A COMPARISON OF SIX METHODS OF STRETCH ON THE ACTIVE RANGE OF HIP FLEXION

by

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ABSTRACT

Basically all methods of stretching can be termed ACTIVE or PASSIVE in terms of the type of the range of motion acquired. Active stretching methods require that the range of movement be made voluntarily, while passive stretching methods refer to movement through a range due to external force such as gravity or manual assistance. It was the purpose of this study to investigate the effects of six methods of stretch on the active range of right hip flexion.

The sample consisted of 119 volunteer college women in physical education at the University of British Columbia. Approximately twenty subjects were randomly assigned to each of seven treatment groups by pairs. In addition to the Control group, six exercise groups were taught various stretching regimens to be practiced ten minutes with a partner three times a week for three weeks. All subjects were measured before and after the study as well as before and after exercise on the first day of each week. The active range of right hip flexion was measured by the Leighton Flexometer and the strength of hip flexion at the 45 degree angle was measured by a cable tensiometer.

All groups increased in active range of hip flexion as indicated by the mean gains, including the Control group.

The following hypotheses were tested for significance

at the .05 level and were rejected.

1. Active stretching methods give a greater improvement in active range of hip flexion than do passive methods of stretching.

2. The method, Active Proprioceptive Neuromuscular Facilitation, gives a greater improvement in active range of right hip flexion than does the method, Ballistic and Hold.

Active stretching methods did not contribute significantly better to active range over passive methods, nor did the Active PNF method and Ballistic and Hold method show significant differences in their contribution to active range. Since passive methods of stretching contributed as well as active methods to active range of hip flexion, it is apparent that theoretically for active range of motion, it may be as important to reduce the resistance of the muscle being stretched as to increase the strength of the active opposing muscle. The results of this study indicate that both active and passive methods of stretching are effective in increasing active range of motion.

The Relaxation method contributed significantly better than other passive methods to active range of hip flexion apparently due to a more effective reduced resistance from the contractile component of the muscle.

The strength of hip flexion as measured at the 45 degree angle was not differentially improved by the various exercise treatments for the probable reason that the angle at which the strength was measured was well below the range at which specific strength gains might have taken place.

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PREFACE

A dual study was undertaken to satisfy the interests of two graduate students who wished to combine their efforts in an attempt to multiply the value of their research. It was the opinion of the students that the dual aspect of the study greatly enhanced the educational value and stimulated deeper understanding of the thesis topic.

Originally, it was the intent of each student to thoroughly investigate three stretching methods each and pool the data from the Control group. Following the Committee's recommendation, it was then decided that, in terms of the statistical analysis, it would more productive to collaborate the dual efforts even more closely. Thus the data from all six exercises, as well as the Control group, was utilized by both students, but one student has dealt with the results for the active range of flexibility, while the other has dealt with the results for the passive range. This thesis represents one half of the total research accomplished by the dual study.

ACKNOWLEDGEMENTS

A gracious thank you is extended to Keith Russell, who as "comrade in research" made the dual aspect of this study not only possible, not only more enjoyable, but in every decision to be made along the way, he substantiated the cliché that " two heads are better than one."

CHAPTER I

INTRODUCTION TO THE PROBLEM

Flexibility, or joint mobility, appears to be of significance as an aspect of physical fitness (DeVries, 1972; Leighton, 1960), as a factor in successful performance in certain kinds of motor activities (Jencks, 1974; Olsen, 1956), and as a factor in relieving pain (DeVries, 1974; Grieve, 1971) and reducing injury (Holt, 1971; Williams, 1968). Specific types of flexibility are considered to be advantageous qualities for athletes (Hartley, 1971; Johnson, 1974; Tucker, 1963) while the needs and demands of a particular sport dictate which joints must be flexible and to what extent. Karpovich (1959:287) states, "Besides fitness for the intensity of the effort, fitness for the quality of the effort is of practical importance." Flexibility may be important to the athlete for some or all of the following reasons:

1. Freedom of movement and thus greater amplitude over which to apply force.
2. Movement efficiency (less resistance to movement) and thus greater economy of work output.
3. Prevention of soft tissue damage due to limited range of motion.

4. Aesthetic impression and perceived ease of movement.

5. Mechanical advantage i.e. wrist and hip flexibility allow a gymnast to place the center of gravity over the base of support, the hands, in order to facilitate application of force in the "press to handstand."

In collaboration with Russell (1976), the investigator co-designed the following theoretical model indicating how flexibility may be increased. Figure 1 shows that there are basically two approaches to increasing range of motion: one approach is to decrease the resistance of the soft, supportive tissues of the muscle and joint, and the second approach is to increase the force (strength) of the opposing muscles to actively move through a range. Physiologically, resistance can be decreased in two ways:

1. Actual physical lengthening of the soft tissues (i.e. muscle, connective tissue, tendon, ligament).

2. Relaxation or inhibition of contraction of the muscle.

Increasing strength of the muscles that will activate the range of motion can be accomplished by various muscle loading activities as well as by reflexive facilitory techniques. In order for active range of motion to increase, it seems that at least one of these physiological events (reduced resistance or increased strength) must occur. As can be seen in Figure 1, there are numerous physical and psychological courses of action by which one may attain the physiological conditions.

Figure 1

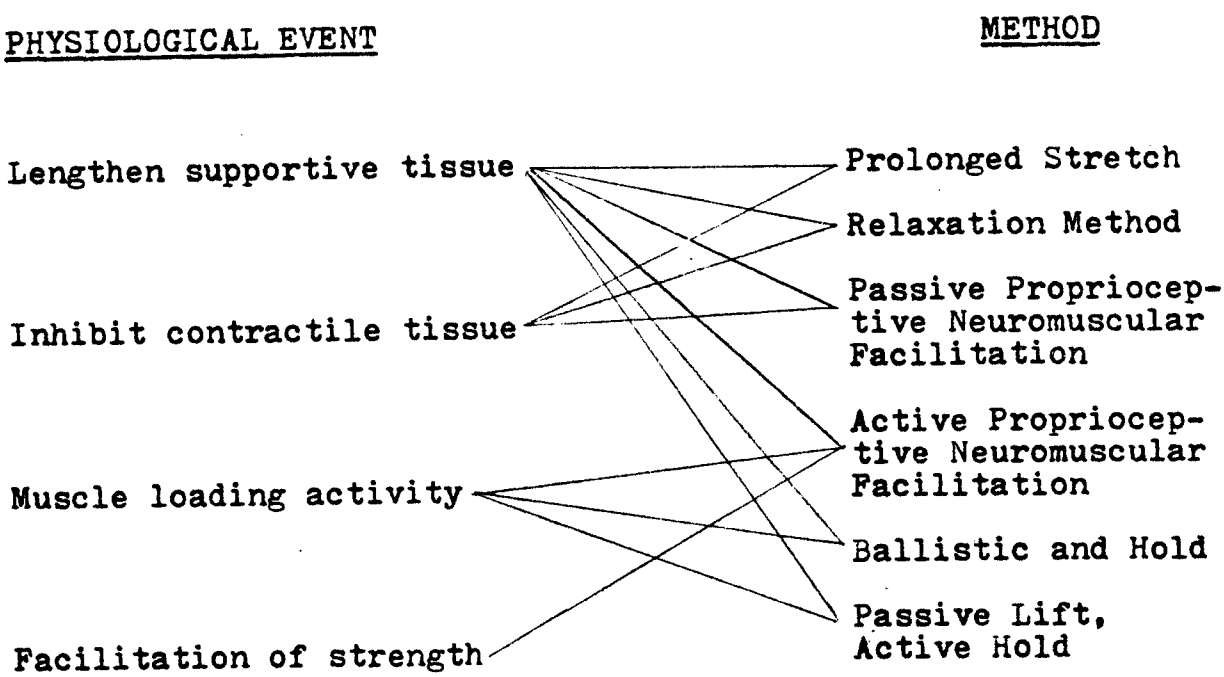
Theoretical Model of Approaches and Courses of Action to Improve Range of Motion

APPROACH	PHYSIOLOGICAL CONDITIONS	COURSES OF ACTION: PHYSICAL	COURSES OF ACTION: PSYCHOLOGICAL
DECREASE RESISTANCE OF TARGET AREA	LENGTHEN CONNECTIVE TISSUE	a) Prolonged stretch b) Contract target area while under stretch	?
	RELAX MYOTATIC REFLEX	a) Reciprocal Inhibition b) Accommodation c) Heat, ice, massage, exercise fatigue etc.	a) Mind-set (Gamma bias) b) Biofeedback (monitered inhibition) c) Relaxation Training
INCREASE STRENGTH OF OPPOSING MUSCLES	MUSCLE LOADING	a) Isometric b) Concentric c) Eccentric	a) Motivation
	FACILITATION TECHNIQUES	a) Successive induction (proprioceptive neuromuscular facilitation)	a) Learning: recruitment, coordination, synchronization

The physical educator or coach interested in increasing the flexibility of students or athletes encounters few documented methods that claim to improve specific joint range of motion. Basically all methods of stretching can be designated as ACTIVE or PASSIVE. Active stretching methods require that a subject move voluntarily through a range of motion, while passive stretch refers to movement occurring due to external force such as gravity or manual assistance. An interesting conjecture, which has yet to be resolved, is which range is more important to the athlete. It is thought by some that active range is more valuable to the athlete in that the range of most movement is provided by muscular effort, and for that reason, the active range simulates more closely the athlete's needs in sport. In this regard DeVries (1974:434) states:

> It may be hypothesized that the flexibility of motion may be of greater importance to physical performance than the ability to achieve an extreme degree of flexion or extension in the joint!

It was the interest of this study to determine if certain flexibility methods do in fact contribute to active range of motion. From the previous theoretical model (Fig. 1), six methods of stretching were selected as the experimental treatments. Represented in the methods are two traditional, two contemporary, and two theoretically sound, but as yet non-researched stretching exercises.



The six methods of stretch represent all four physiological conditions and in all cases are combinations of at least two. For a detailed theoretical interpretation behind the selection of these methods, the reader is referred to Appendix B.

STATEMENT OF THE PROBLEM

The purpose of this study was to investigate the differences of six methods of stretching on the active range of right hip flexion in college women.

SUBPROBLEMS

1. What is the effect of active and passive stretching methods on the rate of improvement in active range of hip flexion?
2. Is there one method that is superior to the others in increasing active range of hip flexion?

THE HYPOTHESES

1. Active stretching methods (Active PNF, Ballistic and Hold) give a greater improvement in active range of flexibility over passive methods (Passive PNF, Prolonged Stretch, Relaxation Method). Rationale: Active stretching methods, by definition, involve the effort of the flexor muscles, and strength is an apparent factor in voluntarily mobilizing the limb maximally.

2. The Active PNF method is superior to the Ballistic and Hold method in increasing active range of hip flexion. Rationale: Optimum soft tissue lengthening will be facilitated by an isometric contraction under stretch.

DELIMITATIONS

The four week study involved one hundred and nineteen volunteer women physical education students at the University of British Columbia. The experiment was limited to one flexibility action only: the active range of right leg hip flexion. The six methods investigated were thought to represent the main mobilizing exercises available, although it is possible that others do exist that are not within the realm of this study.

LIMITATIONS

1. The experimenter had no control of the subjects' activities outside of the testing situation although subjects were specifically requested to avoid unusual activity.
2. Since the subjects were all members of physical education classes, it was expected that some gains of mobility would be attributable to subjects' activities in these classes. A control group was included in the study to determine this effect.
3. Very flexible and very inflexible individuals were not excluded from the study, although the potential of these individuals to improve their range of motion

were likely quite different.

4. By the nature of the free swinging dial of the Leighton Flexometer, it was difficult to make accurate readings of the active range when the maximal effort caused some subjects to exhibit a shaking of the leg at the "hold" position.

DEFINITIONS

Flexibility: A broad descriptive term, as is strength and endurance, which refers to that physical component describing the ease and the extent of movement at a given joint.

Amplitude: A more specific term meaning the total angular displacement of a body segment around a given joint i.e. flexion and extension combined.

Range: The maximum angular displacement in one direction only i.e. range of hip flexion. This term must be further qualified into:

a) Active Range: that range achieved by voluntary muscle contraction. If the contraction is very strong and results in the limb being quickly propelled to an endpoint, then the range is termed the fast or dynamic active range. (The commonly used term "ballistic" for this type of movement is an incorrect usage of that

word since ballistic refers to an object separated from the source of its energy.) Momentum is a contributory factor to dynamic active range. If the contraction is slow, then the range is the slow or static active range.

b) Passive Range: that range achieved through some external force such as gravity or manual assistance.

Active Stretching Methods: refer to exercise regimens requiring voluntary contraction of the agonists at some point during the range of motion. In the case of hip flexion, the iliopsoas and rectus femoris of quadriceps are active in some phase of the exercise.

Passive Stretching Methods: refer to exercise regimens requiring no voluntary effort of the agonist muscles during the range of motion (flexion).

CHAPTER II

REVIEW OF RELATED LITERATURE

Definition

Flexibility is most often defined simply as "the range of joint motion" (DeVries, 1974; Holland, 1968; Holt, 1971; Johnson, 1974). As a term extended to muscle stretch in animal studies, flexibility is described in the literature as extensibility (Fieldman, 1960; Gardner, 1972), deformation (Buchtal and Kaiser, 1944) and compliance (Goubel et al., 1971). The return of a muscle to its "normal" length has been called elasticity or rebound (Wright and Johns, 1962). According to Holland (1968), the term flexibility implies just flexion and therefore could be considered a misnomer. Sigerseth (1962:88) claims that the term flexibility is derived from the Latin "bilis", meaning capability, and "flectere", meaning to bend.

> ...the meaning in scientific use pertains to the moving of articulating segments of the body about a joint and can therefore be used to describe movement from a position of extension to that of flexion or the opposite movement. (1962:88)

Flexibility was more specifically defined by Dickinson (1968:78), who in studying the flexion and extension of

the human wrist found that flexion and extension of the same joint were not correlated.

> If the flexibility is specific to individual movements of the joint (flexion or extension), then a range of motion (flexion plus extension) would be a combination of two unrelated measurements and not applicable to most situations. (1968:78)

In addition to the problem of defining flexibility, there has been surprisingly poor acknowledgement in the literature of the fact that flexibility can be expressed in two forms: active range of motion or passive range of motion. The two ranges were recognized by Glanville and Kreezer (1937) who obtained "norms" based on voluntary and passive movement of joints in ten normal male adults. Kraus and Weber (1949) used active and passive measures in their study of contractures. Fleishman (1961) found by factorial analysis that two statistically distinct components of flexibility existed that appeared to depend upon the speed of the range of movement. Thus he expressed the separate components as extent flexibility (slow or static) and dynamic flexibility (fast, repetitive). Passive and active ranges of motion were both included in the extent exercises, while the dynamic exercises were apparently active. Since Fleishman's study, awareness of the active and passive ranges of motion has either been taken for granted, or perhaps naively ignored.

Flexibility and Speed of Motion

DeVries (1963) hypothesized that flexibility contributed a "looseness factor"" in speed and oxygen consumption

activities. He thought that improvement of flexibility should decrease resistive forces involved in running and thus improve the speed. However, confirmation of this hypothesis could not be made. Norman (1970) suggested but could not confirm that the velocity of leg extension at the knee may be restricted by the shortness of tightness of the muscles that cross the knee joint. Despite contrary evidence, it still seems logical that increased range of motion offers greater amplitude over which to apply force, and therefore increased velocity at the point of force application. However, from the literature to date, it seems that flexibility improvement has little, if any, effect on speed of movement.

Instrumentation

Since the World Wars, measurement of flexibility became important to medical people who needed efficient and accurate instruments to document joint limitations for purposes of insurance investigations and evaluation of patients' progress. A complete review of the inovative creations that were developed in the early 1900's is beyond the interest of this study, but excellent reviews already do exist. The reader is referred to Wiechec and Krusen (1939) for a review up to the 1940's, to Darcus and Salter (1953) and Leighton (1954) covering up to the mid-1950's, and to Clarke (1975), Dickinson (1968) and Johnson and Nelson

(1974) for comprehensive reviews up to the current time.

Since Leighton's development of the Flexometer (1954), numerous studies have adopted this instrument as the most practical and accurate means of measuring flexibility. It could be said that since the early 1960's, the Leighton Flexometer has been the most dominant instrument used in the flexibility research field in physical education. Interestingly, the rather simple two arm goniometer, developed early in the history of instrumentation, is still the preferred method of evaluation in the field of rehabilitaion medicine.

Specific Activity and Flexibility Differences

Support exists for the idea that joints which are mobilized in regular exercises increase to an optimum value specific to the movement patterns of the particular activity. Individuals who are physically active tend to be more flexible than inactive individuals (McCue, 1953). Highly specialized performers apparently differ significantly from non-specialized individuals and also from specialists in other activities (Lemiere, 1952; Odgers, 1969; Syverson, 1950). Moderately engaged activity such as a semester of modern dance may make little contribution to flexibility changes (Bennett, 1955; Bushey, 1956), while rigorous strengthening sports such as football may actually impede the normal ranges of movement (Haliski and Sigerseth, 1950). Sports such as gymnastics and rowing can cause significant increases and decreases of flexibility in certain joints within a few

months (Denk, 1971; Kingsley, 1952; Ruhl, 1972; Shaw, 1968).

There is no evidence that flexibility exists as a single general characteristic of the human body (Harris, 1969; Hupprich, 1949; Lawther, 1956). Each joint and even direction of movement (flexion-extension) is unrelated (Dickinson, 1963). However, since noone can perfectly control the activity and stress endured by each joint, the structural makeup for each side of the body could be comparatively similar at birth, but differ significantly due to one-sided use and different physical requirements throughout life. Rather alone in her conflicting results is Spande (1954), who revealed through factorial analysis, that flexibility variables do have tendancies toward a general pattern. A high degree of similarity was shown in range of movement in ten out of twelve paired variables of university women. The issue has not been sufficiently resolved despite the more recent interpretation that specificity is innate.

Morphology and Flexibility

Controversy still exists over the validity of linear measures as a "fair" measure of trunk-leg flexibility regardless of limb-trunk ratio. Mathews (1957) concluded that flexibility, as measured by the Kraus-Weber standing toe touch or the Wells sit and reach, is independent of lower limb length. Harvey and Scott (1967) and Laubach and McConville (1966) have had concurring conclusions. Several studies, however, report conflicting results. Broer and Galles (1958)

found that women with extremely long trunks and arms, with short legs were facilitated on the toe touch test. Wear (1963) obtained the same conclusion for men. Dinkheller (1969) acquired significant relationships between five anthropometric measures and three flexibility measures.

Data from one hundred and five of the fattest, thinnest and most muscular college students was collected by Tyrance (1958) but he failed to determine a significant relationship of the extreme body types to flexibility (19 measures over 8 joints). Similarly, Laubach and McConville (1966) have concluded that flexibility is not related to body fat as measured by skinfold calipers.

Posture

Deviant posture apparently cannot be blamed on variable stiffness or mobility, although imbalanced muscular strength due to hypertension may be a factor (Hutchins, 1965). Relationships could not be found between specific joint flexibilities and round shoulder divergency (Coppock, 1958) or lumbar lordosis (Flint, 1964).

Strength and Flexibility

It was once thought that strength and flexibility were mutually interfering (Morehouse and Miller, 1967). However, it seems probable that strength and power can both accompany flexibility gains, even promote gains (Tucker, 1963),

and neither is hindered providing that the exercise takes place in the entire range of joint motion (Liverman, 1970; Massey and Chaudet, 1956; Taylor, 1928).

It has been demonstrated that the expression of strength can be expected to decrease in the extreme ranges of joint motion (Clarke and Munroe, 1970; Wehr, 1964). Jensen and others (1971), obtaining measurements of force generated by hip muscle in hip flexion, found that normal males gave maximum strength scores at thirty to thirty-five degrees. Gevlich (1971) emphasized that it is important that strength and flexibility accompany one another in development so as to preserve integrity of the joint.

Sex and Age Differences

The idea that males are less flexible than females is only speculative. Research to this point indicates that males and females often do differ with respect to mobility in certain joints at particular ages, but it is not clear whether activity or growth patterns may be more important determinants of differences than genetic sex. Leighton's two studies (1954, 1956) on boys over a range of ages suggest that specific changes in joint range of motion are more a reflection of movement pattern characteristics than age level differences.

Among elementary school children, girls have been found to be superior to boys in flexibility (Kirchner and Glines, 1957; Phillips et al., 1955). The studies of Buxton (1957), Phillips et al.(1955) and Schaffer (1959) indicate

that girls of all ages (six to fifteen years) surpassed the boys in the percentage of individuals passing the Kraus-Weber toe touch test.

Not all studies have concluded that the sexes differ in flexibility. Forbes (1950) found girls were flexible in more joints at age twelve, but boys were flexible in more joints at age eighteen. He concluded that boys and girls do not vary greatly in the flexibility of principle joints. Holland (1968) has reported on a study by Kendall and Kendall involving 4,500 children, kindergarten to highschool age, in performing the toe touch and forehead to knees tests. At age five, 98 percent of the boys and 86 percent of the girls could perform the toe touch test. Beginning at age six, there was a sharp decline in this percentage, so that by age twelve, only 30 percent of both sexes could pass the test.

There is unanimous agreement that flexibility, by and large, declines with age (Hupprich, 1949; Downie, 1970; Wright and Johns, 1962; Sigerseth, 1962) although the degree to which this happens is variable and depends to some extent on the health of the individual and on the degree of physical activity maintained. There is less agreement on which age group is the most flexible considering an overall evaluation of flexibility. It is quite conclusive that children become less flexible generally as they grow older, reaching a low point during the growth spurt (age ten to twelve for girls, later for boys) and then improving somewhat toward young adulthood (Hupprich, 1949; Buxton, 1957; Gurewitch and

O'Neill, 1944; Downie, 1970). The age at which flexibility decline ensues is largely dependent on the age that the child reduces his or her physical activity (Leighton, 1954, 1956).

Although the joint suppleness of the younger years is seldom maintained or regained in average individuals, there is some opinion that it should be so. DeVries (1974: 432) claims that, "considerable evidence indicates that maintenance of good joint mobility prevents, or to a large extent, relieves the aches and pains that grow more common with increasing age." Sigerseth (1962:90) states that, "associated with advanced age is the gradual impairment of movement, despite increased success in physical activities." Even though flexibility tends to decline with age, older age groups still respond very well to strength and mobility programs (Jette, 1969; Chapman, 1971). Of all age group categories of women, Jervey (1961) found that women age twenty-five to twenty-nine were the most flexible.

Norms for Hip Flexion

There is only limited normative data available on human range of motion in spite of the many techniques and tests developed to measure males and females of various ages. Comparisons between studies is extremely difficult because of numerous uncontrolled variables operating. Holland (1168:55) summarizes the problem:

> The data which have been collected involved the use of many different test procedures (for some of which the validity and reliability is questionable), which makes it difficult to generalize about the relationship of flexibility to such variables as sex, age, body type, warmup etc.

Normative data that is relevant to the nature of this study is available from a few sources. Sigerseth (1962) reported norms for males and females of ages six to eighteen for various joints. For right leg flexion and extension combined, the 50th percentile was 116 degrees. According to Kelly (1971), hip flexion from the anatomical position can be passively carried through approximately 120 degrees if the knee joint is flexed. Limitation of movement occurs due to contact of the thigh against the abdomen and contractile insufficiency. Kelly (1971:235) claims that, "with the knee extended, the hamstrings generally limit the flexion range to about 90 degrees." Hupprich (1949), Hutchins (1965), and McCue (1953) all report comparative angular measures on hip flexion of young adult women. Respectively, they obtained hip flexion means of 104.62 degrees, 105.40 degrees, and 119.38 degrees. McCue's subjects ranged in amplitude of movement from 76 to 120 degrees. Generally, the average young adult woman can be expected to show about 90 to 110 degrees of hip flexion.

Warmup

Evidence exists to state that warmup (in terms of practice trials) allows subjects to display immediate gains in flexibility (Fieldman, 1966; Rochelle et al., 1960). In terms of heat therapy, warmup can be considered a positve aid to range of motion (Frey, 1970; Grobaker, 1974; Lehman et al., 1970; Wehr, 1964). According to Wear (1963), dynamic

flexibilty was improved twenty percent by local warming of a joint to 113 degrees Fahrenheit, and was decreased ten to twenty percent by cooling to 65 degrees. Contradiction exists for cold application. Holt (1971) claimed that direct ice application on the muscle group during stretching exercise facilitated improvement in the range of movement, while others (Frey, 1970; Grobaker, 1974) have found cold application to be of no significant effect.

Retention of Flexibility

Flexibility tends to improve best (Kingsley, 1952) and retain improvement longer (Hansen, 1962) in those articulations that have initially lower ranges of motion. Improved range of motion is retained up to three hours after the stretching exercise (Hansen, 1962) but the effects of a training program can persist for a considerable period of time (McCue, 1953) depending upon the duration and extent of the exercise program.

The Role of Relaxation

Muscles, providing they are kept passive and relaxed, are known to cause little resistance to stretch. There is a fair amount of evidence indicating that inducing relaxation is in harmony with the goals of flexibility, and therefore relaxation can be considered to be an important component of flexibility improvement. Levine (1954:218) states:

> When relaxation occurs, a measurable increase in range results; simultaneously, there is a decrease as well in the resistance to initiating the passive movement.

Along the same line, Jacobsen (1967:7) explains:

> Tension means for us muscular contraction, whether grossly visible or microscopic. Accordingly, relaxation means muscular lengthening when this occurs as a common, natural physiological process...

Jacobsen's Progressive Relaxation (1938) describes a method that has potential application to flexibility in that it aims to make the individual increasingly observant of muscular contractions in various parts of the body. Cultivation of a muscle-sense occurs because sensations from contracting muscles are taught with care to be distinguished from those arising in joints.

> Frequent repetitions tend to make the individual familiar with the peculiar qualities of the experience of joint sensations in contrast with those arising in contracting muscles which can voluntarily be relaxed. (1938:37)

Progressive relaxation is apparently a practical means of obtaining muscle quiescence and eliminating muscle tension (Best and Taylor, 1966). In describing the essentials for proper movement, Rathbone (1959:12) states:

> For proper movement, as far as the muscular system is involved, several conditions are necessary: the complete possibility of motion in all joints, ability to relax any muscle while its antagonist contracts, and ability of certain muscles to hold the right degree of tension to make certain joints stable so that others may be free for movement.

Awkwardness in movement is assigned by Rathbone to either abnormality in joint shape limiting flexibility, or to muscle spasm preventing reciprocal relaxation (inhibition)

of antagonistic muscles. Her main point is that "one's joints do not become relaxed, nor one's muscles flexible" (1959:13).

Autogenic therapy, as designed by Schultz in the early 1920's and documented in his joint literary work with Luthe (1969), is another form of muscle relaxation that is based upon regular mental concentration exercises. The approach is apparently not related to sleep or deep hypnotic states although Jencks, a follower of Schultz, describes autogenic training as a "psycholophysiological method of self-hypnosis" (1973:1). The Jencks Exercise Manual is based upon the six standard exercises developed by Schultz to be used in the management of stress by self-relaxation.

Van Anne (1962) studied the relationship between neuromuscular hypertension and flexibility in college women electromyographically. She found small correlations showing some association of increased flexibility of the ankle, hip and shoulder joint with decreased residual tension in the gastrocnemious, biceps femoris and pectoralis major.

Recently, Bates (1974) proposed a new method of training for flexibility in his paper "Mind over Matter" called cybernetic stretch. This method uses "cybernetics or self-image to set the boundaries of individual accomplishment. Expand the self-image and you expand the area of the possible" (1974:6). By use of the imagination, mental images are set up that the servo-mechanism works to fulfill. "Thus before every direct flexibility practice it is absolutely necessary that you set aside time to get a new mental picture

of yourself, for example, 'making it flat' in the splits" (1974:8). The implication is that cybernetics alone will accomplish a new range of motion, but that stretching in conjunction with cybernetic mind-set is even more effective. Interestingly, Bates doesn't support these claims with research, although he does make reference to evidence documented in Bernstein and Borkovec's 1974 publication, Progressive Relaxation Training.

Bernstein and Borkovec (1974) claim that levels of arousal or tension are physiological events that can be descriminated and dealt with through the application of progressive relaxation. Basically the method is to develop strong isometric tension by simultaneous contraction of both agonists and antagonists of a specified body part, followed by concentrated physical and mental relaxation. Bernstein and Borkovec do cite research supporting significant decreases in muscle tension, heart rate and respiration with this kind of relaxation training. However, direct application to joint mobility was not their concern.

Relaxation, in terms of reduction of a local myotatic stretch reflex, can occur through biofeedback training, and control of muscle acitvity has obvious implications for reducing the resistance in flexibility training. In the 1970's Basmajian has become a significant pioneer in the area of individual muscle motor unit training claiming that "man can control his individual muscles" (1973:257). There is no doubt that it can be done since "...electromyographers have

clearly demonstrated that a voluntary muscle can be completely relaxed by a small effort of the will" (1973:259). According to Zappala (1970), previous training is a positive factor in enabling individuals to isolate and to control single motor units; for unexplained reasons, a larger proportion of males than females respond more favourably to biofeedback training.

To conclude this section, it is interesting to note that DeVries (1972) found that following exercise at a heart rate of 100, electrical activity in the musculature was lowered by twenty percent. Although the psychological manipulation of man has apparently much to offer in promoting a relaxed state for flexibility, the exercise modality should not be overlooked when a tranquilizer effect is desired.

Introduction to the Physiology of Stretch

To a large extent, man responds and adapts to movement automatically and without conscious concern. Proprioceptive interaction and stabilizing mechanisms automatically operate whenever man moves. Proprioceptive reflex mechanisms are outside of conscious control much of the time, and yet appear to be of great significance in facilitating and limiting joint mobility; it is only to our benefit that we learn to operate in alliance with, and not against these natural reflexes. As Rathbone explains (1959:14):

> ...it must be remembered that flexibility is a characteristic of joints and that relaxation, contraction and tonus are characteristic of the neuromuscular mechanism.

It is because the complex neural and proprioceptive response to stretch is not well understood at the cellular level even today, that practical application to human exercise is in its beginning stages. This section deals with the basics of neuromuscular physiology in order to review the "grass roots" machinery of muscle stretch, and its implications for the area of flexibility.

What is Stretched?

The term "stretch", as applied to increased joint amplitude in humans, may be thought of as a temporary physical change in length of certain muscle and joint tissues. The interesting question then, in regard to this semi-permanent change in tissue length is, "What is stretched?" General opinion seems to agree that it is not the contractile elements of the muscle, for relaxed muscle filaments can be stretched to almost twice their resting length without damage or loss of their ability to return to a normal resting length (Banus and Zetlin, 1938). The main limiting factors are thought to be due to the various connective tissues (tendons, ligaments, fasciae and scar tissue) according to Ramsey and Street (1940). These tissues do not have the relaxation and contractile properties of the nerve supplied muscle filaments, and thus appear to offer the main resistive force to stretch.

> Evidence seems to indicate that initial tension produced by the muscle when externally stretched is practically all due to the connective tissue and not to the contractile elements of the muscle. (Banus and Zetlin, 1938:403)

Wright and Johns (1962) progressively severed the tissue layers of a cat's wrist to determine that the joint capsule contributed 47 percent, passive motion of the muscles 41 percent, the tendons 10 percent, and the skin 2 percent to the total torque (resistance) required to move the joint in its mid-range. The restraining effects of tendons apparently become more important toward the extremes of joint motion, since passive stretch on a resting excised muscle gives greater resistive forces, the greater it is lengthened (Ramsey and Street, 1940). It is therefore probable that short-term changes in joint mobility through sport training do not involve a semi-permanent length change in the contractile apparatus of the muscle, particularly if they are in a relaxed state. More certainly, the fascial sheaths (epi, endo, and perimysium) surrounding the muscle filaments and bundles are undergoing the actual change in physical length.

Force Application of a Stretched Muscle

It is well known that a muscle under a slight stretch can produce a greater force (Billig, 1951; Cavagna et al., 1971; Inman et al., 1952) and a faster reaction time (Schmidt, 1967). But in reference to highly stretched vertebrate muscle fibres, Gordon and others (1966a, 1966b) found that tension development failed almost completely when frog muscle fibres were stretched to striation spacings of 3.65 microns. The explanation for this was based upon

Huxley's overlapping filament theory involving actin and myosin crossbridges.

> When a part of a fibre with uniform striation spacing is stretched so far that there is presumably no overlap of filaments, the tension developed is very small. (Gordon et al., 1966b:142)

Although it is doubtful that human muscle in an in vivo situation would accomplish this degree of stretch, the phenomenon may help to explain why athletes find they cannot generate large isometric forces at the ends of movement range.

Tonus and Adaptive Shortening

Adaptive shortening of muscle, as it occurs in normal individuals, plays a role as a limiting factor in maintaining and regaining range of motion. Excessive residual tension, prolonged inactivity, aging and poor circulation are thought to contribute to somewhat "permanent" losses of flexibility called "passive insufficiency" (Bourne, 1960).

The tonus of striated muscle in man was of interest to Edmund Jacobsen (1938, 1967), who with rather insensitive equipment, inaccurately concluded that a state of slight contraction was maintained in healthy muscle during a state of rest. More recently, evidence has been accumulated to show that complete quiescience does exist in resting muscle.

> Most neurophysiologists now agree that electromyography shows conclusively the complete relaxation of normal human striated muscle at rest... (Basmajian, 1974)

However, in more serious conditions of mechanical

restraints, paralysis or muscle spasm, contractures can result. Contractures, or the excessive and prolonged shortening of skeletal muscle, is associated with changes in its properties whereby muscle becomes set at a new length and fails to return to its original length during relaxation (Hajek et al., 1947).

Permanent changes affecting mobility can also occur in the joint as Akeson suggests that:

> The proliferation of connective tissue newly formed would create a mechanical obstruction to full contraction and relaxation of an affected muscle and would be expected to restrict joint mobility. (Akeson, 1961:1033)

Furthermore, he established that mucopolysaccharides, the lubricating elements of collagen bundles, are rapidly lost in restricted joints, so that cross-linkage formation of the collagen fibres is facilitated. Most authorities agree that joints which do not experience full amplitude of movement, and muscles which are never lengthened fully, lose their mobility and elasticity. Even animals are wise to this point, as Billig (1951:14) reminds us:

> ...cats instinctively stretch or loosen up upon arising by stretching luxuriously in all directions.

The Reflex Control of Movement

The postural duty of the hip joint requires it to be the most sensitive joint in the body in detecting small angular changes. Incredibly, 0.2 to 0.4 degrees are detected by the proprioceptive mechanisms so long as the movement is

not slower than three degrees per second (Gardner, 1972). A most remarkable and early understanding of the sensory apparatus of movement was achieved by Sherrington (1898), who designated as proprioceptors, those end organs located in the muscle so as to effectively secure inside information, cooperation and coordination of movement. The sensory organs maintaining the "unconscious control of movement" were identified as muscle spindles and Golgi tendon organs, both of which are incorporated into the gross structure of the muscle.

The Stretch Reflex

The so-called myotatic stretch reflex is actually more complex than previously thought, and is well documented by Best and Taylor (1966), DeVries (1974), Gardner (1972), Guyton (1974) and Ruch and Patton (1965, 1966). The sense organ that is responsible for producing the stretch reflex is the muscle spindle.

> When a stretched muscle with an intact nerve supply is stretched, it contracts. This response is called the stretch reflex. The stimulus that initiates the reflex is stretch of the muscle, and the response is contraction of the muscle being stretched. (Ganong, 1973:66)

Muscle stretch results in widespread and complex changes about the joint involved. Muscle spindles are:

> ...sensitive to muscle length, responding by changes in impulse frequency to both velocity of imposed stretch (phasic resonse) and to the extent of a constant length (tonic response). Their activity produces excitation (contraction) of the muscles in which they lie. (Gardner, 1969:3)

The spindles act as "brakes" to lengthening of muscle

by evoking contraction in their own muscle and its synergists as well as reciprocally inhibiting the antagonists. This automatic mechanism is operating at all times controlling the lengthening ability within its own muscle.

Ganong (1973) describes the muscle spindles as consisting of 2 to 10 muscle fibres enclosed in a connective tissue capsule. They are called intrafusal fibres to distinguish them from the extrafusal fibres, the contractile units of the muscle which surround and lie parallel to the splindles. The two ends of the intrafusal fibre are contractile but the middle portion is filled with nuclei (nuclear bag region) and is probably non-contractile. In the nuclear region, the primary or annulospiral endings, which are large afferent sensory nerves, are located. These nerve endings form the Primary afferent (Ia) component in the classification scheme for sensory fibres and are the receptors for the stretch reflex. The impulses originating in the spindle are conducted to the CNS via these large and fast conducting fibres which pass directly to the motor neurons (alpha system to the extrafusal tissue; gamma system back to the spindle) of the same muscle.

On either side of the annulospiral endings are the secondary or flower spray endings, which are the receptor ends belonging to the group II sensory fibre category. The secondary afferents also respond to stretch, but in a less sensitive way as explained by Matthews (1964:245):

> ...When a muscle is being stretched the muscle spindle endings signal both the instantaneous length of the muscle and the velocity at which it is being stretched, while the secondary endings signal mainly the instantaneous length.

Although the effect of the secondary afferents is not well understood, it is believed by some (Ganong, 1973; Patton, 1971) that their excitation facilitates flexor muscles and inhibits extensor muscles regardless of the type of muscle in which they lie.

The muscle spindles also have a motor supply of their own called the gamma loop or gamma efferent system.

> The motor neurons of the gamma efferent system are regulated to a large degree by decending tracts from a number of areas in the brain. Via these pathways, the sensitivity of the muscle spindles and hence the threshold of the stretch reflexes in various parts of the body can be adjusted... (Ganong, 1973:67)

The Inverse Stretch Reflex

"Up to a point, the harder a muscle is stretched, the stronger is the reflex contraction" (Ganong, 1973:68). However, a contraction can suddenly cease and the muscle relax if the tension developed is strong enough to stimulate the inverse myotatic reflex. This relaxation in response to strong stretch is also called autogenic inhibition and is regulated by sensory fibres called Golgi tendon organs. The afferent fibres from these organs are classified as group Ib sensory nerves. Unlike the spindles, the tendon organs inhibit the muscle in which they lie. Located at

the musculotendinous junction in series with the contractile fibres, the Golgi tendon organs can be excited by strong passive stretch (Stuart et al., 1970), but are increasingly stimulated as contractile tension mounts (Libet et al., 1955). The reason for this is given by Ganong (1973:69):

> The degree of stimulation by passive stretch is not great because the more elastic muscle fibres take up much of the stretch, and this is why it takes a strong stretch to produce relaxation. However, discharge is regularly produced by contraction of the muscle, and it now appears that the Golgi tendon organ functions as a transducer in a feedback circuit which regulates muscle tension in a fashion analogous to the spindle feedback circuit which regulates muscle length.

Practical Application of Neurophysiological Theory

Physical therapists have found neurophysiological support for much of their successful therapeutic procedure. Therapeutic exercise is based to a large extent on three basic physiological principles first established by Sherrington (1898) and summarized by Griffin (1974). These principles are immediate induction, reciprocal innervation and successive induction.

> These three principles form a reflex basis for normal movements: as movement begins and proceeds, agonists and synergists are facilitated (immediate induction) and antagonists are inhibited (reciprocal innervation); at the end of the movement, the antagonists are facilitated (successive induction) promoting movement in the opposite direction. (Griffin, 1974:1073)

A therapeutic technique called proprioceptive neuromuscular facilitation (PNF) was developed by Kabat (1958) to restore muscle function through the utilization of

reflexes to augment the voluntary response of his patients. Kabat used the term "reversal of antagonists" to describe the phenomenon of successive induction. Others such as Knott and Voss (1968), Holt (1971) and Tanigawa (1972) have also applied the theoretical role of the stretch reflex to practical situations of limb mobilization.

In addition to the facilitated contraction that successive induction provides for the opposing muscle group, it appears also that greater muscle relaxation occurs after a significant contraction. Knuttson (1973:168) refers to an unpublished paper by Jungwirth and Myrenberg that found that after a maximal volitional contraction, the stretch reflexes in the previously active muscles were depressed about 4 seconds, starting 1-2 seconds after the end of contraction.

> This post-contraction depression, which is the basis for the "hold-relax" technique in PNF, is often ascribed to an autogenetic inhibition due to the mobilization of Golgi tendon organs...Although inhibitory effects on the stretch reflexes of this duration might quite possibly be due to a sustained primary afferent depolarization, there are no findings to support such a mechanism. (Knuttson, 1973:168)

The utilization of the principle of successive induction to facilitate increased range of motion has met with a great deal of success in some studies as shall be seen in the section of "Methods of Stretching".

Cortical Control of the Stretch Reflex

There is some reason to believe that the subcortical

control of the myotatic reflex can be overcome by volition from higher neural centers (Arlib, 1972; Glaser and Higgins, 1968; Gray, 1971; Smith et al., 1972; Zappala, 1970). Basmajian (1973) has shown that electromyography makes possible for man, with a small effort of will, to completely relax individual motor units of voluntary skeletal muscle. Volition may also play a role in maintaining contraction under extreme tension despite the protective influence of the Golgi tendon organs. Gardner (1969:11) states:

> If as seems likely, all contractions activate tendon organs, their inhibitory effect upon their own muscles must be offset by voluntary effort. When volition ceases, these receptors probably become responsible for the immediate relaxation of the muscle.

It appears that volition has the ability to dominate to some extent, but not always, as is evidenced by the "breaking point" of collapse in Indian arm wrestling. The loss of the contest usually occurs abruptly, when mounting tendon organ inhibition finally overcomes the voluntary effort (Gardner, 1972). Thus the human brain has an important, but not totally dominating contribution to make in overcoming the proprioceptive reflex. It is possible that the neural complexity of the cortex makes it possible for intelligence, motivation and perhaps even skill of movement to contribute to the control of muscle action.

Gamma Bias

An interesting phenomenon, with implications for

changing man's muscle lengthening ability, has been called "gamma bias" (Eldred, 1953; Gardner, 1959; Granit, 1955). This can best be described as an anticipatory length setting of the muscle spindles which are judgmentally governed to keep firing levels at a minimum until some critical position of movement is reached. The cerebral cortex is considered to be the dominant station for sensimotor integration (Herman,1970). For fast movements, parallel connections of alpha (α), which go to the extrafusal muscle fibres, and gamma (γ), which go to the intrafusal (spindle) fibres, are linked to control behaviour (Shambes, 1969; Smith et al.,1972). In other words, for quick movements, both the contracting muscle and its sensory equipment are notified simultaneously about the command. In this way the gamma loop contributes to the precise timing of the movement and sets its "critical length" to what is expected based upon past experience (Gardner, 1972).

Gamma bias is a consideration in flexibility limitation in that it is conceivable that the judgement mechanisms protectively and habitually underestimate the extent of joint mobility. Early onset of the myotatic reflex is perceived as an uncomfortable "tightness" and is a reminder that the joint does have limitations. However, it has not been determined how early in the stretching movement that warning signals are given. It may be speculated that gamma bias operates very early in individuals who are inactive and

inexperienced with their potential range of motion. These individuals do not know their limitations and could be adaptively setting to a much reduced and unrealistic range. Yet to be ascertained is how accurate gamma bias is, and how it is affected by motivation, learning and high levels of physical training. Gamma bias does seem to play some part, however, in the area of flexibility as an anticipatory response to range, speed and force application.

Methods of Stretching

The question of which methods are considered superior for improving range of motion has received little attention, especially in comparison to the scientific evidence evaluating various strength and endurance programs. Historically, two styles of stretching have been identified: the slow, static, prolonged stretch as opposed to the fast, ballistic, dynamic type of stretch.

Weber and Kraus (1949) worked with poor posture and poliomyelitus cases six to twelve years old and found that "spring" stretch (dynamic) was three degrees better on an average than "plain" stretch (static) in improving hip flexion. Pathological subjects were only able to obtain a mean improvement of one degree with the "plain" stretch!

Several recommendations exist supporting slow, static stretch (Anderson, 1971; Bates, 1971; Rathbone, 1959; Young, 1950) and particularly for certain joint movements such as hip flexion (Riddle, 1956). Rathbone (1959) says

that slow stretch methods such as found in Hatha Yoga are desirable to avoid the stretch reflex.

> When it comes to actually increasing flexibility, a distinction is made between rapid motions of a swinging character, and slow ones which demand precise stretching of joint structures at the limit of the motion. The latter are more effective... when a muscle is stretched suddenly, it reflexly contracts. Stretching must be maintained for an interval of time to be effective. (Rathbone, 1959: 100)

Stafford (1958) voiced similar concern over "bobbing activity". While he admitted that rebounding stretch was distinctly effective, caution in its use was suggested. "The jerks must be no greater than the extensibility of the muscle" (Stafford,1958).

A comparative study of three stretching methods was conducted by Holt, Travis and Okita (1970). Along with the dynamic and the static stretching exercises, a proprioceptive neuromuscular facilitation technique (PNF) was included as a new approach to increasing range of motion. Actually the method was a modified version of Kabat's (1958) therapeutic PNF: rather than working limb mobilizations in diagonal patterns as is emphasized in the writings of Knott and Voss (1968), movement and exercise occurred in one plane. The modified method was referred to in Holt's study as IA-CA depicting the pattern, Isometric contraction of the Antagonist, Concentric contraction of the Agonist. Two exercises for each method were practiced, for equal intervals of time.

Holt's procedure for one minute is described:

> The IA-CA exercises were administered with assistance from one of the investigators. The first exercise was performed with the S lying in a supine position. S was told to keep both knees extended throughout the exercise. He then was told to raise one leg upward (hip flexion) until he could feel stretch on the hip extensor muscles. E positioned himself securely behind S's upraised leg and placed one hand on the achilles tendon and the other on the anterior aspect of the knee. S was then told to extend his hip, causing an isometric contraction of the hip extensors against E's hand. The contraction was to gradually increase until a maximum effort was reached. Immediately following this contraction (5 to 6 seconds), S was told to contract his hip flexors concentrically in order to increase the range of motion of the hip extensors. (1970:614)

Holt does not state how the range of motion was measured. After a three week period, it was concluded with a $p<.001$, that differences did exist among the methods in increasing range of motion. The mean improvement for the static stretch exercise was 3/4 inch, for the dynamic stretch 3/4 inch, and for the IA-CA method 2.1 inches.

Facilitation methods were originally adopted to rehabilitate for strength, but in that very sense are applicable to the facilitation of <u>active</u> flexibility. Holt's promising results with the PNF method prompted its application to sport in a much broader way and stimulated investigation of the underlying theoretical mechanisms of facilitation by other physical educators. A summary of the theory of stretch as reviewed by Holt can be found in the 1971 manual called <u>Scientific Stretching For Sport</u>.

An investigation using a facilitation technique

to promote passive range of motion was conducted by Tanigawa (1972). It was demonstrated that male subjects receiving the PNF Hold-relax procedure (described as Passive PNF in Appendix C) increased their range of passive straight leg raising to a greater degree and at a faster rate than subjects receiving passive mobilization. Tanigawa did not examine active range. He explained the greater effects of the PNF stretch to be due to a greater lengthening of the connective tissue as it is under the dual stretch of internal isometric contraction and external lengthening.

Duration of Stretch

The optimal time period to spend in a position of maximal stretch (static) is 60 seconds according to Bates (1971). Individuals already at a high level of flexibility were able to improve equally well in a position held only 30 seconds, while less flexible individuals needed the longer time period to improve maximally.

The PNF methods have usually been conducted in six second intervals of alternating direction of motion, and the alternation of effort is repeated for up to a minute or more. The designation of timing has been apparently based on the 4 second post-contraction depression, one to two seconds following a maximal volitional contraction (Knuttson, 1973). The minute duration of stretching exercise is supported by the findings of Bates (1971) above.

CHAPTER III

METHODS AND PROCEDURES

Sample Selected

The sample consisted of one hundred and nineteen volunteer physical education women students at the University of British Columbia. The women ranged in age from seventeen to thirty-one years, averaging 20.19 years. The mean height of the total group was 1.65 meters, and the mean weight was 60.15 kilograms. The subjects were paired in their classes and randomly assigned by pairs to a treatment group.

Time and Duration of the Study

The study took place between mid-January and mid-February, 1976. Over a four week period the subjects were seen eleven times; the first and last sessions were initial and final measure days, and the middle nine sessions were exercise days. All subjects established regular time slots with their partner three times per week. Series of half hour sessions were held daily between 8:00 a.m. and 1:30 p.m. A few subjects came twice a week at a 6:30 p.m. time as well at a noon hour.

Working in pairs, subjects could complete the exercise treatment in ten minutes. Every attempt was made by phone to remedy absent subjects by arranging a "make-up" time for the very next day so that all subjects would have equal exercise programs.

Personnel

Prior to the study, several graduate students were trained to assist the experimenter on the testing days. Although the experimenter personally read and recorded all the flexibility measures, the assistants were helpful in organizing the subjects, fixating the knee splint and stabilizing the left leg to the floor.

Testing Area and Equipment

Four testing sites were established in order to meet the subjects in areas close to their classes. Mats or carpeting provided a firm padded surface on which subjects lay supine. The left leg was stabilized in a leg strap placed at mid-thigh so that the leg would not be displaced from the floor during the stretch. The right leg was splinted straight by a padded 3"x 18" x 3/8" wood slat strapped above and below the knee with velcro. The Leighton Flexometer was attached to the proximal end of the splint strap on the lateral side of the right thigh with two inch velcro. The velcro facilitated the ease of

attachment from one subject to another.

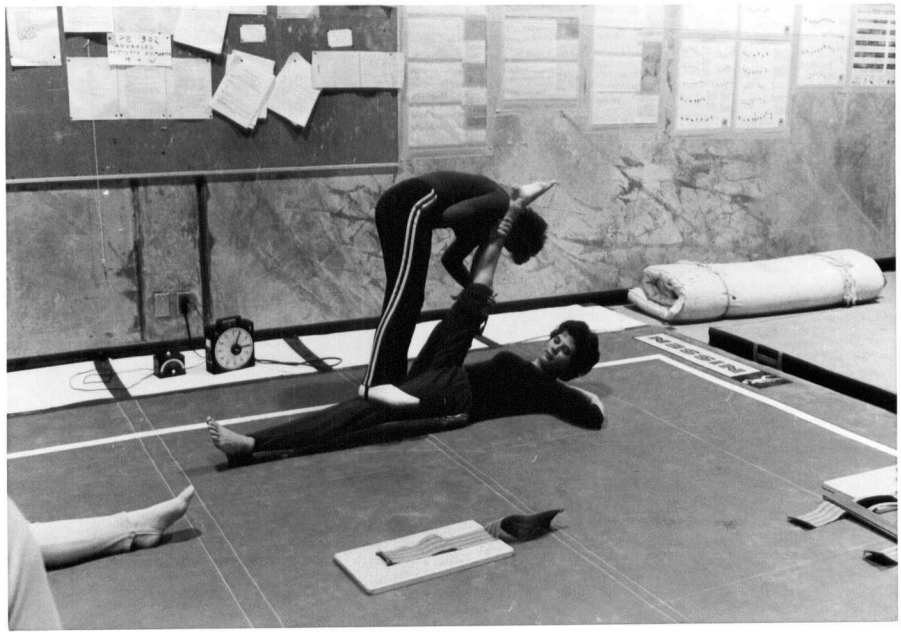


Plate 1. Paired stretching working with the clock

A sixty minute timer with a sixty second sweephand and buzzer was placed in a position visible to all subjects. In addition, a metronome was set at a one second pace to assist the subjects in counting the six second stretching intervals.

A hip flexion strength apparatus was constructed out of a solid bench, plywood and metal braces so that the subject could lie supine with the right leg resting at an incline of 45 degrees. A 3/32 inch cable and tensiometer ran from the thigh at a 90 degree angle through a hole in the inclined section to attach to the metal support on the floor. The cable length was adjustable to account for differences in leg size.

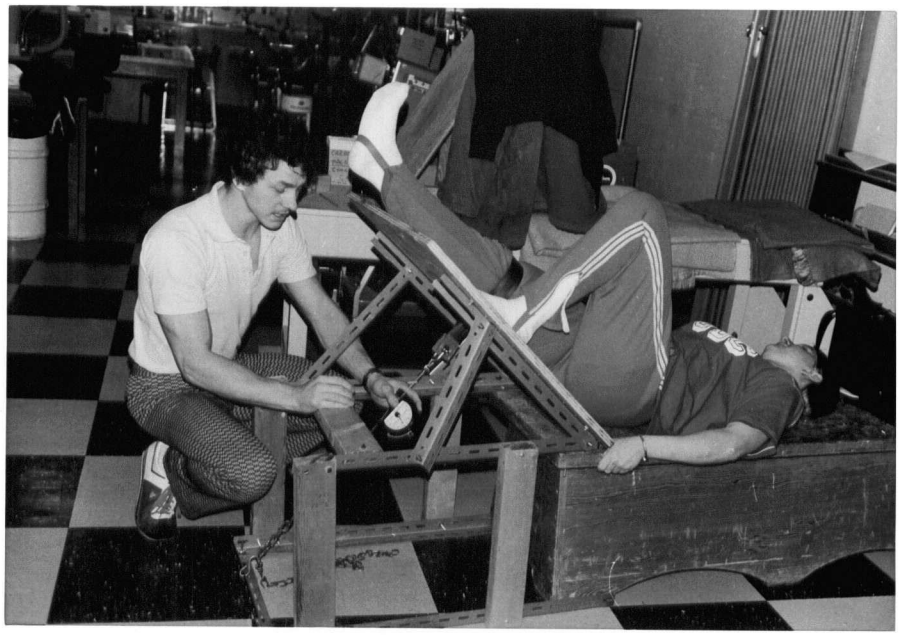


Plate 2. The hip flexion strength apparatus and cable tensiometer

Plate 3. Active range of a flexible subject

Plate 4. Passive range of a flexible subject

General Procedures

At the beginning of the study, the paired subjects were randomly assigned a flexibility exercise. Often the treatment required manual assistance, and the partners could then alternate every minute between exercising and assisting in the same method of stretch. Once attendance was taken, and the timing devices were running, the experimenter was free to supervise and correct the quality of the exercises.

There were nine treatment days, preceded and followed by a measurement day. A three week treatment period with three sessions per week was designed in order to provide adequate time for all of the treatments to take effect without losing motivation of the subjects. A three week time period allowed Holt (1970) to obtain highly significant differences between methods.

On Day 1, subjects were measured in the order active range, passive range and then strength of hip flexion, since it was felt that the passive range would "influence" the active range if performed first. Following the measures, each pair of subjects were taught their assigned stretching method and given a handout to read to thoroughly familiarize them with their particular exercise. Subjects were told not to practice at home with the treatment and it was emphasized that it was extremely important that all subjects had to attend all the scheduled sessions so that the equality of the performances would be maintained.

After the initial instruction on Day 1, the exercise treatment for any individual took ten minutes (60 seconds exercise, 60 seconds rest, five times each). This time interval was chosen based on the evidence of Bates (1971) study that 60 seconds is the optimum time to acquire maximal gains in range of motion. Excessive measuring could constitute a training effect, thus measures were limited to Days 1, 4, 7, 10 and 11.

The method was timed so that the actual time of exercise and rest for each method was standardized.

SUBJECT	PARTNER
60 seconds stretch	Assist if necessary
Assist or rest	60 seconds stretch
60 seconds stretch	Assist or rest
Assist or rest	60 seconds stretch
60 seconds stretch	Assist or rest
Assist or rest	60 seconds stretch
60 seconds stretch	Assist or rest
Assist or rest	60 seconds stretch
60 seconds stretch	Assist or rest
Assist if necessary	60 seconds stretch

The control subjects were seen once a week in order to be measured in the same way as all the others, and two sets of measures (pre and post exercise) were made but without any intervening exercise. During all measurements of the range of motion, the subject's left leg was stabilized to the floor by a strap and the right leg was splinted straight. During the exercise sessions, this equipment was only used

with subjects who had difficulty in keeping the left leg on the floor and the right leg straight.

Specific Procedures for Methods

The six stretching exercise treatments along with the Control group comprised the seven levels of the independent variable (Treatments). Detailed descriptions of each method as they were given to the subjects may be found in Appendix C. The following briefly outlines the main points of each procedure.

Passive lift and active hold: The subject's right leg is lifted by the partner and taken slowly to the end-point (6 seconds). At the end-point, the subject actively holds the position for the next 6 seconds by actively contracting the hip flexors. Passive pressure and active holding alternate every 6 seconds for one minute (five times).

Active PNF: The subject voluntarily lifts her right leg as far into flexion as possible in 6 seconds. On the next 6 seconds, the subject eases into a maximum isometric contraction down against the manual resistance of the partner. The voluntary lift and extensor contraction alternate so that each occur five times in one minute.

Ballistic and hold: Starting from approximately a 45 degree angle, four leg bounces are made to flex the hip and on the fourth bounce and active hold is made to

stop the leg at the end-point. Each leg bounce takes one second, and the "hold" is maintained for 6 seconds. The whole combination is repeated five times in one minute.

Relaxation method: The method is simply the prolonged stretching technique, but in addition, subjects apply a mental relaxation and mind-set technique.

Passive PNF: The subject's right leg is taken passively to the end-point in 6 seconds. On the next 6 seconds, the subject eases into a maximum isometric contraction of the extensors against the manual resistance of the partner. The passive lift and extensor contraction alternate so that each is done five times in one minute.

Prolonged Stretch: The subject's right leg is lifted passively and is taken to the end-point slowly. The end position is to be held passively for one minute just below the pain threshold.

Instruments of Measurement

The primary dependent variable was the active range of right hip flexion. This was measured from the supine position in degrees by the Leighton Flexometer. The gravity weighted dial of the Flexometer is known to take the angular reading with a reliability well above .90 (Leighton, 1955). Early in the study, a reliability test was made on the first seventeen subjects to determine if it was necessary to take three angular readings for each subject trial. Since r=.95 between the first and second

measures of active range, and r=.95 between the first and third measures, the experiment was conducted with one reading being made on each subject.

A secondary dependent variable was the isometric strength of right hip flexion measured at the 45 degree angle by a 3/32 inch cable tensiometer. This second dependent variable was added to the study in the belief that a concurring change in hip flexion strength might offer insight to the changes in active range. The strength of hip flexion was measured only twice, before and after the three week treatment period. Since the cable tensiometer has a reliability of .947 for hip flexion of college women according to Clarke and Munroe (1970), only one reading was made of the maximal effort.

Experimental Design

A 7 x 5 factorial design with one dependent measure (active range) was used as the initial framework. A second dependent variable (strength) was measured before and after the study. The two independent variables were: A. Treatment factor containing seven levels and B. Time factor containing five levels. In addition, post-exercise measurements were made on the middle three testing days to see the daily effect of the treatment. Each cell contained between fifteen and twenty subjects.

Figure 2

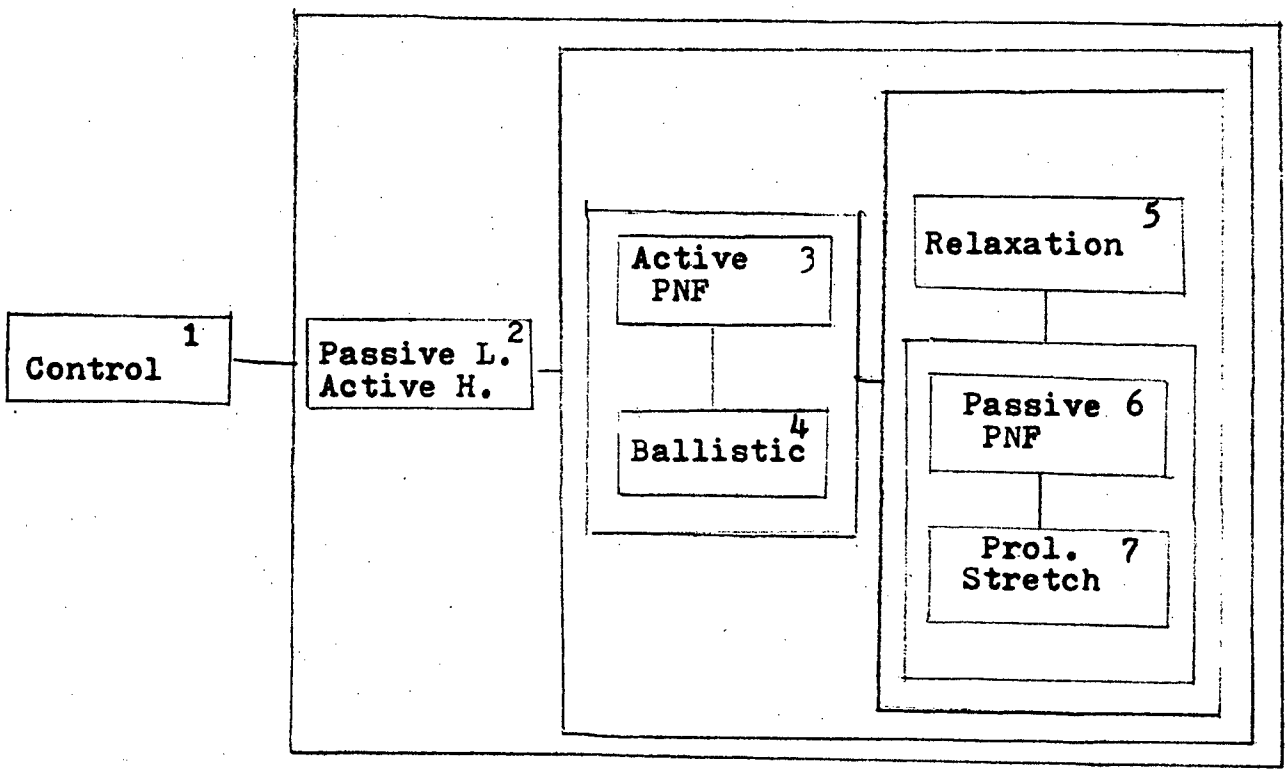
Schematic Diagram of Experimental Design

A= Treatment Factor B= Time Factor

	B1 Day 1	B2 Day 4	B3 Day 7	B4 Day 10	B5 Day 11
A1	Act.Range Strength	Pre-Act. Post-Act.	Pre-Act. Post-Act.	Pre-Act. Post-Act.	Act.Range Strength
A2	"	"	"	"	"
A3	"	"	"	"	"
A4	"	"	"	"	"
A5	"	"	"	"	"
A6	"	"	"	"	"
A7	"	"	"	"	"

The Statistical Treatment

A multivariate analysis of variance was performed using the program MULTIVAR. In order to test the hypotheses, preplanned orthogonal comparisons were made between the seven treatment levels as given below:



METHODS

1	2	3	4	5	6	7
+6	-1	-1	-1	-1	-1	-1
0	-5	+1	+1	+1	+1	+1
0	0	+3	+3	-2	-2	-2
0	0	+1	-1	0	0	0
0	0	0	0	+2	-1	-1
0	0	0	0	0	+1	-1

Figure 3. Contrast Matrix of Treatment Effects

Four transformation matrices tested the hypotheses:

1. A transformation matrix on the time factor reduced the first (initial day) and fifth (final day) levels to a "difference" score in order to show the total change that occurred for the two dependent variables (active range, strength).

2. A second matrix looked at each first and fifth level measures individually to show initial and final differences between the group means (active range and strength).

3. Thirdly, Helmert contrasts were made between each day's pre-exercise active group mean against the average of all the rest of the following active measures.

4. A fourth matrix contrasted group means on each of eight dependent measures for active range: Day 1, Day 4 (pre and post exercise), Day 7 (pre and post exercise), Day 10 (pre and post exercise) and Day 11.

CHAPTER IV

RESULTS AND DISCUSSION

Originally, 140 women volunteered for the study. This number was dropped to 125 subjects in the organizational stages of the study because of problems with students finding time to attend all three weekly sessions. During the study, the attrition rate was remarkably low; six subjects dropped from the study for various reasons of sport injury and miscellaneous outside accidents. One hundred and nineteen women completed the study.

The treatment and testing sessions were productive and organized. Trained assistants were helpful on the busier measuring days, but all active range measurements were made by the experimenter. The study was of adequate duration to accomplish significant gains in active range by all methods ($F= 449.0$, $p=.0001$), although the linear nature of the change showed no signs of plateauing.

The Amount of Improvement in Active Range

Difference scores between the means for Day 1 and Day 11 represent the actual change (gain) in active

range of right hip flexion that occurred during the study and can be seen in Table 1. Each and every one of the treatments contributed more than 15 degrees of mean improvement in active range.

Table 1

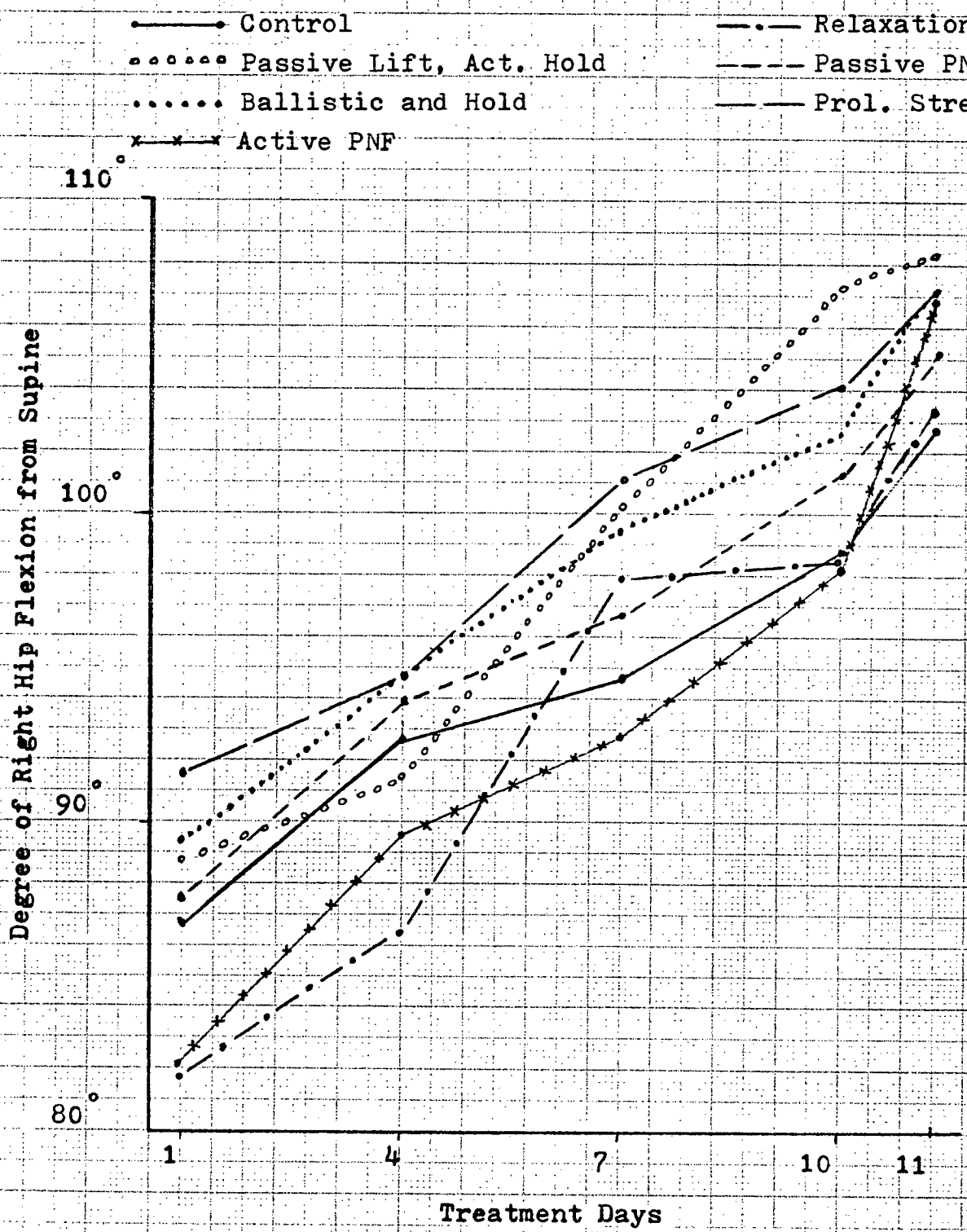
Observed Cell Means for the Active Range of Right Hip Flexion on Day 1, Day 11, and the Improvement (difference) Between Day 1 and Day 11

Treatment Group	Active Range (degrees) Day 1	Day 11	Gain
1. Control	85.8	102.7	16.9
2. Pas. Lift, Act. Hold	88.7	108.2	19.5
3. Active PNF	82.0	98.7	16.6
4. Ballistic and Hold	89.3	107.4	18.1
5. Relaxation	81.7	103.1	21.4
6. Passive PNF	87.4	105.1	17.7
7. Prolonged Stretch	91.6	107.0	15.4
$\bar{X}$ of all Treatments (2-7)	86.8	104.9	18.1
$\bar{X}$ of Active Methods (3,4)	85.7	103.1	17.4
$\bar{X}$ of Passive Methods (5,6,7)	86.9	105.1	18.2

As can be seen in Figure 4, all six treatment groups contributed to active range in similar amount and manner over the study. The Prolonged Stretch group began the study with the highest starting active range of all groups, and finished the study with the second highest range, but overall, showed the least improvement in active range (15.4 degrees). The Relaxation method had the lowest active range of all

Figure 4

The Improvement Trends for Six Methods of Stretch over a Four Week Period



groups to begin with and caught up with some of the groups over the study to accomplish the greatest gain in active range (21.4 degrees). The Passive Lift, Active Hold group (the combination method) showed the second greatest active range improvement over the study (19.5 degrees) and also accomplished the highest final active range (108.2 degrees). The Control group improved comparatively well in active range, and in fact, showed no significant differences for the dependent variable as compared to the average improvement of the treatment groups (Table 1).

The Hypotheses

The first hypothesis stated that active methods of stretching would give a greater improvement in active range over passive methods. This hypothesis was not supported since significant differences between active and passive methods could not be obtained at the .05 level of significance ($F<1.0$; $p=.67$).

The second hypothesis stated that the Active PNF method would increase active range of hip flexion better than Ballistic and Hold method. No significant differences were obtained between the two methods at the .05 level and thus the second hypothesis was not supported. ($F<1.0$; $p=.65$).

Other comparisons (as determined by the contrast

matrix, Figure 3) were made of the change in active range between the initial and final means. None of these contrasts showed significance, although there was a strong tendency for the Relaxation group to improve active range better than the other passive methods ($F=3.4$; $p=.06$). This can be seen in Table 1 which shows that Relaxation subjects improved 21.4 degrees in active range while Passive PNF and Prolonged Stretch subjects improved 17.7 and 15.4 degrees respectively, or an average of 16.6 degrees.

The Initial and Final Means

Initial measurements on active range were tested to see how equal the groups were to start with. The orthogonal comparisons permitted numerous contrasts of the means, only one of which showed that one group was significantly lower than the others initially in active range. The Relaxation group (81.7 degrees) was initially lower than the other passive methods (86.9 degrees) at less than the .05 level of significance ($F=4.3$; $p=.04$). Figure 5 shows that by the end of the study, the Relaxation group was within two degrees of the other passive methods, and was no longer significantly different from them. At the end of the study the treatments were not significantly different as contrasted, although the Active PNF with 98.7 degrees, was somewhat lower than the Ballistic method with 107.4 degrees ($F=3.3$; $p=.07$).

Rate of Active Range Improvement

Although the treatments were not significantly different in the total change in active range, it was considered to be of value to test the nature of the change over the five testing sessions. The five "pre-exercise" active measures (Day 1, 4, 7, 10, 11) were compared (one against the average of all the rest) to give four tests of rate of improvement. Figure 4 shows that all treatments improved in a similar manner over the study. The rate of improvement in the Control group was not significantly different from the average trend of the treatment groups, although it can be seen (Figure 4) that there was a tendency for them to gain very little after Day 4 compared to the treatment groups.

Figure 5 shows that the Relaxation method produced a significantly greater change in active range over the other passive methods from Day 4 on ($F=5.95$, $p=.02$). The two active methods tended to improve in a linear way in active range with no indications of plateauing. Table 2 lists the active range means for each day.

Pre and Post Exercise Changes in Active Range

The six active range means including three "pre" exercise and three "post" exercise measures (Days 4, 7, 10) were contrasted to see if any groups differed in terms of "immediate" improvement in active range (due to tissue lengthening or warmup effect). It should be noted that

Table 2

Observed Cell Means for Active Range of Right Hip Flexion Pre and Post Exercise on Days 4, 7, 10

	Pre-Exercise Active Range (degrees)				
Days:	1	4	7	10	11
Groups*					
1.	85.8	92.7	94.6	98.9	102.7
2.	88.9	91.5	100.2	107.1	108.2
3.	82.0	89.5	92.9	98.1	98.6
4.	89.3	94.6	99.2	102.5	107.4
5.	81.7	86.2	97.8	98.2	103.1
6.	87.4	93.9	96.6	101.3	105.1
7.	91.6	94.8	101.0	104.3	107.0
All	86.8	91.8	98.0	101.9	104.9
Active	85.7	92.1	96.1	100.3	103.1
Passive	86.9	91.6	98.5	101.3	105.1

	Post-Exercise Active Range (degrees)		
Days:	4	7	10
Groups*			
1.	93.3	96.2	99.7
2.	98.1	101.1	105.9
3.	88.4	93.4	97.4
4.	95.0	98.8	105.1
5.	92.9	94.3	99.9
6.	96.3	101.5	101.7
7.	98.9	104.7	104.9
All	94.9	99.0	102.5
Active	92.1	96.1	101.3
Passive	96.0	100.2	102.2

* Method Groups are listed as follows:
1. Control
2. Passive Lift, Active Hold
3. Active PNF
4. Ballistic and Hold
5. Relaxation
6. Passive PNF
7. Prolonged Stretch

All: The mean of all the exercise treatments (2-7)
Active: The mean of the active methods (3,4)
Passive: The mean of the passive methods (5,6,7)

because of the fatiguing nature of the hip flexor activity in the active methods, the daily gains in Active PNF and the Ballistic methods were often negative or minimal. The fatigue effect is seen in Table 3. Even the Control group gained on the average 1.0 degree on their second daily measure of active range. The treatments, on an average, improved active range of hip flexion 1.6 degrees. The Relaxation group gave the greatest <u>single</u> daily gain in the study (6.8 degrees on Day 4), while the Prolonged Stretch method gave the greatest <u>average</u> daily gain (2.8 degrees).

Table 3

The Difference Between Pre and Post Exercise Means for Active Range on Days 4,7,10

Treatment Groups	Days	Daily Gain (degrees)	Mean Gain (degrees)	
1. Control	4	0.64	+ 1.0°	
	7	1.53		
	10	0.82		
2. P.L., Act. Hold	4	6.60	+ 2.0°	
	7	0.93		
	10	-1.26		
3. Active PNF	4	-1.12	- 0.5°	Active
	7	0.47		
	10	-0.76		
4. Ballistic	4	0.38	+ 0.9°	
	7	-0.38		
	10	2.56		
5. Relaxation	4	6.79	+ 1.7°	Passive
	7	-3.53		
	10	1.79		
6. Passive PNF	4	2.35	+ 2.6°	
	7	4.82		
	10	0.50		
7. Prolonged Stretch	4	4.16	+ 2.8°	
	7	3.67		
	10	0.61		
$\bar{X}$ of All Treatments			+ 1.6°	

Strength of Hip Flexion

Hip flexion strength, as measured at the 45 degree angle, improved 5.9 units, or approximately 12 pounds of force on the average for all seven groups, but not in a significantly different way as seen in Table 4. An explanation of this result will be made in the discussion.

Table 4

Observed Cell Means for Hip Flexion Strength on Day 1, Day 11 and Difference (Gain) Between Day 1 and 11

Treatment Group	Hip Flexion Strength (units) Day 1	Day 11	Gain
1. Control	50.0	54.7	4.7
2. Pas. Lift, Act. Hold	51.1	55.7	4.6
3. Active PNF	49.4	56.2	6.8
4. Ballistic and Hold	48.0	54.0	6.0
5. Relaxation	47.1	53.2	6.1
6. Passive PNF	46.9	52.7	5.8
7. Prolonged Stretch	49.1	56.6	7.5

Figure 5

The Improvement Trends for Passive Methods in Active Range over the Four Weeks in Five Measures

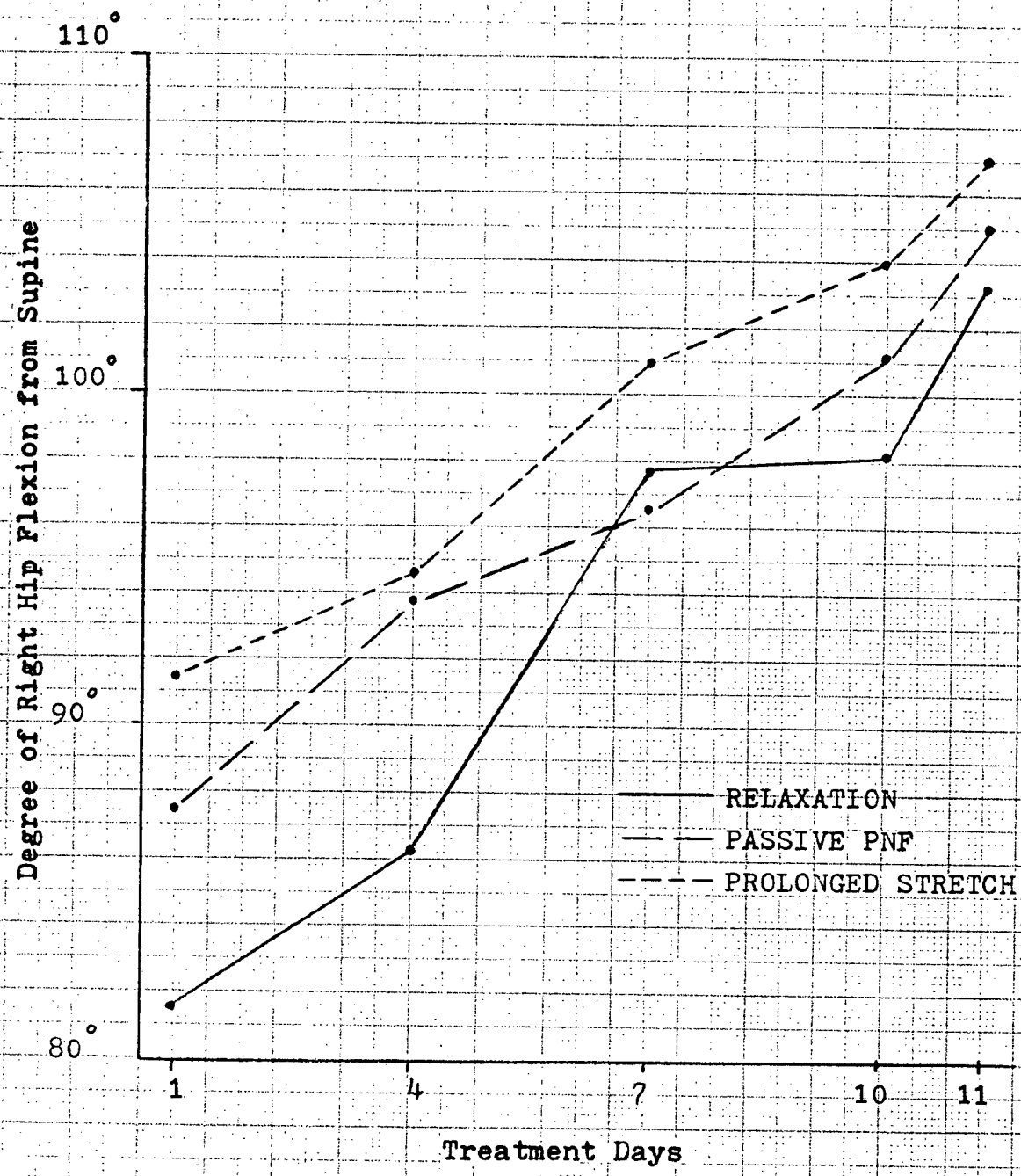


Figure 6

The Improvement Trends for Active Methods in Active Range over the Four Weeks in Pre and Post Exercise Measures

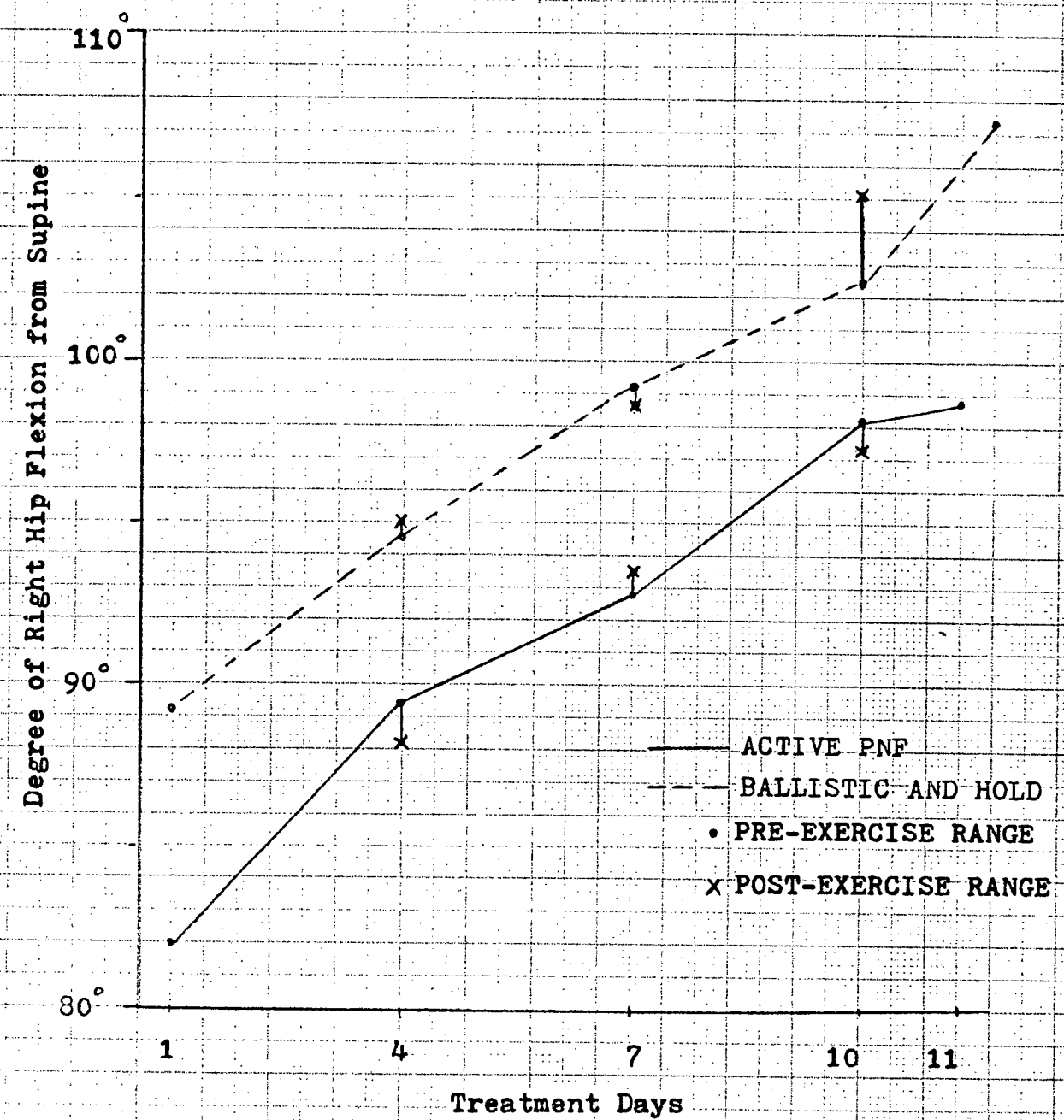


Figure 7

The Improvement Trend in Active Range over a Four Week Period Pre and Post Exercise for the Control Group

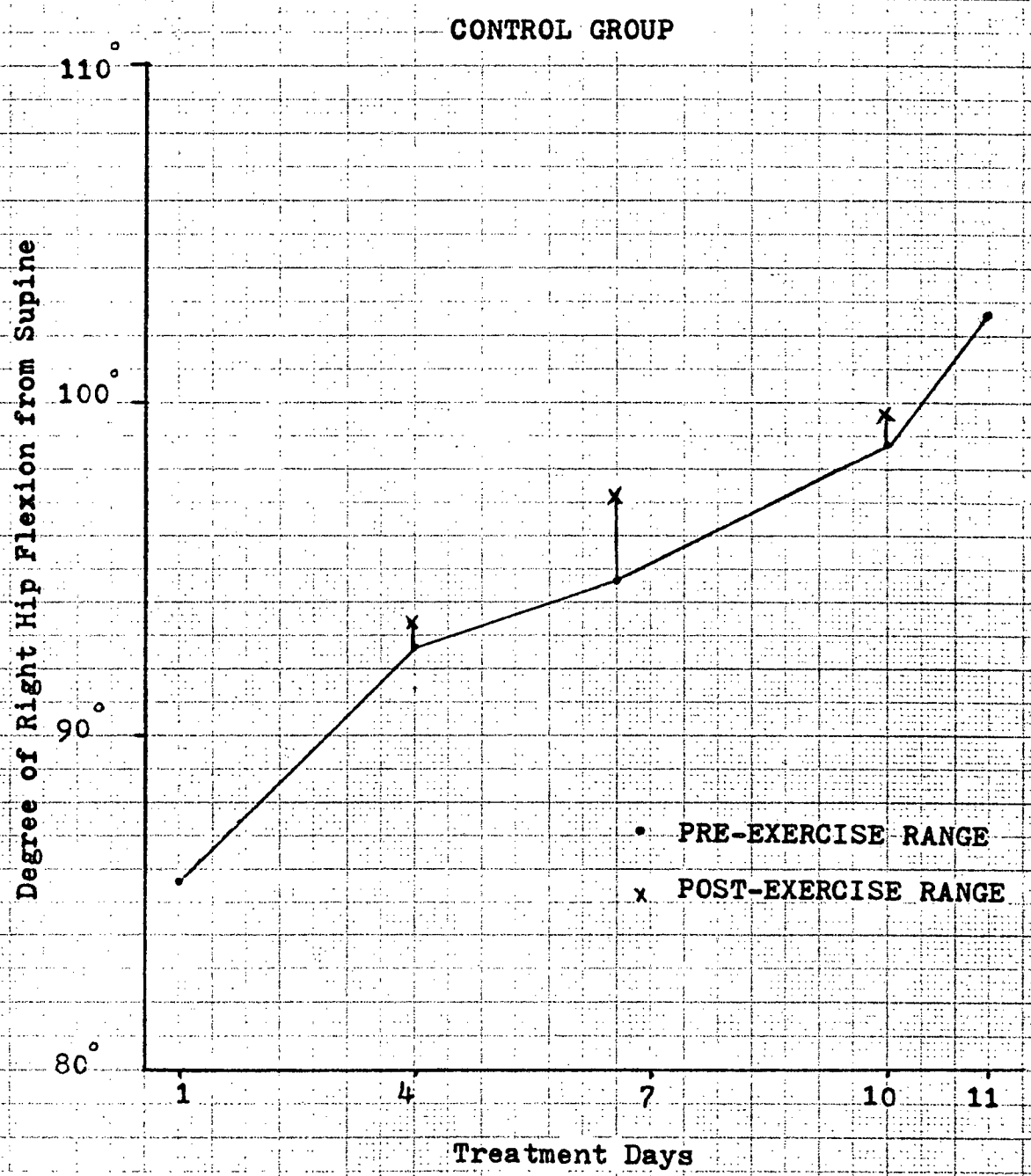


Figure 8

The Improvement Trend in Active Range over a Four Week Period Pre and Post Exercise for Passive Lift, Active Hold

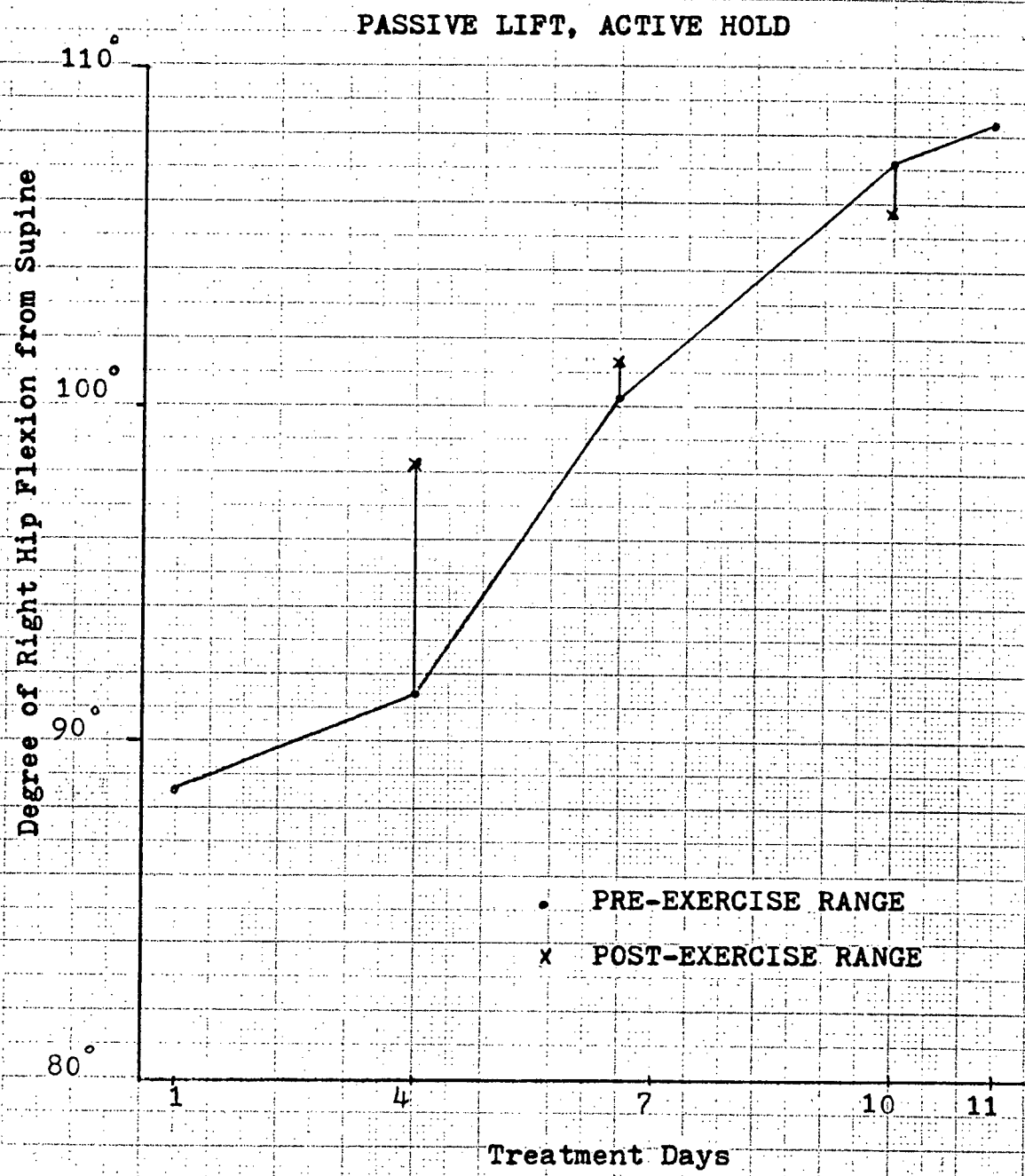


Figure 9

The Improvement Trend in Active Range over a Four Week Period Pre and Post Exercise for the Relaxation Group

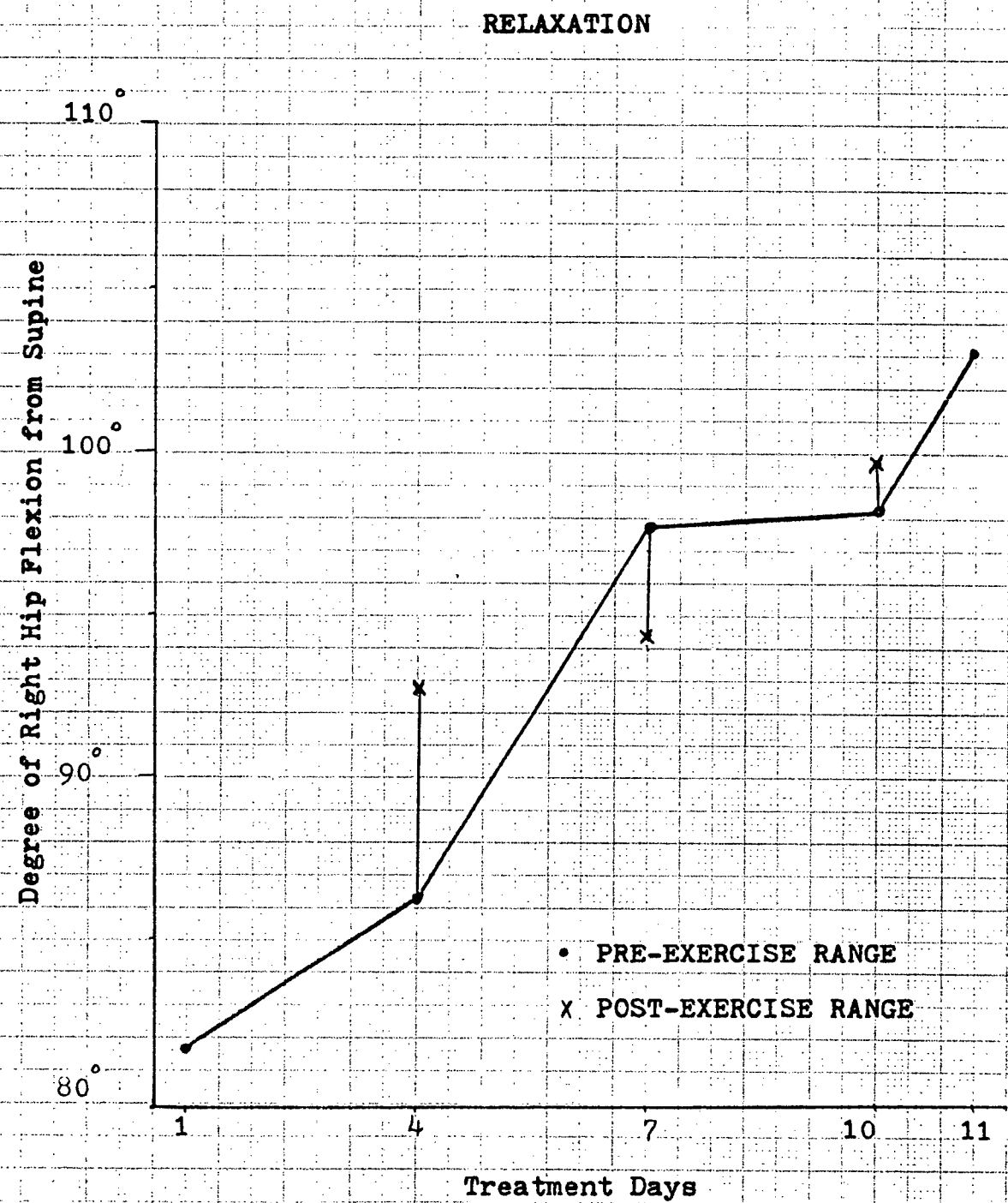


Figure 10

The Improvement Trend in Active Range over a Four Week Period Pre and Post Exercise for the Passive PNF Group

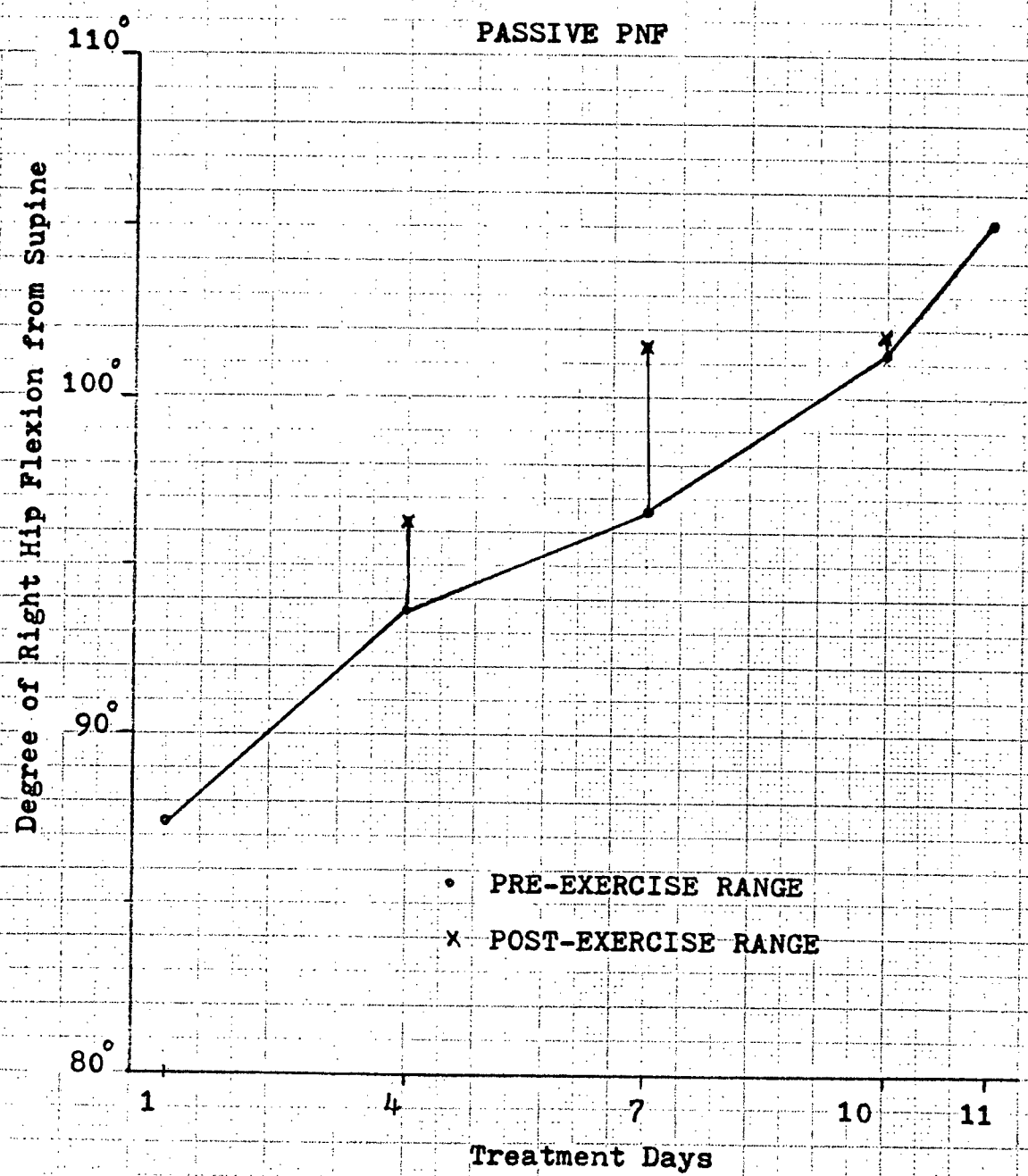
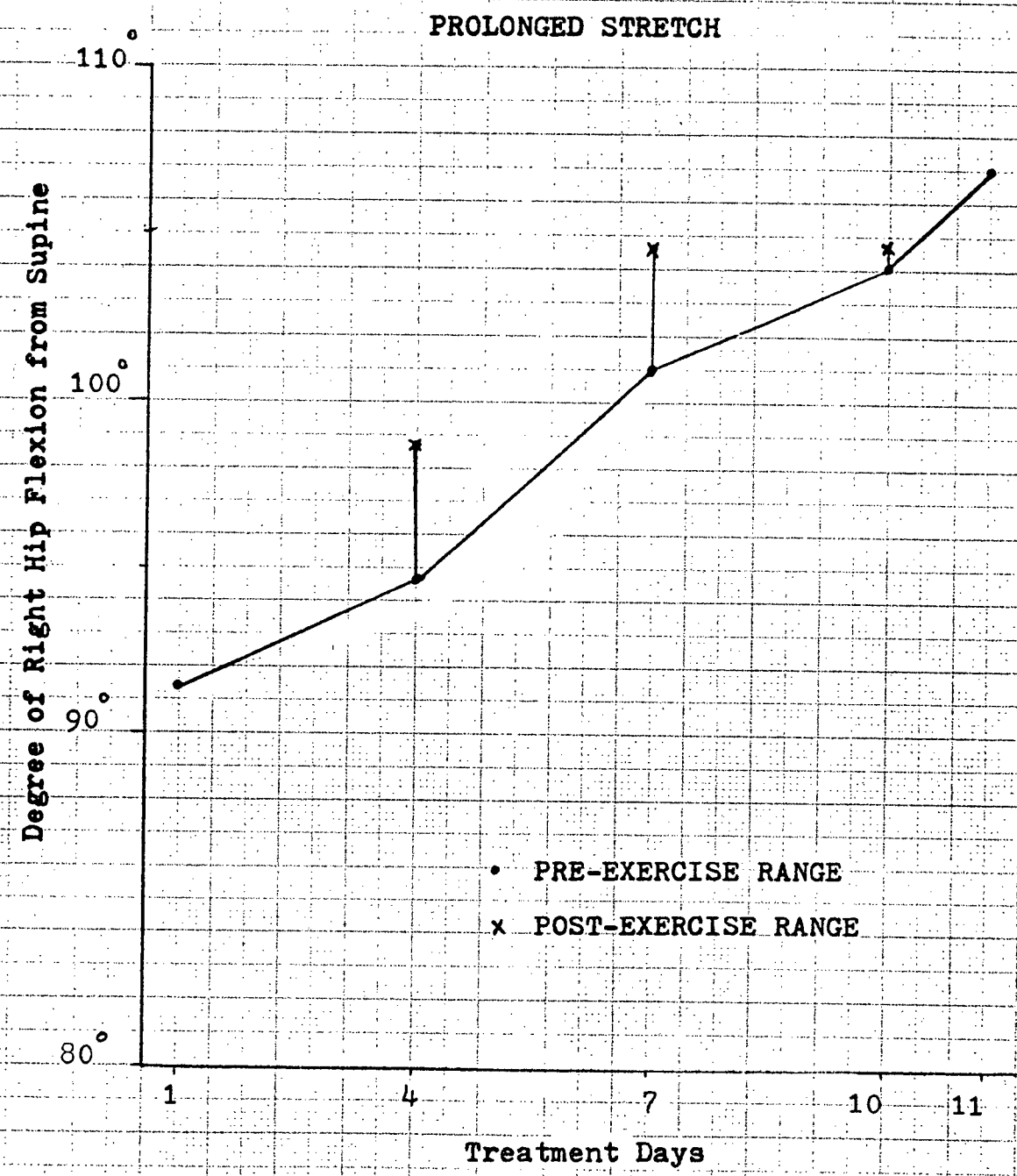


Figure 11

The Improvement Trend in Active Range over a Four Week Period Pre and Post Exercise for the Prolonged Stretch Group



DISCUSSION

The results indicate that active range of hip flexion is promoted comparatively well by both passive and active stretching methods. In addition, none of the stretching methods appear to significantly differ in their contribution to strength of hip flexion as measured at the 45 degree angle. Several interpretations may help to explain the result:

1. The comparable improvement of the Control group in active range reflects the conditioning effect that all groups were undergoing in their daily physical education classes as well as in the weekly testing sessions. It is possible that both of these activities were vigorous enough to act as an influential "training effect."

2. A more important consideration is the possibility that the angle of 45 degrees was not appropriate in measuring the strength of hip flexion. It is almost inconceivable that the Ballistic and Hold method did not make a more appreciable contribution to strength considering the muscular effort that the subjects were required to make. However it is known that the 45 degree angle of strength measure was well below the angle of the actual average active range on the initial day (84.5 degrees), and most certainly was further from the final day's average active position (104.6 degrees). The possibility exists that the hip flexion strength measure was made at an angle too far from the

position where the actual strength gains took place.

3. The passive methods, most notably the Relaxation method, appear to offer some positive quality to active range other than increased strength. This is a most interesting finding considering the premises outlined in the introduction. In order for active range to improve substantially without coinciding strengthening exercise, it seems logical to assume that the active force was being applied to a reduced resistance. In other words, Relaxation subjects apparently learned to reduce the reflex contractions of the stretched hamstrings, and this effect in combination with the physical lengthening exercise, was as effective as increasing the strength of the hip flexors. Active range of motion appears to be highly dependent on lowering the resistance of the extending muscles, perhaps more so than increasing the strength of the flexing muscles.

The findings reveal that the Active PNF method is not as valuable to active range of motion as indicated in Holt's (1970) study. One consideration is that the standardization of time for the exercise regimens may have been a factor in equalizing the effects of the treatments.

Finally, it should be noted that the Relaxation method showed erratic tendencies in that it gave the greatest overall gain in active range of hip flexion, but the improvement trend was not a smooth transition. Apparently this method has much to offer individuals if the proper

conditions exist for the subject to acquire the appropriate frame of mind.

The results from the other half of this study (Russell, 1976) comparing the six methods of stretch on passive range of hip flexion are summarized here to enlighten the reader on the joint findings. In passive range, the Control group gained significantly less ($F=25.8$, $p=.0001$) than the mean of the six exercise groups. As hypothesized, the active stretching methods (Active PNF with 19.9 degrees gain and Ballistic and Hold with 22.9 degrees gain) showed significantly lower mean increase in passive range than did passive methods (which showed mean increases of 26.9 degrees for Relaxation, 27.4 degrees for Passive PNF and 26.4 degrees for Prolonged Stretch) ($F=5.9$, $p=.01$). Passive Lift-Active Hold showed the greatest mean improvement for passive range with 27.7 degrees. The second hypothesis that the Relaxation method would be better than other passive methods was rejected.

Russell found that the exercise sessions had an important immediate effect on passive range improvement. In fact, there was a trend for the daily increase in passive range to be greater than the weekly increase. This positive immediate effect was suggested to be due to a neuromuscular warmup effect (gamma bias resetting or habituation of the spindle firing) or due to actual physical lengthening of the connective tissue.

In joint perspective, the Passive Lift-Active Hold method stands out as the one method best able to contribute to active and passive ranges of motion. This method ranked first for passive range of hip flexion (see Russell, 1976) and second for active range in this study. In addition, this method was easier to teach and administrate than PNF or Relaxation methods. The Prolonged Stretch and Relaxation methods also contributed well to both ranges, and these combined with an active contraction of the hip flexors (to elicit reciprocal inhibition) would appear to result in a maximum stretch and maximum relaxation of the target muscles.

The results of the dual study prompted the experimenters to correlate individual active and passive range measures on the initial and final days, and also to correlate the gains made in each range. The correlations showed fairly high relationship (r=.70) between individual active and passive measures both before and after the study. Individuals high in one range tended to also be high in the other and similarly for the low measuring individuals. Also individuals high in one range to start the study tended to be high to end the study (r=.77 for active, r=.68 for passive). However, the correlation between active range and passive range improvement scores was not high (r=.37). The low correlation indicates that gains did not consistantly occur together i.e. the improvement scores were highly variable and gains in one range have little relationship to gains in

the other. There is some relationship between the two ranges of motion (active and passive) but one cannot predict that improvement in one range will coincide with a similar improvement in the other.

CHAPTER V

SUMMARY AND CONCLUSIONS

The physical educator or coach interested in increasing the flexibility of students or athletes encounters few documented methods that claim to improve specific joint range of motion. Increased range of motion is largely dependent upon the condition of the soft tissues surrounding the joint. The supporting tissues can be physically lengthened through various stretching maneuvres, and the muscles on opposite sides of the joint can play an important role if certain facilitating techniques are applied to assist appropriate relaxation and contraction.

Basically all methods of stretching can be termed ACTIVE or PASSIVE. Active stretching methods require that the range of movement be made voluntarily, while passive stretching methods refer to movement through a range due to external force such as gravity or manual assistance. It was the purpose of this study to investigate the effects of six methods of stretch on the active range of right hip flexion.

The sample consisted of 119 volunteer college women in physical education at the University of British Columbia. Approximately twenty subjects were randomly assigned to each of seven groups by pairs. In addition to the Control group, six exercise groups were taught various stretching regimens to be practiced ten minutes with a partner. The exercise groups attended sessions three times a week for three weeks. All subjects were measured before and after the study as well as before and after exercise on the first day of each week. The active range of hip flexion was measured by the Leighton Flexometer and the strength of hip flexion at the 45 degree angle was measured by a cable tensiometer.

All groups increased in active range of hip flexion as indicated by the mean gains, including the Control group. Active stretching methods did not contribute significantly better to active range over the passive methods as hypothesized. The results indicate that the highly rated Active PNF method and the ill-reputed Ballistic method were not significantly different in their contribution to active range. Since passive methods of stretching contributed as well as active methods to active range of hip flexion, it is apparent that theoretically, it seems to be more important to reduce the resistance of the soft tissue being stretched than to increase the strength of the active contracting

tissue (agonists). Since the Relaxation group contributed significantly better than other passive methods to active range of hip flexion, this method appears to be offering something more than just soft tissue lengthening. The reduced resistance in the Relaxation method may be also attributed to the ability of the subjects to reduce the stretch reflex upon lengthening, thus allowing minimal resistance from the contractile apparatus of the muscle.

The strength of hip flexion as measured at the 45 degree angle was not significantly nor differentially improved by the various exercise treatments despite the vigour of the effort required by the active stretching methods. The angle at which the strength was measured apparently was a poor indicator in that it was well below the range at which specific strength gains might have taken place.

The Relaxation group was more erratic in its improvement trend in active range. It appeared that subjects were better able to concentrate on some days more than others indicating that the method has good potential depending upon the frame of mind. Since all of the passive methods made substantial contributions to active range, it is apparent that reducing the resistance of the stretching tissues is a viable approach to increasing active range.

Recommendations For Further Study

1. Evidence from this dual study indicates that three weeks is adequate time to gain substantially in both active and passive range of motion, but that more time be allowed in a further study to establish how soon, and by which methods a plateau effect will occur.

2. It would be of interest to see if active range of motion can eventually "catch up" to passive range of motion in terms of its final maximum range.

3. Some ingenuity is needed to solve the problem of measuring specific individual hip flexion strength and to correlate strength gains with active range gain to see how important the strength component really is in accomplishing active range of motion.

CONCLUSIONS

1. Active stretching methods give no greater improvement in active range of hip flexion than do passive methods.

2. The Active PNF method and the Ballistic and Hold method do not differ significantly in their overall contribution to active range of hip flexion.

3. If strengthening of the hip flexors occurs in "active" stretching exercises, then it must occur in a more specific location at the end of the range of motion.

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APPENDIX

APPENDIX A

INDIVIDUAL RAW SCORES

Group 1 - CONTROL

Flexibility in degrees

	DAY 1		DAY 4		DAY 7		DAY 10		DAY 11		STRENGTH	
NO.	ACT	PAS	ACT	PAS	ACT	PAS	ACT	PAS	ACT	PAS	PRE	POST
001	098	104	110	125	110	127	122	137	118	136	123	134
002	099	120	102	120	104	130	110	125	110	124	108	138
003	096	130	086	116	096	120	100	123	100	125	100	126
004	067	104	085	117	084	114	084	110	085	108	090	114
005	082	102	095	114	096	113	100	122	100	116	095	115
006	090	100	095	110	090	108	093	113	100	119	101	114
007	093	115	107	130	110	130	102	125	102	125	110	134
008	075	105	080	108	081	109	078	090	079	096	078	105
009	085	102	087	110	087	110	086	102	086	100	098	108
010	090	095	097	105	093	103	094	103	091	099	100	105
011	089	108	091	110	086	110	088	113	091	111	100	127
012	077	084	084	094	083	102	094	105	090	107	091	095
013	103	145	110	135	110	137	117	144	125	153	130	150
014	085	103	087	106	090	110	085	107	090	104	100	117
015	080	088	077	105	080	105	086	111	087	111	085	110
016	080	122	091	128	090	130	085	120	092	123	087	120
017	070	098	091	108	096	113	085	104	089	109	085	102

NO.	DAY 10 ACT	DAY 10 PAS	DAY 11 ACT	DAY 11 PAS	STRENGTH PRE	STRENGTH POST
001	122	136	111	129	40.0	50.0
002	114	140	110	130	46.0	47.5
003	100	132	111	126	57.0	52.5
004	090	120	100	118	55.0	59.0
005	095	115	103	122	38.0	62.0
006	103	115	100	100	40.0	42.0
007	113	131	103	125	43.0	46.0
008	077	100	085	110	47.0	66.5
009	097	106	097	104	61.5	66.0
010	092	104	106	106	47.0	46.5
011	106	122	110	119	54.0	53.5
012	090	096	093	113	44.0	43.5
013	130	157	130	146	68.5	69.5
014	100	119	103	115	59.0	65.5
015	086	110	090	113	54.0	55.0
016	090	116	097	125	62.0	61.5
017	090	113	097	117	33.0	44.0

Group 2 - PASSIVE LIFT, ACTIVE HOLD

	DAY 1		DAY 4		DAY 7		DAY 10		DAY 11		STRENGTH	
NO.	ACT	PAS	ACT	PAS	ACT	PAS	ACT	PAS	ACT	PAS	PRE	POST
055	095	105	095	120	105	125	103	121	103	130	65.0	72.0
056	078	096	084	117	088	123	097	124	097	131	53.0	65.0
057	070	074	085	095	082	097	098	100	100	114	58.0	53.5
058	067	074	072	073	094	090	083	085	085	087	56.0	48.5
059	090	093	083	096	085	106	085	097	089	107	42.0	55.5
060	120	143	128	150	127	151	125	149	121	156	52.0	51.0
061	108	130	100	129	110	135	140	158	128	146	62.0	60.5
062	079	094	087	103	095	120	080	102	080	105	45.0	47.0
063	101	111	097	120	110	132	106	133	113	144	48.0	51.5
064	072	091	084	121	075	110	081	110	080	120	49.0	54.5
065	088	096	081	117	105	132	095	112	105	127	30.0	54.0
066	080	090	082	101	084	110	096	123	093	121	53.0	55.0
067	097	095	102	113	107	127	105	116	121	138	54.5	61.5
068	084	121	090	126	095	145	100	132	090	135	67.0	72.0
069	101	107	103	119	110	133	109	123	112	128	32.0	34.5

DAY 10		DAY 11	
ACT	PAS	ACT	PAS
105	137	117	132
105	149	099	130
105	118	089	110
091	093	090	095
097	125	092	116
145	150	136	164
127	154	132	155
093	122	110	114
136	140	113	138
087	125	101	116
113	123	110	133
085	125	095	127
128	140	135	143
104	135	098	124
123	148	106	138

Group 3 - ACTIVE PNF

	DAY 1		DAY 4				DAY 7				DAY 10				DAY 11		STRENGTH	
NO.	ACT	PAS	ACT	PAS	ACT	PAS	ACT	PAS	ACT	PAS	ACT	PAS	ACT	PAS	ACT	PAS	PRE	POST
087	075	095	088	111	088	113	100	124	097	125	095	120	088	121	098	123	55.5	62.0
088	060	083	072	087	065	082	075	097	080	100	084	106	087	106	082	097	52.0	74.0
089	073	073	080	084	077	096	080	092	082	105	080	102	085	103	075	093	48.0	52.0
090	075	120	081	119	085	136	086	125	093	130	094	104	091	127	089	107	50.0	53.0
091	083	090	095	090	093	102	077	097	085	105	101	102	098	107	097	104	43.0	41.5
092	086	097	098	106	106	127	102	118	100	120	102	115	100	120	097	124	52.0	59.5
093	090	110	102	104	095	103	099	102	104	121	102	108	105	118	115	140	59.5	60.0
094	079	100	087	110	088	110	088	115	085	109	102	126	095	126	097	129	39.0	45.5
095	085	097	097	106	090	109	095	110	095	117	107	112	108	120	115	112	54.5	60.0
096	102	101	115	128	108	125	115	125	117	126	120	127	107	113	120	134	42.5	50.0
097	109	092	085	097	080	100	090	095	085	102	098	102	105	111	090	105	50.0	66.5
098	090	127	100	135	095	140	096	130	100	133	105	136	105	147	103	138	49.5	54.0
099	103	121	100	117	108	137	110	126	111	140	113	140	110	145	120	138	49.0	60.0
100	080	103	093	113	095	130	110	121	100	124	105	128	100	134	110	120	48.0	60.0
101	068	070	076	085	080	088	095	105	083	097	090	100	096	110	095	098	55.5	58.0
102	071	068	070	083	072	082	075	083	075	090	080	089	085	095	082	095	35.0	39.0
103	065	076	082	103	077	100	086	098	095	114	090	110	090	110	092	104	58.0	60.5

Group 4 - BALLISTIC AND HOLD

	DAY 1		DAY 4		DAY 7		DAY 10		DAY 11		STRENGTH	
NO.	ACT	PAS	ACT	PAS	ACT	PAS	ACT	PAS	ACT	PAS	PRE	POST
104	093	097	091	105	091	113	095	108	095	113	095	111
105	100	127	097	147	100	150	096	153	100	162	088	114
106	096	115	090	110	090	119	102	123	092	123	110	124
107	080	097	070	096	075	099	090	100	090	110	102	106
108	085	103	105	111	095	114	098	113	100	127	101	120
109	101	112	103	111	102	116	106	104	111	124	117	122
110	095	104	092	102	095	116	101	109	095	106	100	107
111	067	084	090	105	093	115	095	102	088	118	097	120
112	092	090	090	098	093	103	094	103	090	104	107	114
113	083	087	093	108	093	109	098	110	095	102	097	108
114	083	095	096	098	092	104	095	103	095	114	105	111
115	083	104	087	113	090	123	100	127	097	124	095	120
116	075	093	096	103	101	128	087	107	096	123	098	118
117	093	105	092	110	090	118	100	121	103	121	094	119
118	083	097	110	116	106	122	110	123	114	120	112	124
119	119	121	112	132	114	135	120	138	120	143	122	138

NO.	ACT	PAS	ACT	PAS	PRE	POST
104	088	105	100	123	61.0	58.0
105	102	124	112	139	50.0	68.0
106	103	127	090	120	36.0	46.0
107	103	118	109	116	47.0	47.0
108	100	123	110	116	44.5	55.5
109	119	142	122	125	46.5	52.0
110	105	118	106	124	56.0	51.0
111	103	128	095	120	48.0	62.5
112	106	119	100	110	48.5	55.0
113	100	127	105	120	45.5	48.0
114	103	119	100	118	49.0	59.5
115	100	125	109	130	58.5	51.0
116	100	125	100	125	47.0	53.5
117	101	125	125	136	41.5	50.5
118	115	139	100	125	36.0	52.0
119	133	155	135	150	52.5	55.0

Group 5 - RELAXATION

	DAY 1		DAY 4				DAY 7				DAY 10				DAY 11		STRENGTH	
NO.	ACT	PAS	ACT	PAS	ACT	PAS	ACT	PAS	ACT	PAS	ACT	PAS	ACT	PAS	ACT	PAS	PRE	POST
036	073	090	075	103	077	108	087	110	074	105	080	120	083	129	084	128	42.0	44.0
037	070	085	085	102	090	115	090	108	080	105	087	104	086	112	091	110	51.0	60.0
038	086	115	083	115	086	127	091	122	095	120	097	122	106	136	104	126	46.0	56.0
039	085	102	082	118	098	126	108	117	110	135	109	130	110	132	115	132	50.0	55.5
040	080	107	092	125	097	144	117	151	092	150	100	140	116	151	110	144	42.0	55.0
041	072	086	090	122	098	117	104	122	096	118	107	136	100	141	105	133	40.0	43.5
042	080	091	075	101	075	101	090	095	080	093	078	090	080	100	083	109	36.0	54.0
043	059	089	065	103	055	107	060	100	065	102	085	110	072	117	089	112	36.0	40.5
044	092	110	090	115	100	125	105	129	105	123	110	134	102	123	110	121	53.0	50.5
045	065	094	078	108	075	110	074	102	080	119	086	120	090	118	085	111	56.5	56.5
046	086	120	095	130	123	155	113	148	113	148	105	140	093	133	112	142	45.0	49.0
047	084	112	102	115	105	127	100	125	097	129	100	115	105	121	110	130	54.5	51.5
048	105	125	105	132	114	140	115	145	113	141	120	138	116	147	115	152	59.5	55.0
049	098	125	090	120	097	145	105	116	090	122	095	140	104	146	104	130	56.5	58.0
050	094	105	090	100	092	112	103	107	098	117	110	117	117	123	125	130	54.0	62.5
051	087	093	090	101	100	113	105	118	102	114	098	112	104	113	110	114	49.0	66.5
052	066	085	062	089	082	105	090	110	085	106	080	105	085	125	092	122	54.0	62.5
053	071	068	083	098	085	108	105	132	100	133	102	132	105	138	092	122	37.0	41.5
054	100	120	105	140	117	143	100	130	120	144	116	142	125	149	123	145	33.5	49.0

Group 6 - PASSIVE PNF

	DAY 1		DAY 4		DAY 7		DAY 10		DAY 11		STRENGTH	
NO.	ACT	PAS	ACT	PAS	ACT	PAS	ACT	PAS	ACT	PAS	PRE	POST
070	090	112	097	120	112	125	110	123	114	134	52.0	49.0
071	101	106	111	126	125	145	118	140	125	150	64.0	70.0
072	060	091	088	114	085	117	090	115	110	128	50.0	53.5
073	100	109	108	107	105	135	110	128	112	137	50.0	52.5
074	073	095	080	106	080	112	070	118	082	125	45.0	41.0
075	080	104	093	132	093	146	085	125	095	126	49.0	51.0
076	075	095	087	100	085	115	090	113	087	117	28.0	41.0
077	095	111	112	125	106	130	104	131	111	136	44.0	50.0
078	095	110	100	100	097	120	095	112	095	119	48.0	63.0
079	080	080	080	082	087	090	090	088	094	096	62.0	64.0
080	086	115	090	115	110	142	100	126	095	138	54.0	64.0
081	085	092	087	113	090	121	095	116	095	118	47.5	52.5
082	097	100	097	102	085	098	100	114	105	120	47.0	40.5
083	118	140	123	153	132	162	127	150	140	165	51.0	61.0
084	073	090	082	112	077	107	072	105	080	115	32.0	54.0
085	082	105	083	120	080	120	087	125	085	126	42.0	47.0
086	096	104	079	101	088	114	100	118	100	116	32.0	42.0

Group 7 - PROLONGED STRETCH

	DAY 1		DAY 4				DAY 7				DAY 10				DAY 11		STRENGTH	
NO.	ACT	PAS	ACT	PAS	ACT	PAS	ACT	PAS	ACT	PAS	ACT	PAS	ACT	PAS	ACT	PAS	PRE	POST
018	095	120	102	122	109	142	110	127	109	154	115	144	117	145	107	138	51.0	62.0
019	102	112	110	122	117	125	117	136	117	136	117	148	125	154	128	148	52.0	59.0
020	097	101	095	108	096	111	102	117	100	130	104	130	096	122	108	132	36.0	50.5
021	080	105	082	099	080	108	095	118	094	120	093	122	087	120	088	111	42.5	52.5
022	075	076	080	090	085	102	080	100	083	110	084	105	084	106	093	105	42.0	47.5
023	110	135	105	133	111	150	120	156	114	155	130	152	143	169	131	159	45.5	46.0
024	092	108	092	118	085	126	090	125	095	137	103	140	085	136	102	143	48.0	56.0
025	075	084	076	107	075	104	089	110	095	114	095	108	092	111	095	113	32.0	43.0
026	085	094	090	097	092	097	089	097	090	104	095	111	098	127	097	122	55.5	72.0
027	073	100	085	100	092	110	088	100	092	114	092	110	096	120	097	117	64.5	66.0
028	078	102	085	110	085	121	075	110	090	135	086	116	090	125	090	125	59.0	74.0
029	085	104	095	119	093	125	100	110	105	120	103	125	090	122	107	128	40.0	53.5
030	127	155	114	150	120	160	130	160	142	162	124	150	140	170	127	165	48.5	51.5
031	085	110	080	110	085	125	090	132	095	136	097	143	092	147	098	145	50.0	53.5
032	093	095	088	097	105	115	110	110	120	122	107	118	107	118	111	115	55.0	54.5
033	110	127	125	142	125	153	125	142	124	153	127	140	129	145	133	155	49.0	58.0
034	086	114	087	131	111	148	098	134	108	148	111	147	113	145	110	152	56.0	64.5
035	100	105	115	117	115	131	110	127	111	135	085	117	095	134	114	150	56.5	54.0

APPENDIX B

INTERPRETATION OF PHYSIOLOGICAL MECHANISMS UNDERLYING THE SIX METHODS

All of the following methods are assumed to have an effect on the lengthening of soft tissue. However, each method has a unique approach to the problem of increasing range of motion.

Prolonged Stretch:

It is well known that the myotatic reflex declines over time. The prolonged position of stretch is thought to introduce fatigue and/or accommodation in the tonic stretch receptors. In prolonged stretch, the phasic component of the myotatic response is effectively eliminated and thus the reflex to contract the stretched muscle is potentially reduced.

Relaxation and Prolonged Stretch

It can be reasoned that the ability of muscle fibres to lengthen is dependent upon their state of relaxation. Mindset techniques as well as progressive relaxation deal with this goal in terms of tension awareness. If a relaxed state can be induced in combination with the prolonged stretch exercise, the following is expected:

1. Reduction of the myotatic reflex due to accommodation
2. Voluntary inhibition of the reflex due to tension awareness

3. Later onset of the reflex due to gamma bias accomplished by mind-set.

Passive PNF

The physiological bases for this method is that the soft tissue undergoing passive lengthening will undergo even greater stretch, particularly at the tendinous junctions, during the isometric extensor contraction phase. The maximal extensor contraction also facilitates the relaxation of the extensors when they cease contraction.

Active PNF

The physiological bases for the Active PNF method appear to be:

a) facilitation of flexor contraction following extensor contraction (successive induction)

b) facilitation of extensor relaxation due to inhibition of the stretch reflex following extensor contraction

c) facilitation of extensor relaxation due to the contribution of the tendon reflex (inverse myotatic reflex).

Ballistic

The rationale for "ballistic and hold" is that the "hold" introduces a quality of control at the joint limit that may prevent tissue damage which has been a concern with this method. The dynamics of this activity allows it to contribute to flexor strength and fast lengthening action of the extensors as is required for sport movements.

Passive Lift and Active Hold

This method not only employs the passive lengthening of the extensors, but is thought to facilitate reciprocal inhibition (relaxation) of the extensors by active contraction of the flexors when the hip flexors (iliopsoas and rectus femoris) are actively called upon in terms of strength to hold the leg in a position of maximal extension.

APPENDIX C

INSTRUCTIONAL SHEETS ON THE METHODS

NAME.....

The group that you have been assigned to in this experiment is called the CONTROL GROUP.

Basically this means that you will not be active in terms of exercising but that you will be a full participant in terms of all measurements to be made. In this sense you will be part of a group that act as a "standard" that will be used as a performance comparison for the exercise groups. For this reason, it is very important that you not take specific action to mobilize or strengthen the right leg in hip flexion over the next four weeks. It is appropriate that you continue with your normal activities as usual.

As a control group member, you will be required to attend only the measuring sessions (Days 1. 4, 7, 10, 11). This means that if we are meeting three times a week with your class or group, then you will be required on the same day of the week for four weeks, and then also on the next class day right after that.

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NAME.....

The stretching method that you have been assigned to is called PASSIVE LIFT AND ACTIVE HOLD. Please read the following instructions carefully prior to practicing with your partner.

INSTRUCTIONS FOR PASSIVE LIFT, ACTIVE HOLD METHOD

1. While lying on your back, just relax and let your partner raise your right leg slowly. The left leg remains on the floor with the knee extended, and it is important to keep the right leg straight throughout the exercises. Over a six second period, the partner will take your leg to the limit of your pain-free range (i.e. a position of stretch that you can maintain for the remainder of the six seconds) and will support the leg in the position where you say "stop."

2. After the six second mobilization of the leg, the partner will slowly release her support on the leg and it is then up to you to hold the leg in the position where it is released. If the leg slips back a little, try very hard to stop it as soon as you can, Actively hold your leg this way for six seconds.

3. On the next six second interval, the partner will give you support again, and move you slowly to at least your original position of limitation. If it is possible to go further than before, let your leg be moved to a new position before you say "stop."

4. The procedure is continued with the passive lift and active hold phases alternating every six seconds, a total of five times in one minute. After one minute the subject changes over to assist the partner in her stretch. The exercise will take place in ten minutes (5 minutes exercise, 5 minutes rest).

ASSISTING PARTNER

The partner stands facing the subject on the platform that stabilizes the subject's left leg. Taking hold

behind the subject's right ankle, the partner slowly elevates the leg. The knee can be supported also if it is bending. The leg is to be mobilized to the limit of the subject's pain-free range in the 6 second interval. The partner then releases pressure on the leg very gradually so that the subject can maintain that position on her own for 6 seconds.

The partner then resumes her position supporting the ankle (and knee if necessary) and mobilizes the leg to its original position (if the leg has slipped back), or to a new range in the next six second interval.

All movements in passive stretching are slow and gentle since the subject will be working at her end-point most of the time. Remember that your assistance is primarily to maintain the end-point position of the leg so that the subject can rest there at least part of the time; mobilizing the subject's leg to a new passive position will not be possible every time, especially as she approaches her maximum range.

The whole procedure will take 10 minutes (5 minutes of exercise and 5 minutes of rest alternating in one minute intervals). It is recommended that you go easy on the first day.

NAME.....

The stretching method that you have been assigned to is called the ACTIVE PNF method (proprioceptive neuromuscular facilitation). Please read the following instructions carefully prior to practicing with your partner.

INSTRUCTIONS FOR ACTIVE PNF METHOD

1. While lying on your back, you will first be required to slowly lift your right leg upward, keeping it straight, directly pulling it toward your face as hard as you possibly can. The left leg remains stabilized on the floor during the exercise with the knee extended. You will have six seconds to lift the leg and hold it in its maximal position. Your partner will then step in and support your stretching leg for the next six second phase.

2. Next, you will gradually try to push your leg back down to the floor as hard as you can, and this will be an isometric contraction (i.e. the partner will resist the down movement) for six seconds.

3. You now lift your leg again, to a new position if possible, or at least maintain your present position for six seconds.

4. This alternating lift and isometric push-down are repeated until one minute is up (five times each per minute). Then you can rest your leg and assist your partner for the next 60 seconds. Altogether you will be exercising for five minutes and resting for five minutes. It is recommended that you go easy on the first day.

ASSISTING PARTNER

The partner is positioned so that she serves as an immovable object when the subject commences to exercise. She will stand facing the subject on the platform that stabilizes the subject's left leg. The partner must be prepared to resist the downward force when the subject is in the push-down phase. She does this by bracing her legs,

slightly flexed, and supports the back of the ankle with her hands or shoulder. The partner must resist completely all movement downward in order to make the subject's contraction isometric.

In the six second lift up phase, the partner does not assist the subject, but follows the movement and prepares for the next isometric contraction down from the new end-point. There are five resistive down phases in a one minute period, and the total exercise will take ten minutes (five minutes exercise and five minutes resting in alternating onemminute intervals).

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NAME.....

The stretching method that you have been assigned to is called the BALLISTIC AND HOLD method. Please read the following instructions carefully prior to practicing with your partner.

INSTRUCTIONS FOR BALLISTIC AND HOLD METHOD

1. While lying on your back, raise your right leg directly forward to approximately a 45 degree angle and use this position as a starting point for the exercise. The exercise is called "ballistic" but a better description of what we want you to do is " a controlled bounce." You can use the momentum of your leg swing to gain flexibility if you swing your leg in a controlled way at and past your original end-point. You are required to swing the right leg upward from the elevated starting position four times up and down. It is recommended that you go easy until you know where your end-point is, and then try to surpass your limit gradually

with gentle momentum. On the fourth swing, you go up to the end-point and hold the leg there without bouncing back for six seconds. Try your best not to let the leg drop from that end-point.

2. After the leg hold, the leg is moved back to the 45 degree angle once more and you proceed with the four leg swings upward again. Altogether the ballistic swings and the hold are repeated six times in one minute. In total the exercise will take five minutes, alternating with five one minute rest intervals.

The left leg is kept extended and stabilized on the floor while the right leg is kept straight during the activity. Go as far as you with a straight leg, and take it easy on the first day.

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NAME.....

The stretching method that you have been assigned to is called the RELAXATION method. Actually you and your partner will follow the same physical instructions as the PROLONGED STRETCH group, but in addition, there will be some "thinking" processes attached to your method. Please read the following instructions carefully prior to practicing with your partner.

INSTRUCTIONS FOR RELAXATION METHOD

This method has not been researched and your understanding of it is most important. Firstly, it involves a "mind-set" or a mental picture of the goal you are aiming for. Once you can visualize what you want to do, you can

better inhibit or over-ride reflexes that are preventing you from achieving this goal.

For example, when you stretch a limb past its usual (everyday) range, the muscle has a built in reflex that says, "Whoa! You are stretching me further than I usually go, so I'm letting you know." This is called the myotatic reflex. In effect, the muscle being stretched will actually contract or tighten when normal range is exceeded! You are then trying to stretch a contracted muscle and the tightness and pain are due to the fact that you have reached the physiological limit of stretch. If you could "inhibit" or override this myotatic reflex, you could move your limb much further.

To do this, you first need a mental picture of where you want to be, and then you need to concentrate very hard on this picture when you stretch. You are concentrating on relaxing the stretched muscle and the more you relax, the less pain you will feel because the muscle will stop contracting. This is of course what is done in some yoga nethods minus the scientific jargon.

It must be appreciated that in hip flexion there is no anatomical reason why you cannot be "very flexible." In fact, inactivity is the prime reason for lack of flexibility. Make sure that you do not allow your partner to stretch you so much that you are really uncomfortable. You cannot possibly "relax" if this occurs. Instead, have your partner stop just as you feel a tightness behind the leg and then "concentrate" on relaxing the muscle being stretched. As you relax, tightness will subside and you can have the partner increase the stretch. Remember this method calls for more "mental effort" than physical, and you must CONCENTRATE on your desired goal and on RELAXING the stretched muscle.

NAME.....

The stretching method that you have been assigned to is called the PASSIVE PNF method (proprioceptive neuromuscular facilitation). Please read the following instructions carefully prior to practicing with your partner.

INSTRUCTIONS FOR PASSIVE PNF METHOD

1. While lying on your back, just relax your right leg and let your partner raise it slowly. The left leg remains stabilized on the floor with the knee extended and the right leg must remain straight throughout the exercise. Over a six second period, the partner will take your leg to the limit of your pain-free range (i.e. a position which you can tolerate for several seconds) and will support the leg in the position where you say "stop."

2. When the six seconds are up the partner will say "push" and you will then gradually try to push your leg back down to the floor as hard as you can against your partner's resistance. This is a six second effort and should be a maximal isometric contraction (as hard as you can with no movement occurring).

3. You can relax your right leg on the next six seconds, so that the partner can gently take your leg into the stretch again. At the limit of your pain-free range you again say "stop" and let her hold your leg at that position, keeping the leg straight. You may find that following each isometric push down that you can be passively moved to a slightly greater range each time (five stretches, five push downs in one minute). You will be active for five minutes altogether with five minutes of rest intervals. Take it easy on your first day.

ASSISTING PARTNER

The partner is positioned facing the subject so that she serves as an immovable object when the subject commences to exercise. She will be standing on the platform that stabilizes the subject's left leg.

Taking hold behind the subject's right ankle, the partner slowly elevates the leg directly upward through the subject's pain-free range. At the limit, the subject says "stop" and the partner holds the leg in this maximal position keeping the leg straight if necessary by holding above the knee with one hand and behind the ankle with the other.

After the six second period allotted to the above movement, the partner prepares to resist the downward leg push of the subject. In order to stop all movement downward and make the contraction an isometric one, the partner braces her legs slightly flexed while supporting the ankle with her hands or shoulder. The partner must take care that the subject's leg is mobilized in direct line with the body, and at no time should there be twisting of the hips.

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NAME.....

The stretching method that you have been assigned to is called the PROLONGED STRETCH method. Please read the following instructions carefully prior to practicing with your partner.

INSTRUCTIONS FOR PROLONGED STRETCH METHOD

1. While lying on your back, just relax and let your partner raise your right leg slowly. The left leg remains stabilized on the floor with the knee extended, and it is

important to keep the right leg straight throughout the exercise. The partner will take your leg to the limit of your pain-free range (i.e. a position of stretch that you can maintain for a minute) ans will support the leg in the position where you say "stop." If you have misjudged the position and experience discomfort, you can ask your partner to ease off a little until you are in a more comfortable position.

2. The stretch position is held by your partner (passively on your part) for one minute. After the minute, you change over with your partner and mobilize her right leg in the same way. Altogether you will be exercising five minutes and resting five minutes.

ASSISTING PARTNER

The partner stands facing the subject on the platform that stabilizes the subject's left leg. Taking hold behind the subject's right ankle, the partner slowly elevates the leg to the limit of the subject's pain-free rnage. The partner holds the right leg in its maximal position, keeping it straight if necessary by holding above the knee and behind the ankle for the minute period. The subject then lowers the leg. Take care to insure that the leg is mobilized in direct line with the body. It is recommended that all subjects go easy on the first day.