E.M.G. Calibration graph:

Cal. in			Resets
V.L.	0 mV.	:	3
	1 mV.	:	47
V.M.	0 mV.	:	0.5
	1 mV.	:	43
R.F.	0 mV.	:	1
	1 mV.	:	48

D) Torque/volts curves in kg. cm./mV. (W.T.1):

Torque	E.M.G.- Resets & Volts						F-Transd. Deflec. mm.
	V.L.		V.M.		R.F.		
	R	V	R	V	R	V	
Leg at rest	-	-	-	-	-	-	0
Leg only	7.6	0.12	5.0	0.11	2.5	0.03	0
Wt 1 X d	15.0	0.28	14.6	0.34	14.5	0.28	21
Wt 2 X d	17.0	0.32	20.0	0.46	20.5	0.41	39
Wt 3 X d	18.0	0.34	21.0	0.48	28.0	0.57	52
Wt 4 X d	24.5	0.49	26.0	0.60	33.0	0.68	73
Wt 5 X d	28.0	0.57	31.0	0.72	35.0	0.72	78

E) Histogram of Volts/patterns (W.T.2):

Pattern	E.M.G.- Resets & Volts					
	V.L.		V.M.		R.F.	
	R	V	R	V	R	V
Wt 5 X d (W.T.1)	28.0	0.57	31.0	0.72	35.0	0.72
I	26.0	0.53	18.0	0.42	6.0	0.1
II	24.0	0.48	24.0	0.55	13.0	0.26
III	19.0	0.36	20.0	0.46	16.0	0.32
IV	15.0	0.28	17.0	0.39	17.0	0.34
V	21.0	0.41	20.0	0.46	17.0	0.34
VI	18.0	0.34	23.0	0.54	12.0	0.23
VII	8.0	0.11	11.0	0.25	10.0	0.19

DATA SHEET

Name ______ Br. ______ No. 1 Session # 2 Date ______

A) Force-Transducer Calibration: Load: 24.54 kg. Deflection: 73 mm.

B) Force-Transducer Calibration graph:

Torque	Deflection
leg 125.88 kg.cm.	______ mm.
weight 883.44 kg.cm.	______ mm.
leg + Wt 100932 kg.cm.	72 mm.

C) E.M.G. Calibration graph:

Cal. in			Resets
V.L.	0 mV.	:	0
	1 mV.	:	59
V.M.	0 mV.	:	0
	1 mV.	:	42
R.F.	0 mV.	:	2.4
	1 mV.	:	44

D) Torque/volts curves in kg. cm./mV. (W.T.1):

Torque	E.M.G.- Resets & Volts						
	V.L.		V.M.		R.F.		F-Transd. Deflec. mm.
	R	V	R	V	R	V	
Leg at rest	–	–	–	–	–	–	0
Leg only	4.0	0.07	19.5	0.47	2.5	0.01	0
Wt 1 X d	8.9	0.15	12.0	0.29	8.5	0.15	21
Wt 2 X d	14.0	0.24	21.0	0.51	12.5	0.25	37
Wt 3 X d	21.5	0.37	28.0	0.67	21.5	0.46	57
Wt 4 X d	20.5	0.35	28.0	0.67	24.5	0.54	72
Wt 5 X d	23.0	0.39	32.0	0.77	24.5	0.54	87

E) Histogram of Volts/patterns (W.T.2):

Pattern	E.M.G.- Resets & Volts					
	V.L.		V.M.		R.F.	
	R	V	R	V	R	V
Wt 5 X d (W.T.1)	23.0	0.39	32.0	0.77	24.5	0.54
I	15.5	0.26	31.0	0.74	10.5	0.19
II	17.0	0.29	26.0	0.56	8.0	0.14
III	12.0	0.21	20.5	0.49	5.6	0.08
IV	23.4	0.40	32.5	0.78	15.0	0.31
V	21.2	0.36	27.2	0.65	19.0	0.40
VI	27.5	0.47	34.9	0.83	13.0	0.26
VII	16.9	0.28	20.5	0.49	10.9	0.20

DATA SHEET

Name ___ Da. ___ No. 2 Session # 2 Date ___

A) Force-Transducer Calibration: Load: 24.54 kg. Deflection: 57.5 mm.

B) Force-Transducer Calibration graph:

Torque	Deflection
leg 131.36 kg.cm.	___ mm.
weight 907.98 kg.cm.	___ mm.
leg + Wt 103934 kg.cm.	58 mm.

C) E.M.G. Calibration graph:

Cal. in		Resets
V.L.	0 mV.	.35
	1 mV.	22
V.M.	0 mV.	0
	1 mV.	41
R.F.	0 mV.	0
	1 mV.	34

D) Torque/volts curves in kg. cm./mV. (W.T.1):

Torque	E.M.G.- Resets & Volts V.L.		V.M.		R.F.		F-Transd. Deflec. mm.
	R	V	R	V	R	V	
Leg at rest	-	-	-	-	-	-	0
Leg only	4.5	0.2	12.9	0.01	3.5	0.09	0
Wt 1 X d	8.1	0.37	14.5	0.06	16.0	0.31	16
Wt 2 X d	12.2	0.56	18.0	0.19	22.9	0.66	28
Wt 3 X d	18.0	0.95	23.0	0.36	26.0	0.77	45
Wt 4 X d	22.0	1.00	29.7	0.59	29.0	0.86	58
Wt 5 X d	26.0	1.20	32.0	0.68	38.0	1.12	73

E) Histogram of Volts/patterns (W.T.2):

Pattern	E.M.G.- Resets & Volts V.L.		V.M.		R.F.	
	R	V	R	V	R	V
Wt 5 X d (W.T.1)	26.0	1.20	32.0	0.68	38.0	1.12
I	25.5	1.18	20.5	0.27	13.0	0.38
II	17.2	0.79	18.0	0.19	7.9	0.24
III	31.5	1.46	32.0	0.68	16.0	0.31
IV	11.9	0.55	23.5	0.38	33.5	0.99
V	12.5	0.57	17.0	0.15	27.0	0.80
VI	8.8	0.40	18.0	0.19	18.0	0.53
VII	13.5	0.62	17.1	0.15	20.5	0.61

DATA SHEET

Name G1. No. 3 Session # 2 Date

A) Force-Transducer Calibration: Load: 24.54 kg. Deflection: 77 mm.

B) Force-Transducer Calibration graph:

Torque	Deflection
leg 126.48 kg.cm.	mm.
weight 883.44 kg.cm.	mm.
leg + Wt 100992 kg.cm.	75 mm.

C) E.M.G. Calibration graph:

Cal. in			Resets
V.L.	0 mV.	:	0
	1 mV.	:	28
V.M.	0 mV.	:	0
	1 mV.	:	20
R.F.	0 mV.	:	0
	1 mV.	:	40

D) Torque/volts curves in kg. cm./mV. (W.T.1):

Torque	E.M.G.- Resets & Volts V.L. R	V.L. V	V.M. R	V.M. V	R.F. R	R.F. V	F-Transd. Deflec. mm.
Leg at rest	-	-	-	-	-	-	0
Leg only	13.0	0.47	20.5	1.03	10.1	0.27	0
Wt 1 X d	14.8	0.53	25.5	1.28	21.0	0.52	20.5
Wt 2 X d	13.0	0.46	28.0	1.41	32.9	0.82	37.0
Wt 3 X d	21.0	0.75	33.0	1.66	41.0	1.02	58.0
Wt 4 X d	27.5	0.98	31.0	1.55	43.5	1.09	75.0
Wt 5 X d	29.9	1.06	33.8	1.70	39.0	0.98	83.0

E) Histogram of Volts/patterns (W.T.2):

Pattern	E.M.G.- Resets & Volts V.L. R	V.L. V	V.M. R	V.M. V	R.F. R	R.F. V
Wt 5 X d (W.T.1)	29.9	1.06	33.8	1.70	39.0	0.98
I	32.0	1.15	36.5	1.84	17.5	0.41
II	38.0	1.36	30.0	1.50	18.0	0.45
III	43.0	1.54	34.5	1.73	27.0	0.67
IV	25.8	0.92	43.0	2.15	47.0	1.18
V	28.9	1.03	24.9	1.25	23.0	0.58
VI	24.5	0.87	29.9	1.49	22.0	0.55
VII	23.0	0.82	29.0	1.45	25.0	0.62

DATA SHEET

Name ______ Gr. ______ No. 4 Session # 2 Date ______

A) Force-Transducer Calibration: Load: 24.54 kg. Deflection: 85 mm.

B) Force-Transducer Calibration graph:

Torque	Deflection
leg 100.10 kg.cm.	____ mm.
weight 809.82 kg.cm.	____ mm.
leg + Wt 909.92 kg.cm.	85 mm.

C) E.M.G. Calibration graph:

Cal. in			Resets
V.L.	0 mV.	:	0
	1 mV.	:	29
V.M.	0 mV.	:	0
	1 mV.	:	20
R.F.	0 mV.	:	1
	1 mV.	:	41

D) Torque/volts curves in kg. cm./mV. (W.T.1):

Torque	E.M.G.- Resets & Volts						F-Transd. Deflec. mm.
	V.L.		V.M.		R.F.		
	R	V	R	V	R	V	
Leg at rest	–	–	–	–	–	–	0
Leg only	6.8	0.20	18.1	0.51	1.0	0.02	0
Wt 1 X d	7.5	0.26	19.5	0.61	11.0	0.27	28
Wt 2 X d	8.5	0.30	19.0	0.58	14.5	0.36	50
Wt 3 X d	10.9	0.38	19.0	0.58	20.0	0.49	78
Wt 4 X d	19.0	0.66	22.0	0.79	28.0	0.60	85
Wt 5 X d	19.6	0.68	24.0	0.93	31.0	0.76	91

E) Histogram of Volts/patterns (W.T.2):

Pattern	E.M.G.- Resets & Volts					
	V.L.		V.M.		R.F.	
	R	V	R	V	R	V
Wt 5 X d (W.T.1)	19.6	0.68	24.0	0.93	31.0	0.76
I	15.5	0.54	20.8	0.70	7.5	0.18
II	17.2	0.59	23.0	0.85	11.0	1.27
III	12.8	0.45	19.9	0.64	7.5	0.18
IV	8.6	0.30	22.5	0.82	21.0	0.51
V	8.9	0.31	17.8	0.49	16.0	0.39
VI	6.0	0.21	24.5	0.97	5.0	0.17
VII	6.5	0.23	19.5	0.61	6.5	0.22

DATA SHEET

Name Ji. No. 5 Session # 2 Date

A) Force-Transducer Calibration: Load: 24.54 kg. Deflection: 78 mm.

B) Force-Transducer Calibration graph:

Torque	Deflection
leg 109.86 kg.cm.	mm.
weight 846.63 kg.cm.	mm.
leg + Wt 956.49 kg.cm.	76 mm.

C) E.M.G. Calibration graph:

Cal. in			Resets
V.L.	0 mV.	:	0.6
	1 mV.	:	86
V.M.	0 mV.	:	5.8
	1 mV.	:	86
R.F.	0 mV.	:	0
	1 mV.	:	44

D) Torque/volts curves in kg. cm./mV. (W.T.1):

Torque	E.M.G.- Resets & Volts						F-Transd. Deflec. mm.
	V.L.		V.M.		R.F.		
	R	V	R	V	R	V	
Leg at rest	–	–	–	–	–	–	0
Leg only	11.50	0.13	8.2	0.03	3.0	0.07	0
Wt 1 X d	28.0	0.33	25.0	0.24	13.5	0.31	24
Wt 2 X d	32.0	0.37	31.5	0.32	17.5	0.40	45
Wt 3 X d	53.0	0.62	37.0	0.39	24.5	0.56	69
Wt 4 X d	44.0	0.51	35.5	0.37	20.0	0.45	76
Wt 5 X d	41.0	0.48	38.5	0.41	21.5	0.49	92

E) Histogram of Volts/patterns (W.T.2):

Pattern	E.M.G.- Resets & Volts					
	V.L.		V.M.		R.F.	
	R	V	R	V	R	V
Wt 5 X d (W.T.1)	41	0.48	38.5	0.41	21.5	0.49
I	39.5	0.46	41.0	0.44	9.5	0.22
II	45.0	0.52	34.0	0.35	7.0	0.17
III	34.0	0.39	22.5	0.21	5.5	0.13
IV	37.0	0.43	24.9	0.35	16.5	0.38
V	36.0	0.42	48.0	0.53	22.5	0.51
VI	20.0	0.23	14.5	0.11	13.0	0.30
VII	15.0	0.17	13.9	0.10	26.0	0.59

DATA SHEET

Name ______ Ra. ______ No. 6 ______ Session # 2 ______ Date ______

A) Force-Transducer Calibration: Load: 24.54 kg. Deflection: 54 mm.

B) Force-Transducer Calibration graph:

Torque	Deflection
leg 112.65 kg.cm.	______ mm.
weight 797.55 kg.cm.	______ mm.
leg + Wt 910.20 kg.cm.	54 mm.

C) E.M.G. Calibration graph:

Cal. in			Resets
V.L.	0 mV.	:	13
	1 mV.	:	43
V.M.	0 mV.	:	10
	1 mV.	:	42
R.F.	0 mV.	:	0
	1 mV.	:	46

D) Torque/volts curves in kg. cm./mV. (W.T.1):

Torque	E.M.G.- Resets & Volts						
	V.L.		V.M.		R.F.		F-Transd. Deflec. mm.
	R	V	R	V	R	V	
Leg at rest	-	-	-	-	-	-	0
Leg only	17.5	0.16	17.0	0.24	11.5	0.25	0
Wt 1 X d	28.0	0.51	23.0	0.41	27.0	0.59	15
Wt 2 X d	32.0	0.64	31.0	0.66	44.0	0.96	27
Wt 3 X d	32.9	0.66	31.5	0.68	64.0	1.39	42
Wt 4 X d	35.0	0.74	42.0	1.00	72.0	1.57	54
Wt 5 X d	54.0	1.37	34.0	0.76	96.0	2.09	73

E) Histogram of Volts/patterns (W.T.2):

Pattern	E.M.G.- Resets & Volts					
	V.L.		V.M.		R.F.	
	R	V	R	V	R	V
Wt 5 X d (W.T.1)	54.0	1.37	34.0	0.76	96.0	2.09
I	75.0	2.65	53.0	1.35	45.0	0.98
II	64.0	1.70	46.5	1.14	31.0	0.67
III	90.0	2.56	51.0	1.29	29.0	0.63
IV	51.0	1.27	39.9	0.94	61.0	1.33
V	44.0	0.95	38.5	0.90	67.0	1.46
VI	38.0	0.84	36.0	0.82	41.0	0.89
VII	23.5	0.35	25.5	0.49	40.0	0.87

DATA SHEET

Name ______ Ro. ______ No. 7 Session # 2 Date ______

A) Force-Transducer Calibration: Load: 24.54 kg. Deflection: 80 mm.

B) Force-Transducer Calibration graph:

Torque		Deflection	
leg 117.10	kg.cm.	______	mm.
weight 834.36	kg.cm.	______	mm.
leg + Wt 951.46	kg.cm.	82	mm.

C) E.M.G. Calibration graph:

Cal. in			Resets
V.L.	0 mV.	:	0.3
	1 mV.	:	44
V.M.	0 mV.	:	0
	1 mV.	:	42
R.F.	0 mV.	:	0
	1 mV.	:	50

D) Torque/volts curves in kg. cm./mV. (W.T.1):

Torque	E.M.G.- Resets & Volts						F-Transd. Deflec. mm.
	V.L.		V.M.		R.F.		
	R	V	R	V	R	V	
Leg at rest	-	-	-	-	-	-	0
Leg only	9.5	0.16	14.0	0.34	4.5	0.09	0
Wt 1 X d	21.0	0.44	16.5	0.40	14.0	0.28	25
Wt 2 X d	24.0	0.52	19.5	0.47	32.5	0.65	45
Wt 3 X d	30.9	0.68	29.0	0.69	36.0	0.72	71
Wt 4 X d	32.0	0.72	24.0	0.58	35.0	0.70	82
Wt 5 X d	37.0	0.84	27.0	0.65	31.5	0.63	92

E) Histogram of Volts/patterns (W.T.2):

Pattern	E.M.G.- Resets & Volts					
	V.L.		V.M.		R.F.	
	R	V	R	V	R	V
Wt 5 X d (W.T.1)	37.0	0.84	27.0	0.65	31.5	0.63
I	30.5	0.68	20.0	0.48	14.9	0.29
II	26.0	0.57	23.9	0.58	10.0	0.20
III	30.5	0.68	30.0	0.60	26.5	0.52
IV	17.0	0.35	17.9	0.43	9.5	0.19
V	12.2	0.23	20.5	0.49	10.5	0.21
VI	22.9	0.48	21.9	0.53	18.5	0.37
VII	16.5	0.33	17.5	0.42	19.0	0.38

DATA SHEET

Name Br.   No. 1   Session # 3   Date

A) Force-Transducer Calibration: Load: 24.54 kg.   Deflection: 66 mm.

B) Force-Transducer Calibration graph:

Torque		Deflection	
leg 125.87	kg.cm.		mm.
weight 883.44	kg.cm.		mm.
leg + Wt 1009.31	kg.cm.	67	mm.

C) E.M.G. Calibration graph:

Cal. in			Resets
V.L.	0 mV.	:	0
	1 mV.	:	43
V.M.	0 mV.	:	0
	1 mV.	:	43
R.F.	0 mV.	:	0
	1 mV.	:	44

D) Torque/volts curves in kg. cm./mV. (W.T.1):

Torque	E.M.G.- Resets & Volts V.L. R	V.L. V	V.M. R	V.M. V	R.F. R	R.F. V	F-Transd. Deflec. mm.
Leg at rest	-	-	-	-	-	-	0
Leg only	8.9	0.21	6.5	0.16	3.7	0.08	0
Wt 1 X d	11.5	0.27	8.5	0.20	9.7	0.22	18
Wt 2 X d	13.6	0.32	17.8	0.42	21.4	0.48	33
Wt 3 X d	16.0	0.38	21.0	0.50	28.0	0.63	51
Wt 4 X d	18.2	0.43	19.0	0.45	29.0	0.66	67
Wt 5 X d	42.5	0.97	31.0	0.73	38.0	0.86	91

E) Histogram of Volts/patterns (W.T.2):

Pattern	E.M.G.- Resets & Volts V.L. R	V.L. V	V.M. R	V.M. V	R.F. R	R.F. V
Wt 5 X d (W.T.1)	42.5	0.97	31.0	0.73	38.0	0.86
I	18.5	0.44	16.0	0.38	8.0	0.18
II	16.5	0.39	13.5	0.32	7.5	0.17
III	14.0	0.33	14.9	0.35	8.5	0.19
IV	23.8	0.56	31.0	0.73	33.0	0.75
V	25.0	0.59	20.0	0.47	28.0	0.64
VI	27.0	0.63	22.5	0.53	12.0	0.27
VII	16.5	0.39	15.8	0.37	16.0	0.36

DATA SHEET

Name Da. No. 2 Session # 3 Date

A) Force-Transducer Calibration: Load: 24.54 kg. Deflection: 51 mm.

B) Force-Transducer Calibration graph:

Torque		Deflection	
leg 131.36	kg.cm.		mm.
weight 907.98	kg.cm.		mm.
leg + Wt 103934	kg.cm.	50	mm.

C) E.M.G. Calibration graph:

Cal. in			Resets
V.L.	0 mV.	:	0
	1 mV.	:	22
V.M.	0 mV.	:	0
	1 mV.	:	42
R.F.	0 mV.	:	0
	1 mV.	:	45

D) Torque/volts curves in kg. cm./mV. (W.T.1):

Torque	E.M.G.- Resets & Volts						F-Transd. Deflec. mm.
	V.L.		V.M.		R.F.		
	R	V	R	V	R	V	
Leg at rest	-	-	-	-	-	-	0
Leg only	13.0	0.6	13.4	0.32	4.2	0.09	0
Wt 1 X d	13.8	0.63	14.5	0.35	17.5	0.39	17
Wt 2 X d	14.0	0.64	22.0	0.52	25.0	0.56	30
Wt 3 X d	15.0	0.68	28.9	0.69	39.0	0.87	47
Wt 4 X d	16.8	0.77	25.0	0.60	43.5	0.97	50
Wt 5 X d	20.0	0.91	29.8	0.71	48.0	1.07	81

E) Histogram of Volts/patterns (W.T.2):

Pattern	E.M.G.- Resets & Volts					
	V.L.		V.M.		R.F.	
	R	V	R	V	R	V
Wt 5 X d (W.T.1)	20.0	0.91	29.8	0.71	48.0	1.07
I	13.6	0.62	22.5	0.54	11.0	0.24
II	15.0	0.68	22.0	0.53	12.6	0.28
III	18.3	0.83	12.9	0.31	12.0	0.27
IV	9.5	0.43	12.8	0.31	42.0	0.94
V	8.0	0.37	16.0	0.38	40.5	0.90
VI	5.1	0.24	14.4	0.34	26.0	0.58
VII	3.8	0.18	13.9	0.33	26.0	0.58

DATA SHEET

Name G1. No. 3 Session # 3 Date ______

A) Force-Transducer Calibration: Load: 24.54 kg. Deflection: 64 mm.

B) Force-Transducer Calibration graph:

Torque	Deflection
leg 126.48 kg.cm.	______ mm.
weight 883.44 kg.cm.	______ mm.
leg + Wt 1009.92 kg.cm.	66 mm.

C) E.M.G. Calibration graph:

Cal. in			Resets
V.L.	0 mV.	:	0
	1 mV.	:	30
V.M.	0 mV.	:	0
	1 mV.	:	21
R.F.	0 mV.	:	0
	1 mV.	:	38

D) Torque/volts curves in kg. cm./mV. (W.T.1):

Torque	E.M.G.- Resets & Volts						F-Transd. Deflec. mm.
	V.L.		V.M.		R.F.		
	R	V	R	V	R	V	
Leg at rest	-	-	-	-	-	-	0
Leg only	13.5	0.46	3.2	0.16	7.9	0.21	0
Wt 1 X d	14.6	0.49	6.0	0.30	17.5	0.47	18.5
Wt 2 X d	18.0	0.62	10.8	0.52	27.0	0.72	33
Wt 3 X d	26.0	0.87	19.5	0.94	37.0	0.99	52
Wt 4 X d	32.0	1.07	23.6	1.13	41.0	1.09	66
Wt 5 X d	36.0	1.20	20.5	0.99	32.0	0.85	74

E) Histogram of Volts/patterns (W.T.2):

Pattern	E.M.G.- Resets & Volts					
	V.L.		V.M.		R.F.	
	R	V	R	V	R	V
Wt 5 X d (W.T.1)	36.0	1.20	20.5	0.99	32.0	0.85
I	39.0	1.31	25.8	1.24	19.8	0.52
II	45.0	1.50	25.0	1.20	19.0	0.51
III	48.0	1.61	26.8	1.28	39.0	1.04
IV	25.8	0.86	9.2	0.45	17.5	0.47
V	30.0	1.0	11.0	0.53	15.0	0.4
VI	41.3	1.38	21.0	1.0	9.5	0.25
VII	19.9	0.50	12.5	0.61	6.0	0.16

DATA SHEET

Name________ Gr.________ No. 4 Session # 3 Date________

A) Force-Transducer Calibration: Load: 24.54 kg. Deflection: 83 mm.

B) Force-Transducer Calibration graph:

Torque	Deflection
leg 100.10 kg.cm.	____ mm.
weight 809.82 kg.cm.	____ mm.
leg + Wt 909.92 kg.cm.	86 mm.

C) E.M.G. Calibration graph:

Cal. in			Resets
V.L.	0 mV.	:	0
	1 mV.	:	21.5
V.M.	0 mV.	:	7
	1 mV.	:	20
R.F.	0 mV.	:	0
	1 mV.	:	42

D) Torque/volts curves in kg. cm./mV. (W.T.1):

Torque	E.M.G.- Resets & Volts						F-Transd. Deflec. mm.
	V.L.		V.M.		R.F.		
	R	V	R	V	R	V	
Leg at rest	-	-	-	-	-	-	0
Leg only	13.0	0.61	16.0	0.7	3.2	0.08	0
Wt 1 X d	14.5	0.68	17.0	0.77	9.0	0.22	24
Wt 2 X d	11.9	0.53	18.0	0.84	21.9	0.54	43
Wt 3 X d	14.0	0.65	21.0	1.09	30.9	0.73	67.5
Wt 4 X d	16.0	0.75	21.0	1.09	33.0	0.81	86
Wt 5 X d	25.5	1.19	21.0	1.09	32.0	0.77	93

E) Histogram of Volts/patterns (W.T.2):

Pattern	E.M.G.- Resets & Volts					
	V.L.		V.M.		R.F.	
	R	V	R	V	R	V
Wt 5 X d (W.T.1)	25.5	1.19	21.0	1.09	32.0	0.77
I	18.0	0.84	21.0	1.09	12.9	0.31
II	22.6	1.06	24.0	1.32	12.8	0.30
III	21.0	0.98	24.5	1.35	14.0	0.34
IV	21.9	1.02	23.9	1.31	34.0	0.82
V	21.0	0.98	22.9	1.23	24.0	0.58
VI	14.0	0.65	18.9	0.93	21.0	0.50
VII	14.0	0.65	21.0	1.09	13.0	0.31

DATA SHEET

Name Ji. No. 5 Session # 3 Date

A) Force-Transducer Calibration: Load: 24.54 kg. Deflection: 65 mm.

B) Force-Transducer Calibration graph:

Torque		Deflection
leg	109.86 kg.cm.	mm.
weight	846.63 kg.cm.	mm.
leg + Wt	956.49 kg.cm.	64 mm.

C) E.M.G. Calibration graph:

Cal. in			Resets
V.L.	0 mV.	:	5.8
	1 mV.	:	88
V.M.	0 mV.	:	0.8
	1 mV.	:	87
R.F.	0 mV.	:	0
	1 mV.	:	42

D) Torque/volts curves in kg. cm./mV. (W.T.1):

Torque	E.M.G.- Resets & Volts V.L.		V.M.		R.F.		F-Transd. Deflec. mm.
	R	V	R	V	R	V	
Leg at rest	-	-	-	-	-	-	0
Leg only	13.4	0.10	8.9	0.10	6.0	0.15	0
Wt 1 X d	23.0	0.22	27.0	0.30	13.5	0.32	18
Wt 2 X d	33.8	0.35	30.5	0.35	16.0	0.38	33
Wt 3 X d	51.0	0.55	46.0	0.53	25.0	0.60	51
Wt 4 X d	63.0	0.70	51.0	0.59	27.0	0.65	64
Wt 5 X d	65.0	0.73	49.5	0.57	28.9	0.69	69

E) Histogram of Volts/patterns (W.T.2):

Pattern	E.M.G.- Resets & Volts V.L.		V.M.		R.F.	
	R	V	R	V	R	V
Wt 5 X d (W.T.1)	65.0	0.73	49.5	0.57	28.9	0.69
I	34.8	0.36	30.0	0.35	7.8	0.19
II	39.0	0.41	40.9	0.56	9.7	0.23
III	27.8	0.27	31.0	0.36	7.5	0.13
IV	37.5	0.39	40.0	0.46	23.0	0.56
V	44.0	0.47	40.8	0.56	21.8	0.52
VI	27.8	0.27	17.4	0.20	4.8	0.11
VII	23.8	0.23	26.0	0.30	18.5	0.44

DATA SHEET

Name ______ Ra. ______ No. 6 Session # 3 Date ______

A) Force-Transducer Calibration: Load: 24.54 kg. Deflection: 60 mm.

B) Force-Transducer Calibration graph:

Torque	Deflection
leg 112.65 kg.cm.	______ mm.
weight 797.55 kg.cm.	______ mm.
leg + Wt 910.20 kg.cm.	60 mm.

C) E.M.G. Calibration graph:

Cal. in			Resets
V.L.	0 mV.	:	0
	1 mV.	:	44
V.M.	0 mV.	:	13.5
	1 mV.	:	41
R.F.	0 mV.	:	0
	1 mV.	:	40

D) Torque/volts curves in kg. cm./mV. (W.T.1):

Torque	E.M.G.- Resets & Volts V.L. R	V.L. V	V.M. R	V.M. V	R.F. R	R.F. V	F-Transd. Deflec. mm.
Leg at rest	–	–	–	–	–	–	0
Leg only	13.5	0.31	16.0	0.10	9.0	0.15	0
Wt 1 X d	23.0	0.53	26.5	0.46	35.5	0.89	17
Wt 2 X d	21.0	0.48	28.5	0.55	47.0	1.18	30
Wt 3 X d	24.5	0.56	30.0	0.60	58.0	1.46	46
Wt 4 X d	20.5	0.47	26.5	0.47	60.0	1.55	60
Wt 5 X d	39.0	0.89	40.0	0.96	73.0	1.83	85

E) Histogram of Volts/patterns (W.T.2):

Pattern	E.M.G.- Resets & Volts V.L. R	V.L. V	V.M. R	V.M. V	R.F. R	R.F. V
Wt 5 X d (W.T.1)	39.0	0.89	40.0	0.96	73.0	1.83
I	62.9	1.42	50.0	1.32	44.0	1.15
II	55.0	1.25	48.0	1.25	33.0	0.83
III	54.0	1.23	41.9	1.03	17.0	0.43
IV	47.0	1.07	48.0	1.25	66.0	I.66
V	37.0	0.85	40.9	0.99	73.0	I.83
VI	41.0	0.94	36.0	0.81	48.0	I.20
VII	11.0	0.25	17.0	0.14	47.0	I.I8

DATA SHEET

Name Ro. No. 7 Session # 3 Date

A) Force-Transducer Calibration: Load: 24.54 kg. Deflection: 73 mm.

B) Force-Transducer Calibration graph:

Torque	Deflection
leg 117.10 kg.cm.	mm.
weight 834.36 kg.cm.	mm.
leg + Wt 951.46 kg.cm.	72.5 mm.

C) E.M.G. Calibration graph:

Cal. in			Resets
V.L.	0 mV.	:	2.8
	1 mV.	:	43
V.M.	0 mV.	:	1.1
	1 mV.	:	43
R.F.	0 mV.	:	0
	1 mV.	:	49

D) Torque/volts curves in kg. cm./mV. (W.T.1):

Torque	E.M.G.- Resets & Volts						F-Transd. Deflec. mm.
	V.L.		V.M.		R.F.		
	R	V	R	V	R	V	
Leg at rest	-	-	-	-	-	-	0
Leg only	9.1	0.17	7.5	0.13	3.4	0.08	0
Wt 1 X d	18.5	0.4	18.0	0.39	13.5	0.27	28
Wt 2 X d	20	0.44	19.0	0.43	24.0	0.49	50
Wt 3 X d	22.2	0.49	21.0	0.46	27.0	0.55	65
Wt 4 X d	23.0	0.51	22.0	0.49	25.0	0.51	72.5
Wt 5 X d	37.1	0.86	26.8	0.59	28.0	0.57	91

E) Histogram of Volts/patterns (W.T.2):

Pattern	E.M.G.- Resets & Volts					
	V.L.		V.M.		R.F.	
	R	V	R	V	R	V
Wt 5 X d (W.T.1)	37.1	0.86	26.8	0.59	28.0	0.57
I	23.0	0.51	18.0	0.39	12.0	0.25
II	25.5	0.56	20.0	0.44	14.0	0.29
III	28.0	0.64	27.9	0.62	30.0	0.62
IV	14.0	0.29	11.4	0.23	7.0	0.15
V	20.2	0.44	14.9	0.31	10.0	0.20
VI	18.1	0.39	14.5	0.30	12.5	0.26
VII	15.0	0.32	14.5	0.30	22.0	0.45

DATA SHEET

Name Br. No. 1 Session # 4 Date ____

A) Force-Transducer Calibration: Load: 24.54 kg. Deflection: 51 mm.

B) Force-Transducer Calibration graph:

Torque	Deflection
leg 125.87 kg.cm.	____ mm.
weight 883.44 kg.cm.	____ mm.
leg + Wt 100931 kg.cm.	51 mm.

C) E.M.G. Calibration graph:

Cal. in			Resets
V.L.	0 mV.	:	6
	1 mV.	:	44
V.M.	0 mV.	:	0
	1 mV.	:	44
R.F.	0 mV.	:	0
	1 mV.	:	54

D) Torque/volts curves in kg. cm./mV. (W.T.1):

Torque	E.M.G.- Resets & Volts						F-Transd. Deflec. mm.
	V.L.		V.M.		R.F.		
	R	V	R	V	R	V	
Leg at rest	-	-	-	-	-	-	0
Leg only	10.5	0.12	7.5	0.16	3.8	0.06	0
Wt 1 X d	11.1	0.13	10.0	0.22	11.0	0.20	14.5
Wt 2 X d	14.0	0.21	19.2	0.43	13.0	0.24	26
Wt 3 X d	15.5	0.25	22.0	0.50	20.0	0.37	39
Wt 4 X d	13.8	0.21	40.0	0.91	31.5	0.58	51
Wt 5 X d	20.0	0.37	42.0	0.96	31.0	0.57	62

E) Histogram of Volts/patterns (W.T.2):

Pattern	E.M.G.- Resets & Volts					
	V.L.		V.M.		R.F.	
	R	V	R	V	R	V
Wt 5 X d (W.T.1)	20.0	0.37	42.0	0.96	31.0	0.57
I	15.4	0.25	22.0	0.50	7.5	0.13
II	12.0	0.16	16.0	0.36	6.4	0.11
III	15.0	0.24	38.5	0.87	12.0	0.21
IV	27.4	0.56	48.0	1.09	26.0	0.48
V	25.0	0.50	40.5	0.92	33.0	0.61
VI	33.0	0.71	48.0	1.09	19.8	0.36
VII	20.4	0.38	25.0	0.56	19.0	0.35

DATA SHEET

Name Da. No. 2 Session # 4 Date

A) Force-Transducer Calibration: Load: 24.54 kg. Deflection: 58.5 mm.

B) Force-Transducer Calibration graph:

Torque	Deflection
leg 131.36 kg.cm.	mm.
weight 907.98 kg.cm.	mm.
leg + Wt 1039.34 kg.cm.	59 mm.

C) E.M.G. Calibration graph:

Cal. in			Resets
V.L.	0 mV.	:	4
	1 mV.	:	30
V.M.	0 mV.	:	2
	1 mV.	:	44.5
R.F.	0 mV.	:	0
	1 mV.	:	40

D) Torque/volts curves in kg. cm./mV. (W.T.1):

Torque	E.M.G.- Resets & Volts						
	V.L.		V.M.		R.F.		F-Transd. Deflec. mm.
	R	V	R	V	R	V	
Leg at rest	–	–	–	–	–	–	0
Leg only	7.8	0.15	10.4	0.21	13.0	0.34	0
Wt 1 X d	10.6	0.26	15.0	0.31	15.0	0.38	16
Wt 2 X d	10.6	0.26	21.0	0.46	26.5	0.67	29
Wt 3 X d	19.5	0.60	26.0	0.57	33.0	0.83	47
Wt 4 X d	17.5	0.53	28.0	0.62	32.0	0.81	59
Wt 5 X d	15.8	0.46	27.0	0.60	36.0	0.91	77.5

E) Histogram of Volts/patterns (W.T.2):

Pattern	E.M.G.- Resets & Volts					
	V.L.		V.M.		R.F.	
	R	V	R	V	R	V
Wt 5 X d (W.T.1)	15.8	0.46	27.0	0.60	36.0	0.91
I	16.5	0.49	23.8	0.52	12.9	0.33
II	13.9	0.39	14.5	0.30	6.7	0.18
III	17.1	0.51	16.0	0.34	15.0	0.38
IV	8.4	0.17	10.0	0.20	36.0	0.91
V	4.1	0.01	7.7	0.14	27.8	0.70
VI	7.2	0.13	12.6	0.26	21.9	0.56
VII	8.0	0.16	9.0	0.17	20.0	0.51

DATA SHEET

Name Gl. No. 3 Session # 4 Date ______

A) Force-Transducer Calibration: Load: 24.54 kg. Deflection: 51.5 mm.

B) Force-Transducer Calibration graph:

Torque	Deflection
leg 126.48 kg.cm.	______ mm.
weight 883.44 kg.cm.	______ mm.
leg + Wt 1009.92 kg.cm.	51.5 mm.

C) E.M.G. Calibration graph:

Cal. in			Resets
V.L.	0 mV.	:	5
	1 mV.	:	22
V.M.	0 mV.	:	0
	1 mV.	:	22
R.F.	0 mV.	:	0
	1 mV.	:	43

D) Torque/volts curves in kg. cm./mV. (W.T.1):

Torque	E.M.G.- Resets & Volts						
	V.L.		V.M.		R.F.		F-Transd. Deflec. mm.
	R	V	R	V	R	V	
Leg at rest	-	-	-	-	-	-	0
Leg only	5.1	0.02	4.1	0.19	16.5	0.39	0
Wt 1 X d	8.0	0.18	12.0	0.55	21.0	0.49	14.5
Wt 2 X d	9.0	0.24	14.0	0.64	37.0	0.86	25
Wt 3 X d	15.5	0.62	18.9	0.86	37.0	0.86	39
Wt 4 X d	21.2	0.96	22.0	1.0	37.0	0.86	51.5
Wt 5 X d	27.0	1.29	23.5	1.06	40.0	0.94	57

E) Histogram of Volts/patterns (W.T.2):

Pattern	E.M.G.- Resets & Volts					
	V.L.		V.M.		R.F.	
	R	V	R	V	R	V
Wt 5 X d (W.T.1)	27.0	1.29	23.5	1.06	40.0	0.94
I	26.0	1.23	30.0	1.36	21.0	0.49
II	25.0	1.17	23.9	1.08	28.0	0.65
III	38.0	1.93	28.9	1.3	45.0	1.05
IV	35.5	1.78	20.5	0.93	31.0	0.72
V	15.0	0.59	15.0	0.68	22.0	0.51
VI	10.0	0.30	12.0	0.54	6.0	0.14
VII	11.0	0.36	10.5	0.48	5.0	0.12

DATA SHEET

Name ______ Gr. ______ No. 4 Session # 4 Date ______

A) Force-Transducer Calibration: Load: 24.54 kg. Deflection: 61 mm.

B) Force-Transducer Calibration graph:

Torque	Deflection
leg 100.10 kg.cm.	______ mm.
weight 809.82 kg.cm.	______ mm.
leg + Wt 999.92 kg.cm.	55 mm.

C) E.M.G. Calibration graph:

Cal. in			Resets
V.L.	0 mV.	:	2.9
	1 mV.	:	22
V.M.	0 mV.	:	0
	1 mV.	:	21
R.F.	0 mV.	:	0
	1 mV.	:	42

D) Torque/volts curves in kg. cm./mV. (W.T.1):

Torque	E.M.G.- Resets & Volts V.L.		V.M.		R.F.		F-Transd. Deflec. mm.
	R	V	R	V	R	V	
Leg at rest	-	-	-	-	-	-	0
Leg only	5.5	0.14	1.4	0.08	1.6	0.04	0
Wt 1 X d	11.0	0.43	4.8	0.23	10.0	0.24	17
Wt 2 X d	13.2	0.54	5.1	0.29	16.0	0.39	30
Wt 3 X d	20.5	0.92	11.0	0.52	32.0	0.77	46
Wt 4 X d	31.8	1.49	15.8	0.75	33.0	0.79	55
Wt 5 X d	28.5	1.32	15.1	0.72	34.9	0.83	60

E) Histogram of Volts/patterns (W.T.2):

Pattern	E.M.G.- Resets & Volts V.L.		V.M.		R.F.	
	R	V	R	V	R	V
Wt 5 X d (W.T.1)	28.5	1.32	15.1	0.72	34.9	0.83
I	32.0	1.50	15.5	0.74	16.0	0.39
II	29.0	1.35	12.0	0.57	10.0	0.24
III	14.0	0.58	8.1	0.39	14.0	0.34
IV	24.4	1.11	13.0	0.62	36.0	0.86
V	28.0	1.30	9.6	0.46	20.0	0.48
VI	16.8	0.73	13.5	0.64	14.0	0.34
VII	20.0	0.89	8.5	0.41	29.5	0.71

DATA SHEET

Name Ji. No. 5 Session # 4 Date

A) Force-Transducer Calibration: Load: 24.54 kg. Deflection: 61 mm.

B) Force-Transducer Calibration graph:

Torque	Deflection
leg 109.86 kg.cm.	mm.
weight 846.63 kg.cm.	mm.
leg + Wt 956.49 kg.cm.	61 mm.

C) E.M.G. Calibration graph:

Cal. in			Resets
V.L.	0 mV.	:	0
	1 mV.	:	91
V.M.	0 mV.	:	4
	1 mV.	:	86
R.F.	0 mV.	:	0
	1 mV.	:	42

D) Torque/volts curves in kg. cm./mV. (W.T.1):

Torque	E.M.G.- Resets & Volts V.L. R	V.L. V	V.M. R	V.M. V	R.F. R	R.F. V	F-Transd. Deflec. mm.
Leg at rest	-	-	-	-	-	-	0
Leg only	14.0	0.15	9.8	0.08	6.9	0.16	0
Wt 1 X d	29.8	0.33	24.0	0.25	13.0	0.31	20
Wt 2 X d	36.0	0.40	39.0	0.43	18.0	0.42	36
Wt 3 X d	44.0	0.48	54.0	0.61	21.0	0.50	55
Wt 4 X d	48.0	0.53	59.5	0.68	25.0	0.59	61
Wt 5 X d	73.0	0.80	56.0	0.64	24.0	0.57	67

E) Histogram of Volts/patterns (W.T.2):

Pattern	E.M.G.- Resets & Volts V.L. R	V.L. V	V.M. R	V.M. V	R.F. R	R.F. V
Wt 5 X d (W.T.1)	73.0	0.80	56.0	0.64	24.0	0.57
I	55.0	0.60	37.5	0.41	9.0	0.21
II	41.0	0.45	36.0	0.39	8.0	0.19
III	33.5	0.37	20.0	0.20	5.5	0.13
IV	35.0	0.38	18.0	0.18	5.2	0.12
V	46.0	0.51	43.7	0.49	21.0	0.50
VI	20.0	0.22	17.2	0.17	4.0	0.09
VII	22.5	0.24	19.0	0.19	14.0	0.33

DATA SHEET

Name ___ Ra. ___ No. 6 Session # 4 Date ______

A) Force-Transducer Calibration: Load: 24.54 kg. Deflection: 57 mm.

B) Force-Transducer Calibration graph:

Torque	Deflection
leg 112.65 kg.cm.	______ mm.
weight 797.55 kg.cm.	______ mm.
leg + Wt 910.20 kg.cm.	58 mm.

C) E.M.G. Calibration graph:

Cal. in			Resets
V.L.	0 mV.	:	0
	1 mV.	:	45
V.M.	0 mV.	:	0
	1 mV.	:	44
R.F.	0 mV.	:	0
	1 mV.	:	43

D) Torque/volts curves in kg. cm./mV. (W.T.1):

Torque	E.M.G.- Resets & Volts V.L.		V.M.		R.F.		F-Transd. Deflec. mm.
	R	V	R	V	R	V	
Leg at rest	-	-	-	-	-	-	0
Leg only	16.8	0.37	10.2	0.23	10.5	0.25	0
Wt 1 X d	26.0	0.57	24.0	0.55	30.0	0.71	16
Wt 2 X d	23.0	0.51	21.5	0.50	30.0	0.71	29
Wt 3 X d	25.6	0.56	28.0	0.64	41.5	0.97	44
Wt 4 X d	31.0	0.69	29.0	0.67	44.0	1.03	58
Wt 5 X d	44.0	0.98	36.0	0.83	51.0	1.19	79

E) Histogram of Volts/patterns (W.T.2):

Pattern	E.M.G.- Resets & Volts V.L.		V.M.		R.F.	
	R	V	R	V	R	V
Wt 5 X d (W.T.1)	44.0	0.98	36.0	0.83	51.0	1.19
I	62.5	1.39	50.0	1.14	43.0	1.0
II	68.5	1.53	35.0	0.80	20.0	0.59
III	59.0	1.32	42.0	0.96	32.0	0.75
IV	37.5	0.84	40.9	0.94	47.0	1.10
V	30.5	0.68	21.0	0.48	32.0	0.75
VI	27.5	0.61	30.0	0.69	44.0	1.03
VII	15.5	0.34	9.0	0.21	13.0	0.31

DATA SHEET

Name ________ Ro. ________ No. 7 Session # 4 Date ________

A) Force-Transducer Calibration: Load: 24.54 kg. Deflection: 65 mm.

B) Force-Transducer Calibration graph:

Torque	Deflection
leg 117.10 kg.cm.	____ mm.
weight 834.36 kg.cm.	____ mm.
leg + Wt 951.46 kg.cm.	59 mm.

C) E.M.G. Calibration graph:

Cal. in			Resets
V.L.	0 mV.	:	5.8
	1 mV.	:	45
V.M.	0 mV.	:	0
	1 mV.	:	44
R.F.	0 mV.	:	0
	1 mV.	:	39

D) Torque/volts curves in kg. cm./mV. (W.T.1):

Torque	E.M.G.- Resets & Volts						F-Transd. Deflec. mm.
	V.L.		V.M.		R.F.		
	R	V	R	V	R	V	
Leg at rest	-	-	-	-	-	-	0
Leg only	9.0	0.09	6.5	0.14	3.5	0.09	0
Wt 1 X d	17.0	0.29	13.0	0.29	13.0	0.33	24
Wt 2 X d	27.5	0.56	25.0	0.57	28.4	0.74	42
Wt 3 X d	23.0	0.44	16.2	0.36	23.1	0.59	49
Wt 4 X d	27.9	0.56	25.0	0.57	33.0	0.85	59
Wt 5 X d	28.0	0.57	24.0	0.54	26.5	0.68	65.5

E) Histogram of Volts/patterns (W.T.2):

Pattern	E.M.G.- Resets & Volts					
	V.L.		V.M.		R.F.	
	R	V	R	V	R	V
Wt 5 X d (W.T.1)	28.0	0.57	24.0	0.54	26.5	0.68
I	21.6	0.41	20.5	0.46	12.0	0.31
II	21.0	0.39	16.0	0.36	6.2	0.16
III	23.0	0.44	21.0	0.47	16.8	0.43
IV	14.8	0.23	11.4	0.25	10.0	0.26
V	21.0	0.39	12.4	0.28	7.0	0.18
VI	21.7	0.42	16.0	0.36	10.0	0.26
VII	12.0	0.17	15.0	0.34	22.0	0.57

DATA SHEET

Name Br. No. 1 Session # 5 Date

A) Force-Transducer Calibration: Load: 24.54 kg. Deflection: 48.5 mm.

B) Force-Transducer Calibration graph:

Torque	Deflection
leg 125.87 kg.cm.	mm.
weight 883.44 kg.cm.	mm.
leg + Wt 1009.31 kg.cm.	48 mm.

C) E.M.G. Calibration graph:

Cal. in			Resets
V.L.	0 mV.	:	5
	1 mV.	:	43
V.M.	0 mV.	:	0
	1 mV.	:	43
R.F.	0 mV.	:	0
	1 mV.	:	39

D) Torque/volts curves in kg. cm./mV. (W.T.1):

Torque	E.M.G.- Resets & Volts						F-Transd. Deflec. mm.
	V.L.		V.M.		R.F.		
	R	V	R	V	R	V	
Leg at rest	–	–	–	–	–	–	0
Leg only	6.5	0.05	6.4	0.15	5.0	0.13	0
Wt 1 X d	9.0	0.11	11.2	0.26	9.0	0.23	13.5
Wt 2 X d	11.4	0.17	15.3	0.36	13.8	0.36	26
Wt 3 X d	14.9	0.26	24.0	0.56	21.0	0.54	39
Wt 4 X d	22.0	0.45	20.0	0.47	27.0	0.70	48
Wt 5 X d	27.3	0.59	37.0	0.86	31.0	0.80	68

E) Histogram of Volts/patterns (W.T.2):

Pattern	E.M.G.- Resets & Volts					
	V.L.		V.M.		R.F.	
	R	V	R	V	R	V
Wt 5 X d (W.T.1)	27.3	0.59	37.0	0.86	31.0	0.80
I	25.5	0.54	28.0	0.65	12.5	0.30
II	26.5	0.57	15.0	0.35	5.2	0.13
III	22.0	0.45	18.0	0.42	6.3	0.16
IV	34.5	0.72	27.0	0.63	22.0	0.57
V	26.5	0.57	32.0	0.75	29.0	0.75
VI	32.0	0.72	31.0	0.72	18.0	0.47
VII	17.0	0.32	21.4	0.50	14.0	0.36

DATA SHEET

Name ______ Da. ______ No. 2 Session # 5 Date ______

A) Force-Transducer Calibration: Load: 24.54 kg. Deflection: 53 mm.

B) Force-Transducer Calibration graph:

Torque	Deflection
leg 131.36 kg.cm.	______ mm.
weight 907.98 kg.cm.	______ mm.
leg + Wt 103934 kg.cm.	52 mm.

C) E.M.G. Calibration graph:

Cal. in			Resets
V.L.	0 mV.	:	0
	1 mV.	:	28
V.M.	0 mV.	:	0
	1 mV.	:	44
R.F.	0 mV.	:	0
	1 mV.	:	40

D) Torque/volts curves in kg. cm./mV. (W.T.1):

Torque	E.M.G.- Resets & Volts						F-Transd. Deflec. mm.
	V.L.		V.M.		R.F.		
	R	V	R	V	R	V	
Leg at rest	-	-	-	-	-	-	0
Leg only	2.0	0.07	2.5	0.06	10.6	0.28	0
Wt 1 X d	9.4	0.33	14.0	0.20	15.5	0.39	15
Wt 2 X d	7.9	0.30	17.0	0.39	24.0	0.60	26
Wt 3 X d	12.0	0.43	20.2	0.46	32.0	0.81	41
Wt 4 X d	12.8	0.46	25.0	0.57	38.0	0.91	52
Wt 5 X d	17.4	0.64	29.5	0.67	40.0	1.0	70

E) Histogram of Volts/patterns (W.T.2):

Pattern	E.M.G.- Resets & Volts					
	V.L.		V.M.		R.F.	
	R	V	R	V	R	V
Wt 5 X d (W.T.1)	17.4	0.64	29.5	0.67	40.0	1.0
I	14.4	0.52	23.0	0.52	16.0	0.40
II	21.0	0.75	24.0	0.55	11.0	0.27
III	12.9	0.46	26.5	0.61	23.5	0.59
IV	9.1	0.33	19.2	0.44	25.0	0.63
V	8.0	0.28	9.7	0.22	22.0	0.56
VI	6.2	0.22	14.0	0.32	22.0	0.56
VII	6.0	0.21	9.0	0.20	26.0	0.65

DATA SHEET

Name G1. No. 3 Session # 5 Date ______

A) Force-Transducer Calibration: Load: 24.54 kg. Deflection: 49 mm.

B) Force-Transducer Calibration graph:

Torque	Deflection
leg 126.48 kg.cm.	______ mm.
weight 883.44 kg.cm.	______ mm.
leg + Wt 1009.92 kg.cm.	49 mm.

C) E.M.G. Calibration graph:

Cal. in			Resets
V.L.	0 mV.	:	5
	1 mV.	:	22
V.M.	0 mV.	:	0
	1 mV.	:	21
R.F.	0 mV.	:	0
	1 mV.	:	39

D) Torque/volts curves in kg. cm./mV. (W.T.1):

Torque	E.M.G.- Resets & Volts						F-Transd. Deflec. mm.
	V.L.		V.M.		R.F.		
	R	V	R	V	R	V	
Leg at rest	–	–	–	–	–	–	0
Leg only	5.4	0.03	4.0	0.19	12.5	0.32	0
Wt 1 X d	10.0	0.29	13.0	0.61	25.0	0.64	14
Wt 2 X d	14.0	0.53	12.5	0.60	35.0	0.90	24.5
Wt 3 X d	16.0	0.65	21.0	1.0	46.0	1.18	38
Wt 4 X d	26.0	1.23	20.0	0.95	45.0	1.16	49
Wt 5 X d	30.0	1.46	22.5	1.07	40.0	1.03	70

E) Histogram of Volts/patterns (W.T.2):

Pattern	E.M.G.- Resets & Volts					
	V.L.		V.M.		R.F.	
	R	V	R	V	R	V
Wt 5 X d (W.T.1)	30.0	1.46	22.5	1.07	40.0	1.03
I	24.9	1.16	24.9	1.18	26.9	0.69
II	31.5	1.55	30.0	1.42	32.0	0.82
III	31.0	1.52	13.5	0.64	25.0	0.64
IV	19.5	0.85	15.2	0.72	20.0	0.51
V	20.0	0.87	14.8	0.70	27.4	0.71
VI	18.5	0.84	12.7	0.61	12.5	0.32
VII	11.0	0.35	13.0	0.62	21.0	0.54

DATA SHEET

Name________ Gr.________ No. 4 Session # 5 Date________

A) Force-Transducer Calibration: Load: 24.54 kg. Deflection: 64 mm.

B) Force-Transducer Calibration graph:

Torque	Deflection
leg 100.10 kg.cm.	______ mm.
weight 809.82 kg.cm.	______ mm.
leg + Wt 909.92 kg.cm.	62.5 mm.

C) E.M.G. Calibration graph:

Cal. in		Resets
V.L.	0 mV.	0
	1 mV.	22
V.M.	0 mV.	0
	1 mV.	21.2
R.F.	0 mV.	0
	1 mV.	44

D) Torque/volts curves in kg. cm./mV. (W.T.1):

Torque	E.M.G.- Resets & Volts V.L. R	V.L. V	V.M. R	V.M. V	R.F. R	R.F. V	F-Transd. Deflec. mm.
Leg at rest	–	–	–	–	–	–	0
Leg only	2.2	0.06	1.0	0.05	1.0	0.02	0
Wt 1 X d	6.8	0.24	4.0	0.19	8.1	0.18	17.5
Wt 2 X d	11.1	0.48	9.0	0.43	14.0	0.32	32
Wt 3 X d	24.5	1.11	13.2	0.63	28.0	0.64	49
Wt 4 X d	35.4	1.62	18.5	0.88	32.0	0.73	62.5
Wt 5 X d	35.0	1.60	19.5	0.93	35.0	0.80	76

E) Histogram of Volts/patterns (W.T.2):

Pattern	E.M.G.- Resets & Volts V.L. R	V.L. V	V.M. R	V.M. V	R.F. R	R.F. V
Wt 5 X d (W.T.1)	35.0	1.60	19.5	0.93	35.0	0.80
I	19.0	0.85	12.0	0.57	9.2	0.21
II	21.0	0.94	21.5	1.02	12.5	0.29
III	11.8	0.52	5.5	0.26	7.0	0.16
IV	22.2	1.05	17.0	0.81	26.0	0.60
V	20.0	0.90	16.7	0.80	25.9	0.59
VI	10.8	0.47	9.5	0.45	12.0	0.27
VII	17.0	0.76	14.0	0.67	23.0	0.52

DATA SHEET

Name Ji. No. 5 Session # 5 Date

A) Force-Transducer Calibration: Load: 24.54 kg. Deflection: 70.5 mm.

B) Force-Transducer Calibration graph:

Torque	Deflection
leg 109.86 kg.cm.	mm.
weight 846.63 kg.cm.	mm.
leg + Wt 956.49 kg.cm.	69 mm.

C) E.M.G. Calibration graph:

	Cal. in		Resets
V.L.	0 mV.	:	0
	1 mV.	:	88
V.M.	0 mV.	:	4
	1 mV.	:	88
R.F.	0 mV.	:	0
	1 mV.	:	38

D) Torque/volts curves in kg. cm./mV. (W.T.1):

Torque	E.M.G.- Resets & Volts						F-Transd. Deflec. mm.
	V.L.		V.M.		R.F.		
	R	V	R	V	R	V	
Leg at rest	-	-	-	-	-	-	0
Leg only	15.8	0.18	14.0	0.12	7.0	0.17	0
Wt 1 X d	26.5	0.30	29.0	0.30	17.1	0.41	21.5
Wt 2 X d	27.5	0.31	29.0	0.30	17.8	0.43	39
Wt 3 X d	36.5	0.42	47.8	0.52	29.5	0.70	60
Wt 4 X d	53.5	0.61	54.0	0.60	30.5	0.73	69
Wt 5 X d	50.0	0.57	53.0	0.58	30.0	0.72	74

E) Histogram of Volts/patterns (W.T.2):

Pattern	E.M.G.- Resets & Volts					
	V.L.		V.M.		R.F.	
	R	V	R	V	R	V
Wt 5 X d (W.T.1)	50.0	0.57	53.0	0.58	30.0	0.72
I	40.5	0.46	29.0	0.30	8.4	0.20
II	52.0	0.59	36.0	0.38	8.0	0.19
III	38.5	0.44	22.5	0.22	7.0	0.17
IV	35.5	0.41	25.4	0.26	8.5	0.21
V	41.8	0.48	40.5	0.44	25.0	0.60
VI	13.9	0.17	13.8	0.12	5.8	0.20
VII	10.8	0.12	11.5	0.10	9.0	0.22

DATA SHEET

Name Ra. No. 6 Session # 5 Date ____

A) Force-Transducer Calibration: Load: 24.54 kg. Deflection: 55 mm.

B) Force-Transducer Calibration graph:

Torque	Deflection
leg 112.65 kg.cm.	____ mm.
weight 797.55 kg.cm.	____ mm.
leg + Wt 910.2 kg.cm.	55 mm.

C) E.M.G. Calibration graph:

Cal. in			Resets
V.L.	0 mV.	:	0
	1 mV.	:	45
V.M.	0 mV.	:	1.5
	1 mV.	:	43
R.F.	0 mV.	:	0
	1 mV.	:	40

D) Torque/volts curves in kg. cm./mV. (W.T.1):

Torque	E.M.G.- Resets & Volts						F-Transd. Deflec. mm.
	V.L.		V.M.		R.F.		
	R	V	R	V	R	V	
Leg at rest	-	-	-	-	-	-	0
Leg only	12.8	0.28	11.8	0.25	8.0	0.20	0
Wt 1 X d	25.0	0.55	20.0	0.46	16.0	0.40	16
Wt 2 X d	34.6	0.76	26.0	0.60	27.9	0.70	28
Wt 3 X d	36.5	0.81	28.0	0.66	31.0	0.78	43
Wt 4 X d	23.5	0.52	26.5	0.61	32.0	0.81	55
Wt 5 X d	39.0	0.87	41.0	0.96	37.0	0.93	71

E) Histogram of Volts/patterns (W.T.2):

Pattern	E.M.G.- Resets & Volts					
	V.L.		V.M.		R.F.	
	R	V	R	V	R	V
Wt 5 X d (W.T.1)	39.0	0.87	41.0	9.96	37.0	0.93
I	48.0	1.07	57.0	1.34	31.0	0.78
II	43.5	0.97	43.0	1.0	14.1	0.35
III	40.0	0.89	47.0	1.1	24.0	0.60
IV	36.6	0.81	42.0	0.98	35.0	0.88
V	31.6	0.69	36.5	0.85	39.0	0.98
VI	38.0	0.84	42.5	0.99	40.0	1.00
VII	17.9	0.39	18.0	0.41	37.0	0.93

DATA SHEET

Name Ro. No. 7 Session # 5 Date

A) Force-Transducer Calibration: Load: 24.54 kg. Deflection: 66.5 mm.

B) Force-Transducer Calibration graph:

Torque	Deflection
leg 117.10 kg.cm.	mm.
weight 834.36 kg.cm.	mm.
leg + Wt 951.46 kg.cm.	65 mm.

C) E.M.G. Calibration graph:

Cal. in			Resets
V.L.	0 mV.	:	6
	1 mV.	:	45
V.M.	0 mV.	:	0
	1 mV.	:	45
R.F.	0 mV.	:	0
	1 mV.	:	44

D) Torque/volts curves in kg. cm./mV. (W.T.1):

Torque	E.M.G.- Resets & Volts						F-Transd. Deflec. mm.
	V.L.		V.M.		R.F.		
	R	V	R	V	R	V	
Leg at rest	-	-	-	-	-	-	0
Leg only	12.5	0.17	13.2	0.29	5.8	0.14	0
Wt 1 X d	18.5	0.32	19.9	0.44	17.5	0.40	20.5
Wt 2 X d	28.5	0.57	21.5	0.48	27.0	0.62	38
Wt 3 X d	36.0	0.77	20.7	0.46	26.0	0.60	59.5
Wt 4 X d	29.0	0.59	20.0	0.44	25.0	0.57	65
Wt 5 X d	32.0	0.67	29.0	0.64	26.0	0.60	72

E) Histogram of Volts/patterns (W.T.2):

Pattern	E.M.G.- Resets & Volts					
	V.L.		V.M.		R.F.	
	R	V	R	V	R	V
Wt 5 X d (W.T.1)	32.0	0.67	29.0	0.64	26.0	0.60
I	25.0	0.48	20.5	0.46	14.0	0.32
II	19.5	0.34	26.0	0.58	13.5	0.31
III	35.0	0.74	22.0	0.49	20.9	0.48
IV	17.0	0.28	11.6	0.26	9.0	0.21
V	22.0	0.41	20.5	0.46	13.0	0.30
VI	20.0	0.35	17.6	0.39	19.0	0.44
VII	18.5	0.32	16.9	0.37	22.0	0.51

Appendix 2: Raw data for W.T.3

DATA SHEET

Name G.M. No. 1 Session # 1 Date

A) Force-Transducer Calibration: Load: 24.54 kg. Deflection: 52 mm.

B) Force-Transducer Calibration graph:

Torque	Deflection
leg 82.9 kg.cm.	mm.
weight 809.8 kg.cm.	mm.
leg + Wt 892.7 kg.cm.	52 mm.

C) E.M.G. Calibration graph:

	Cal. in		Resets
V.L.	0 mV.	:	0
	1 mV.	:	44
V.M.	0 mV.	:	0
	1 mV.	:	44
R.F.	0 mV.	:	0
	1 mV.	:	41

D) Torque/volts curves in kg. cm./mV. (W.T.3):

	V.L.		V.M.		R.F.		AMPLITUDE
	R	V	R	V	R	V	mm.
1	1.80	0.05	0.50	0.02	1.70	0.05	10.0
2	2.20	0.06	1.00	0.03	3.50	0.09	11.5
3	3.80	0.09	2.10	0.05	0.50	0.02	13.0
4	4.70	0.12	2.50	0.06	6.50	0.11	15.5
5	7.00	0.17	6.00	0.14	11.80	0.30	27.0
6	11.60	0.27	9.60	0.22	11.00	0.28	32.5
7	14.90	0.34	14.20	0.33	13.50	0.34	36.0
8	15.60	0.36	15.90	0.37	18.00	0.45	36.5
9	12.70	0.29	13.50	0.31	16.80	0.43	39.0
10	15.50	0.36	16.80	0.39	18.00	0.45	44.0
11	15.70	0.37	27.70	0.63	28.00	0.69	47.0
12	20.50	0.47	37.00	0.85	34.90	0.86	50.0
13	21.50	0.50	31.50	0.72	37.00	0.91	55.0
14	31.00	0.71	46.00	1.05	42.50	1.04	62.0
15	33.00	0.76	38.50	0.88	38.80	0.95	66.5
16	34.90	0.80	49.00	1.12	39.00	0.96	68.0

DATA SHEET

Name G.M. No. 1 Session # 2 Date

A) Force-Transducer Calibration: Load: 24.54 kg. Deflection: 62 mm.

B) Force-Transducer Calibration graph:

Torque		Deflection
leg	82.9 kg.cm.	mm.
weight	809.8 kg.cm.	mm.
leg + Wt	892.7 kg.cm.	62 mm.

C) E.M.G. Calibration graph:

	Cal. in		Resets
V.L.	0 mV.	:	0
	1 mV.	:	44
V.M.	0 mV.	:	0
	1 mV.	:	44
R.F.	0 mV.	:	0
	1 mV.	:	38

D) Torque/volts curves in kg. cm./mV. (W.T.3):

	V.L.		V.M.		R.F.		AMPLITUDE
	R	V	R	V	R	V	mm.
1	6.00	0.15	2.20	0.06	2.10	0.07	8.0
2	3.50	0.90	2.90	0.07	4.50	0.13	21.5
3	6.00	0.15	2.50	0.06	9.50	0.26	22.0
4	6.00	0.15	8.00	0.19	10.00	0.27	25.0
5	9.80	0.23	5.00	0.12	7.50	0.20	29.0
6	14.00	0.32	5.50	0.13	12.00	0.32	41.0
7	14.80	0.34	9.00	0.21	15.00	0.40	46.0
8	12.50	0.29	11.00	0.26	23.00	0.61	47.0
9	14.00	0.33	8.10	0.19	16.00	0.43	51.0
10	15.20	0.35	12.80	0.30	22.00	0.58	52.0
11	26.50	0.61	21.00	0.48	30.00	0.79	66.5
12	40.80	0.93	13.00	0.30	23.00	0.61	67.5
13	36.50	0.83	28.00	0.64	35.00	0.92	78.0
14	54.00	1.23	28.00	0.64	35.00	0.92	79.0
15	56.00	1.27	29.00	0.66	31.00	0.82	82.5
16	50.50	1.15	28.00	0.64	37.00	0.97	83.5

DATA SHEET

Name G.S. No. 2 Session # 1 Date

A) Force-Transducer Calibration: Load: 24.54 kg. Deflection: 45.5 mm.

B) Force-Transducer Calibration graph:

Torque		Deflection
leg	129.2 kg.cm.	mm.
weight	932.5 kg.cm.	mm.
leg + Wt	1061.7 kg.cm.	45.5 mm.

C) E.M.G. Calibration graph:

Cal. in			Resets
V.L.	0 mV.	:	0
	.1 mV.	:	44
V.M.	0 mV.	:	0
	1 mV.	:	44
R.F.	0 mV.	:	0
	1 mV.	:	40

D) Torque/volts curves in kg. cm./mV. (W.T.3):

	V.L.		V.M.		R.F.		AMPLITUDE
	R	V	R	V	R	V	mm.
1	4.20	0.10	3.40	0.08	5.00	0.13	27.0
2	2.80	0.07	1.50	0.04	5.00	0.13	27.5
3	7.90	0.18	4.50	0.10	10.50	0.27	33.5
4	9.20	0.21	7.50	0.17	10.00	0.25	39.0
5	11.90	0.27	8.50	0.20	12.00	0.31	43.0
6	11.90	0.27	10.00	0.34	11.50	0.30	43.0
7	10.50	0.24	7.80	0.18	11.00	0.28	44.5
8	14.90	0.34	14.00	0.32	21.00	0.53	52.0
9	9.70	0.23	9.00	0.21	15.50	0.40	48.0
10	11.50	0.26	8.50	0.20	13.50	0.35	51.0
11	18.50	0.42	17.50	0.40	17.50	0.44	58.5
12	18.00	0.41	12.80	0.30	20.00	0.51	61.0
13	18.50	0.42	19.50	0.45	21.00	0.53	61.0
14	19.00	0.43	24.00	0.55	25.50	0.64	65.5
15	31.00	0.71	30.50	0.70	28.00	0.71	75.0
16	45.00	1.03	28.00	0.64	30.00	0.76	86.0

DATA SHEET

Name G.S. No. 2 Session # 2 Date

A) Force-Transducer Calibration: Load: 24.54 kg. Deflection: 42.5 mm.

B) Force-Transducer Calibration graph:

Torque	Deflection
leg 129.2 kg.cm.	mm.
weight 932.5 kg.cm.	mm.
leg + Wt 1061.7 kg.cm.	42.5 mm.

C) E.M.G. Calibration graph:

Cal. in			Resets
V.L.	0 mV.	:	0
	1 mV.	:	60
V.M.	0 mV.	:	0
	1 mV.	:	44
R.F.	0 mV.	:	0
	1 mV.	:	42

D) Torque/volts curves in kg. cm./mV. (W.T.3):

	V.L.		V.M.		R.F.		AMPLITUDE
	R	V	R	V	R	V	mm.
1	5.90	0.10	3.10	0.08	11.00	0.26	29.0
2	6.80	0.11	6.50	0.14	10.00	0.24	30.0
3	7.00	0.12	6.10	0.15	12.00	0.29	33.0
4	6.50	0.11	5.40	0.13	16.00	0.39	35.0
5	6.80	0.11	7.00	0.16	13.00	0.31	35.0
6	7.50	0.13	6.00	0.14	14.00	0.34	41.5
7	10.00	0.17	8.50	0.20	20.00	0.48	44.0
8	9.00	0.15	11.00	0.25	16.00	0.39	45.5
9	10.00	0.17	11.50	0.27	19.00	0.47	47.5
10	8.10	0.14	9.00	0.21	18.00	0.43	49.0
11	14.50	0.24	18.00	0.42	31.00	0.74	55.5
12	19.50	0.33	21.00	0.48	28.00	0.67	55.5
13	25.80	0.43	27.50	0.63	29.00	0.69	62.0
14	34.00	0.54	32.00	0.73	36.00	0.86	81.0
15	31.50	0.53	32.00	0.73	34.00	0.82	82.5
16	36.00	0.60	30.00	0.69	32.00	0.77	83.0

DATA SHEET

Name T.L. No. 3 Session # 1 Date

A) Force-Transducer Calibration: Load: 24.54 kg. Deflection: 62 mm.

B) Force-Transducer Calibration graph:

	Torque	Deflection
leg	98.5 kg.cm.	mm.
weight	809.8 kg.cm.	mm.
leg + Wt	908.3 kg.cm.	62 mm.

C) E.M.G. Calibration graph:

	Cal. in		Resets
V.L.	0 mV.	:	0.2
	1 mV.	:	92
V.M.	0 mV.	:	0
	1 mV.	:	87
R.F.	0 mV.	:	0
	1 mV.	:	54

D) Torque/volts curves in kg. cm./mV. (W.T.3):

	V.L.		V.M.		R.F.		AMPLITUDE
	R	V	R	V	R	V	mm.
1	4.00	0.04	7.50	0.09	1.40	0.03	10.0
2	6.00	0.06	11.50	0.14	2.90	0.06	13.5
3	6.90	0.07	11.50	0.14	3.00	0.06	14.0
4	6.10	0.06	12.00	0.14	4.00	0.08	14.0
5	12.00	0.13	16.00	0.19	5.60	0.11	19.5
6	12.50	0.14	14.00	0.16	5.00	0.09	21.0
7	10.10	0.11	11.00	0.13	5.00	0.09	21.5
8	14.00	0.15	13.00	0.15	5.00	0.09	22.5
9	15.00	0.16	16.00	0.19	5.60	0.11	24.5
10	16.00	0.17	17.00	0.20	5.50	0.10	25.0
11	16.50	0.18	21.50	0.25	9.00	0.17	32.0
12	20.40	0.22	19.50	0.23	8.50	0.16	37.0
13	20.00	0.22	27.00	0.31	12.00	0.22	38.0
14	29.00	0.31	49.00	0.57	18.00	0.33	54.0
15	39.00	0.42	58.00	0.67	23.00	0.43	67.0
16	46.00	0.50	58.00	0.67	23.50	0.44	68.0

DATA SHEET

Name T.L. No. 3 Session # 2 Date

A) Force-Transducer Calibration: Load: 24.54 kg. Deflection: 60 mm.

B) Force-Transducer Calibration graph:

Torque		Deflection	
leg	98.5 kg.cm.		mm.
weight	809.8 kg.cm.		mm.
leg + Wt	908.3 kg.cm.	60	mm.

C) E.M.G. Calibration graph:

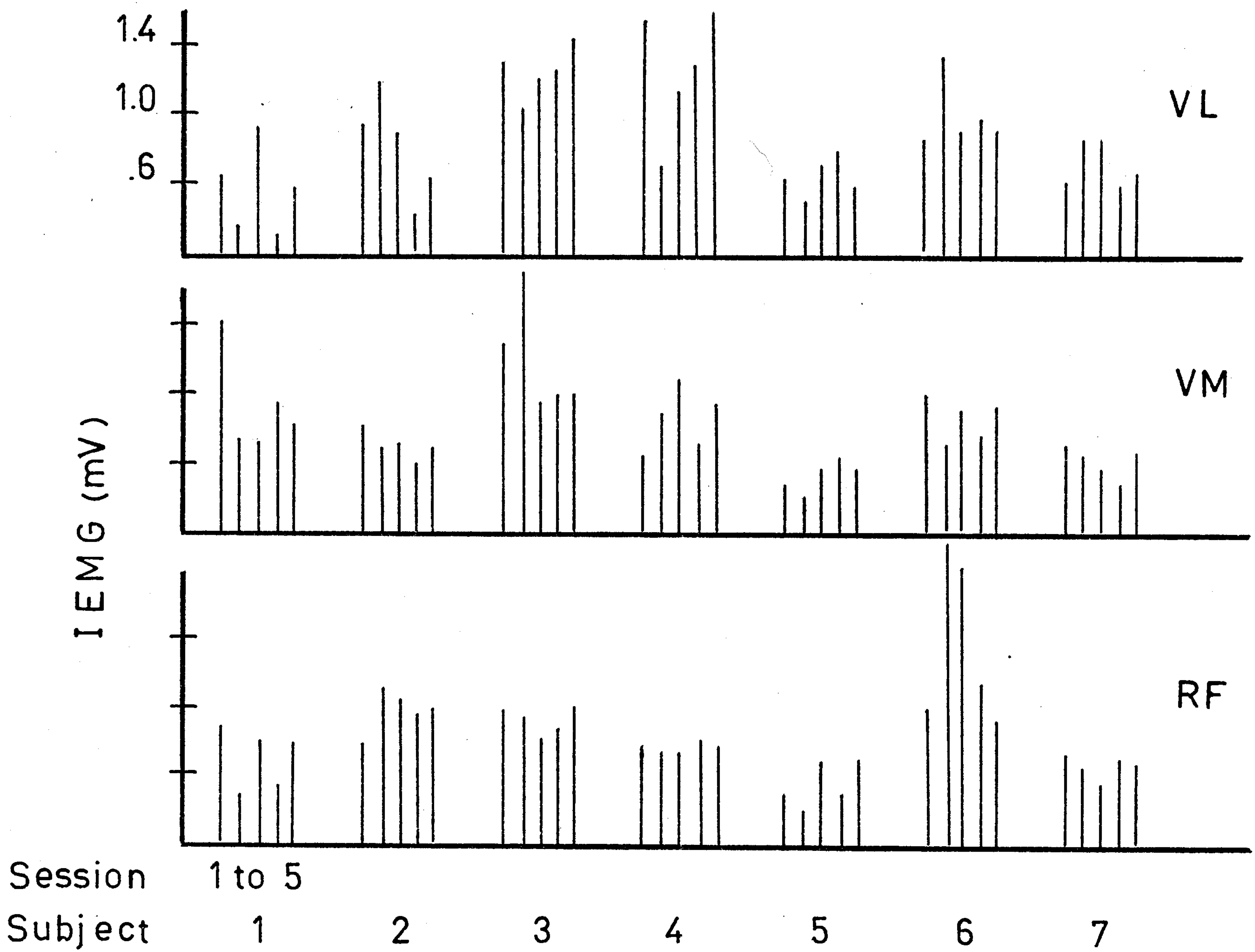
Cal. in			Resets
V.L.	0 mV.	:	0
	1 mV.	:	44
V.M.	0 mV.	:	0
	1 mV.	:	44
R.F.	0 mV.	:	0
	1 mV.	:	38

D) Torque/volts curves in kg. cm./mV. (W.T.3):

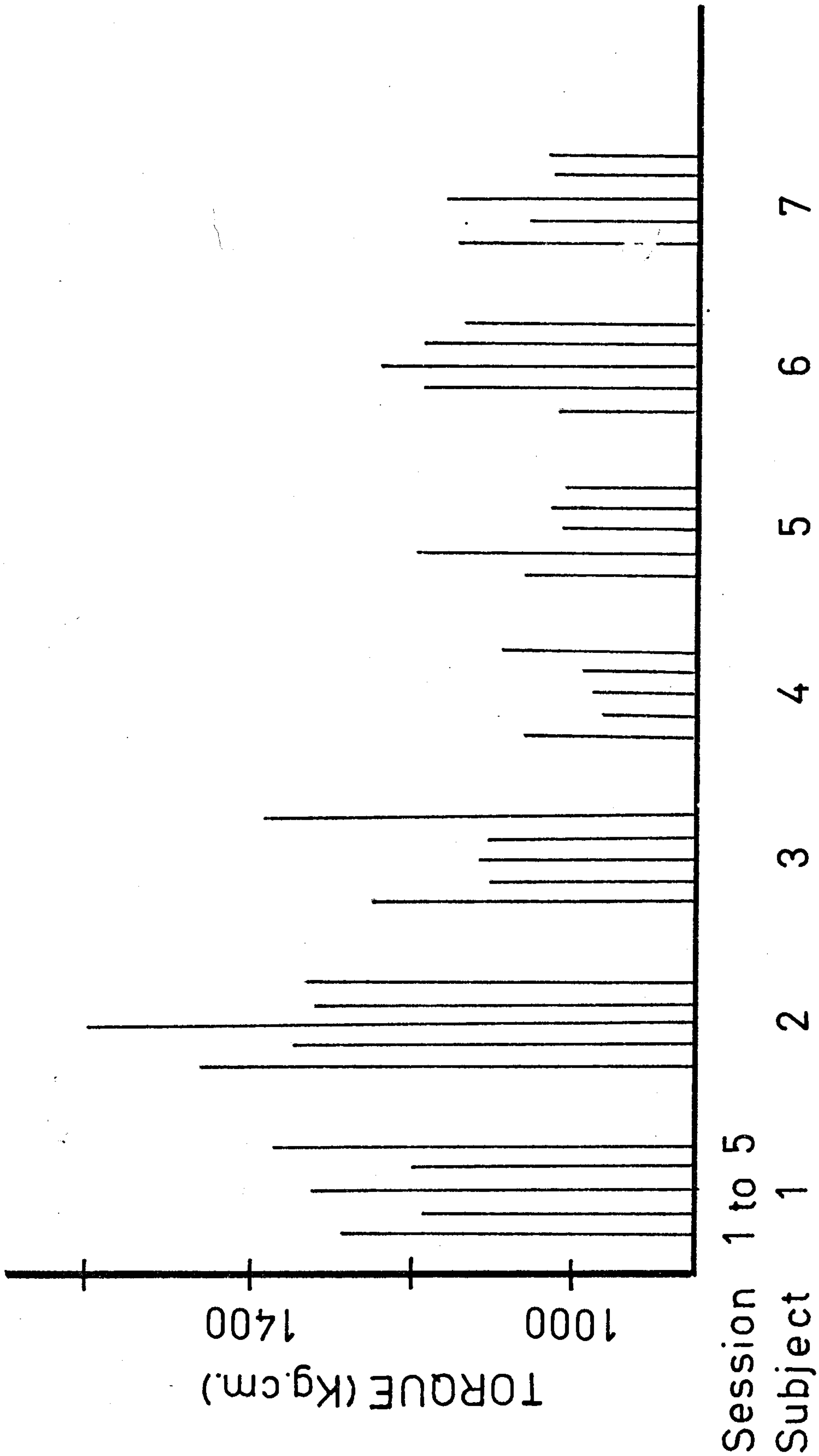
	V.L.		V.M.		R.F.		AMPLITUDE
	R	V	R	V	R	V	mm.
1	7.80	0.18	4.00	0.09	2.70	0.07	24.0
2	7.60	0.17	4.00	0.09	3.10	0.09	25.0
3	4.80	0.11	2.50	0.06	1.50	0.04	26.0
4	8.90	0.20	8.00	0.18	3.90	0.11	30.0
5	10.50	0.24	5.00	0.11	6.00	0.16	30.0
6	10.00	0.23	4.80	0.11	5.00	0.14	32.0
7	12.00	0.27	7.60	0.17	8.50	0.23	36.0
8	16.00	0.36	11.70	0.26	9.00	0.24	37.0
9	14.00	0.32	9.40	0.22	10.60	0.28	37.0
10	16.00	0.36	9.00	0.20	8.50	0.23	43.0
11	13.80	0.31	7.50	0.17	9.00	0.24	43.0
12	16.50	0.38	11.50	0.26	9.00	0.24	44.0
13	18.00	0.41	19.80	0.45	21.00	0.55	47.0
14	20.00	0.46	17.00	0.39	16.00	0.42	54.0
15	31.50	0.72	29.00	0.66	33.50	0.88	73.0
16	32.00	0.73	28.00	0.64	30.00	0.79	80.0

Appendix 3: Histograms of the raw data.

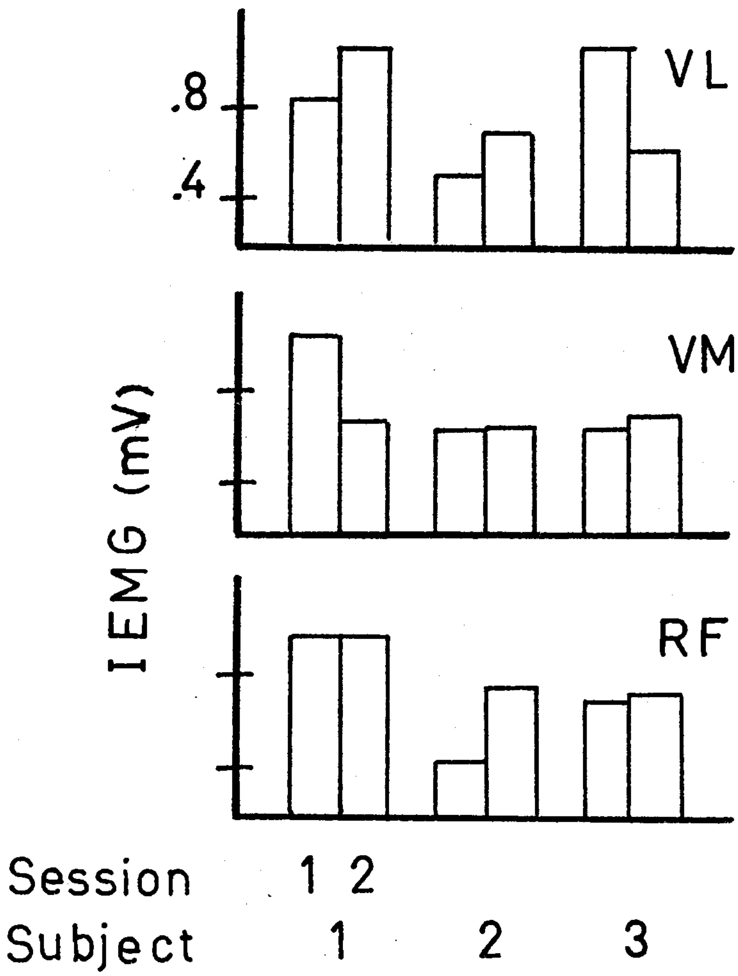
Histograms of the I.E.M.G. (mV.) produced by each muscle (V.L., V.M., R.F.) during maximal torque (wt 5) of W.T.1, for each subject (N=7) from each session (N=5). Each of these values was used to form ratios with the values obtained from the performance of the seven patterns of W.T.2 as described in the Method of Analysis.


1.4
1.0
.6
VL
VM
RF
I E M G (mV)
Session 1 to 5
Subject 1 2 3 4 5 6 7

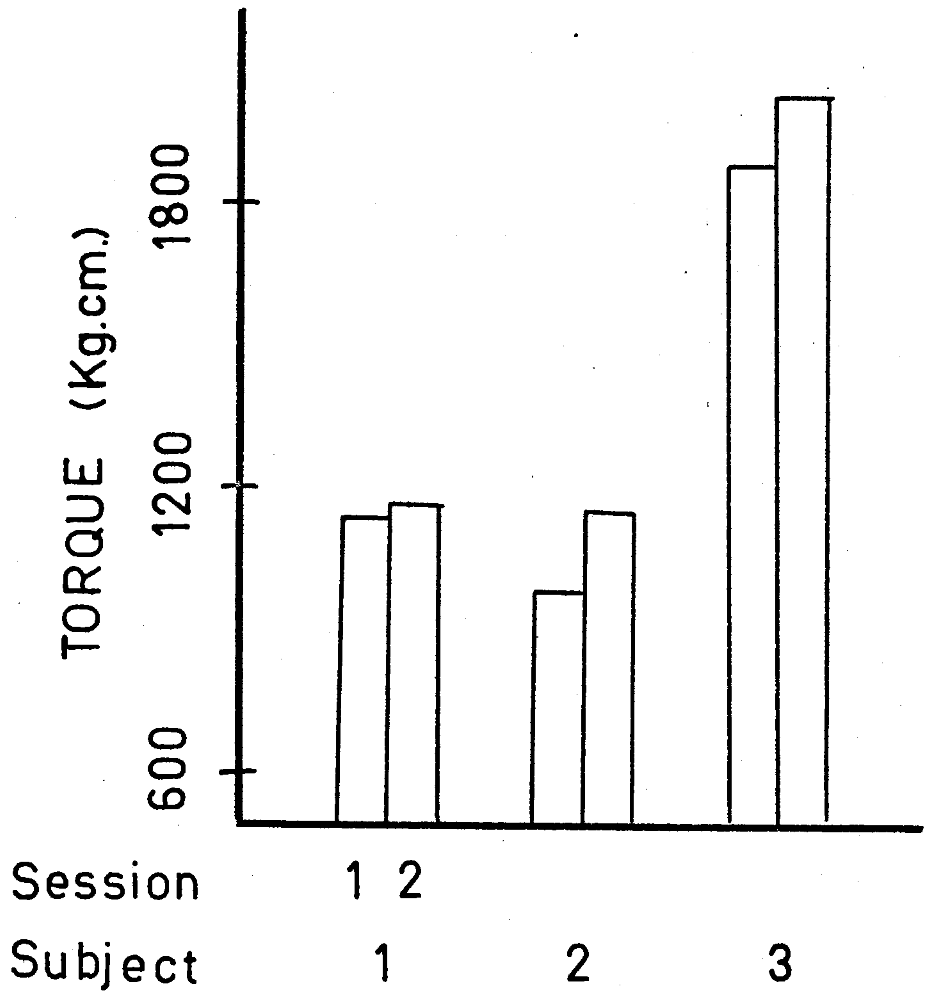
Histogram of maximal torques (Kg.cm.) produced by each subject (N=7) during each session (N=5) of W.T.1 .


TORQUE (Kg.cm.)
1400
1000
Session 1 to 5
Subject
1
2
3
4
5
6
7

Histograms of the I.E.M.G. (mV.)
produced by each muscle (V.L., V.M.,
R.F.) during maximal torque of W.T.3,
for each subject (N=3) during each
session (N=2).


.8
.4
VL
VM
RF
IEMG (mV)
Session 1 2
Subject 1 2 3

Histogram of the maximal torque (Kg.cm.) produced by each subject (N=3) during each session (N=2) of W.T. 3.


TORQUE (Kg.cm.)
1800
1200
600
Session 1 2
Subject 1 2 3