9-1980

The effects of three stretching techniques on flexibility

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THE EFFECTS OF THREE STRETCHING TECHNIQUES ON FLEXIBILITY

A Thesis

Presented to the

School of Health, Physical

Education, and Recreation

and the

Faculty of the Graduate College

University of Nebraska

In Partial Fulfillment

of the Requirements for the Degree

Master of Arts

University of Nebraska at Omaha

by

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September 1980

THESIS ACCEPTANCE

Accepted for the faculty of the Graduate College, University of Nebraska, in partial fulfillment of the requirements for the degree Master of Arts, University of Nebraska at Omaha.

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ACKNOWLEDGMENTS

The author would like to thank Dr. Daniel Blanke and Dr. C. Raymond Millimet for their help and advice on this project. A special thank you is extended to Dr. Stan Sady for his guidance and assistance. Dr. Sady's enthusiasm for this project provided the encouragement necessary for it to be completed. His help was greatly appreciated.

DEDICATION

This study is dedicated to my parents, Mr. & Mrs. Edward H. Wortman. Their moral support and financial assistance made this educational experience possible.

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CHAPTER I

INTRODUCTION

According to deVries (11), flexibility is defined as the range of possible movement in a joint or series of joints. The assessment of flexibility is a concern for both physical education and the medical professions. Apparently, an adequate amount of flexibility is essential for rehabilitation from injury, prevention of injury and superior athletic performance (2, 8, 11, 14, 15, 16, 19, 21, 25, 31, 37, 43, 45). Presently, three stretching techniques are available: 1) static or slow sustained; 2) ballistic or bounce; 3) proprioceptive neuromuscular facilitation (PNF). However, there appears to be no uniform agreement as to the best technique for gaining optimal improvements in flexibility.

Studies comparing the ballistic and static methods indicate similar results for improving flexibility (10, 33, 48). Other investigations (39, 40, 49) indicate that the ballistic is better than the static technique in stretching certain muscle groups. More recently, limited studies have been conducted using the PNF technique (5, 7, 17, 20, 41, 46, 47). This method has its origins in physical therapy (24, 26). The neural circuits are so arranged that contractions of the antagonist results in the stretched muscle (agonist) reflexively relaxing. However, contracting a muscle involves another reflexive influence, the Golgi tendon organ. This tendon receptor gives the opposite reaction of the stretch reflex; that is, strongly contracting a muscle causes the tendon to stretch and thus send an inhibition message back to the motor neurons of the contracting muscle. Since this receptor action slightly outlasts the contraction, the muscle is allowed to be stretched further.

Investigations comparing the PNF method with the static and ballistic techniques also reveal contradictory results. Some possible reasons for these discrepancies include inadequate control, lack of baseline measurements, varied training programs, different instruments for measuring flexibility and different muscle groups utilized.

Review of Literature

This review of literature is divided into two major sections. The first section discusses the various means with which flexibility has been measured. The second section examines the different training techniques employed to increase flexibility.

Measuring Flexibility

Among the problems in various studies of flexibility are different methods of measurement. Also, measurements only deal with one component of flexibility - the static portion. Dynamic flexibility while often ignored and hard to measure, is probably the most essential in physical performance (11, 36). A review of the literature generally reveals two different techniques to assess static flexibility: the direct, objective, single joint method, and the indirect, subjective, composite method.

Direct (Objective, Single Joint):

This technique measures the range of motion about a single joint directly. The score that is obtained is a reliable and valid measure of flexibility.

The most common instrument for measuring flexibility is the goniometer (19). A goniometer is a protractor device with two moveable arms attached so that the pivot point of the arms and center of the protractor are the same. This instrument can measure a joint's degree of movement directly from the protractor scale. High reliability of flexibility scores has been obtained using this device for various muscle groups. For example, Less et al. (30) found reliability coefficients ranging from r = .84 to r = .93 for the range of motion of different fingers in college students (n = 18).

The American Academy of Orthopedic Surgeons (1) and the Departments of the Army and Air Force (23) have prepared manuals with complete instructions on the use of the goniometer for each joint movement. The American Academy of Orthopedic Surgeons (1) states that if landmarks are clear the goniometer measurements can be accurate. However, caution must be applied when the bony landmarks are not clear, because of an excess of soft tissue or other reasons which they do not specify. Salter (42) adds that the faults with a goniometer are usually misapplications of the instrument, such as failing to accurately line up the moveable arms.

One of the more recent and most popular instruments for measuring flexibility is the Leighton Flexometer. The Leighton Flexometer consists of a round case four inches in diameter and one inch thick with a strap connected to the backside. Inside the case is a weighted 360° dial and a weighted pointer with a separate locking device for each. The flexometer is strapped to the body segment to be measured. At one end of the range of motion the dial is locked and at the other end of movement the pointer is locked. The number that the pointer indicates is the number of degrees traveled by the joint in its range of motion.

High reliability has been reported for flexibility scores of various muscle groups in different types of subjects. Leighton (28, 29) obtained test-retest coefficients ranging from $r = .89$ to $r = .99$ in different joints. Similar results have been reported by Sigerseth et al. (45, 48), Massey and Chaudet (35), Riddle (40), Twietmeyer (48), Shasby (44) and Krahenduhl and Martin (27). The subjects in these studies included children and adults of both sexes. The lower reliabilities reported by Puhl (39) ($r = .14$ to $r = .91$) are probably due to her measurement procedures. That is, she reported wide range of extraneous movements and some "motivation" problems.

The Leighton Flexometer appears to overcome many of the problems of the goniometer. That is, no bony landmarks need to be found and lining up the moveable arms is avoided. Harris (18) stated that the flexometer is apparently the most objective instrument for measuring flexibility.

Indirect (Subjective, Composite):

This method measures how close a body part can be brought to a resisting body part or a reference point. Measuring instruments for this linear unit are tapes, rulers, or sliding calipers. Examples of such flexibility measures include the sit and reach test (50) and the Kraus-Weber floor touch test (49). Although high reliability of test scores ($r = .87$ to $r = .99$) have been reported (5, 36) the validity of such linear measurements has been questioned. The concerns expressed by various investigators include: (1) body segment lengths may be related to flexibility scores (28); (2) subjective judgement is required in scoring (19), and; (3) such measurements do not restrict movement to a single joint (18).

On the other hand, Mathews et al. (36) reported high intercorrelations ($r \geq .87$) for the adapted Kraus-Weber floor touch test, the Leighton Flexometer hip flexibility and the Wells sit and reach test in sixty-six college women. Furthermore, none of the tests were related to lower limb length or standing height. Also Broer and Galles (4) obtained an $r = .81$ between the sit and reach test and Leighton hip and back flexibility.

Flexibility Techniques

Holland (19) summarized the structural limits of flexibility: (1) fasciae, (2) tendons, (3) ligaments, (4) cartilage, (5) scar tissue. The joint capsule and associated connect tissues plus the muscles appear to provide about 88% of the resistance to flexibility (22). Apparently these tissues contain a certain degree of elasticity which can be modified by use or disuse.

This review of literature will divide the previous research into three groups: 1) those studies comparing ballistic and static methods, 2) those studies comparing ballistic, static, and other methods, and 3) those studies comparing PNF with other techniques.

Ballistic vs Static

deVries (11) explained the physiology of the static and ballistic stretch. He states that a bouncing or jerking of the muscle actually causes the myotatic stretch reflex in the muscle spindle resulting in contraction of the muscle to be stretched. This contraction is directly proportional to the intensity of the ballistic stretch. Conversely, the held stretch invokes the inverse myotatic reflex which tends to relax the muscles.

Many textbooks tend to agree with deVries (11) in preferring the static over the ballistic method (2, 14, 15, 38). deVries, on the basis of several investigations (9, 10, 12), concluded that static stretching had three definite advantages over the ballistic method: (1) it requires less energy; (2) there is less danger in going beyond the muscle limitations, and; (3) static stretching relieves muscle soreness. However, a review of the literature reveals conflicting results when comparing ballistic and static stretching.

Weber and Kraus (49) compared the ballistic or "spring stretch" with the static or "plain stretch." The subjects were male and female, ranging in age from 6 to 12 years. All 50 subjects had shortened hamstring-gastro-soleus muscles and were referred to the Posture and Corrective Exercise Clinic. Each subject's hamstring muscle groups were pre- and post-tested using a goniometer and a floor touch test. No information was provided to ascertain if baseline measurements were obtained. The ballistic group (n = 25) flexed the hip joint in a quick jerking fashion while the static group (n = 25) performed the same exercise but held the stretch momentarily. No control group was used. Exact numbers of repetitions, sets and duration were not available. Over a two month period the spring stretch increased 6^{o} in hamstring flexibility while the plain stretch increased 2^{o} in hamstring flexibility. They concluded that the ballistic stretch was 200% more efficient in stretching the hamstring-gastro-soleus muscle groups.

Logan and Egstrom (33) compared the ballistic and static stretch with 25 college students as subjects, 12 women and 13 men. Subjects were randomly assigned to a slow stretch or a fast stretch group. No control group was used. A camera picture was used for pre- and post-measurements.

The measured angle of hip flexion was used as the raw score. Baseline measurements were not obtained. The subjects performed 20 repetitions of either static or ballistic stretch daily from a standing position. The static group flexed the trunk as far as possible and held the position momentarily while the ballistic group bounced down and returned rapidly. After a ten day stretching program both groups increased significantly in hip flexion flexibility ($p < .05$), but neither group was better than the other. Unfortunately, no data were presented in order to examine the extent of increase in flexibility.

deVries (10) also compared the ballistic and static stretch using 57 college males. The subjects were randomly assigned to either the static ($n = 28$) or ballistic ($n = 29$) group. No control group was used. The subjects were pre- and post-tested using Cureton's (8) flexibility tests for trunk flexion, trunk extension, and shoulder elevation. Baseline measurements were not taken. The training sessions were held twice a week for three and one half weeks. The static group performed eight stretching exercises. Each exercise was held for 30 seconds and by the fourth workout, was held 60 seconds. The ballistic group also performed eight exercises involving the same muscle groups as the static group. Each exercise was performed in a bouncing fashion for 20 repetitions and going up to 40 repetitions by the fourth session. Both the ballistic and static group showed significant increases in flexibility at the .01 level.

Increase for the static group ranged form 10-21% in the three tests, while the ballistic group ranged from 13-35% increase for the three tests. deVries concluded that no significant differences existed between the two groups.

Twietmeyer (48) used 61 college males to determine the effects of static and ballistic stretching. The subjects met twice a week for seven weeks for their training session. Pre- and post-measurements of trunk-hip flexion-extension, hip flexion-extension, and neck flexion-extension were taken. Baseline measurements were not obtained. The ballistic group (n = 21) performed five stretching exercises each training session. The duration of each exercise started at 15 seconds the first week and progressed to 30 seconds by the last week. The ballistic group did as many repetitions as possible within the time period, while the static group (n = 20) held their stretching position throughout the time period. The two training groups were compared against a control group (n = 20). The increase in flexibility in the various muscle groups ranged from 2-9% for the static group, and from 2-8% for the ballistic group, while the control group showed a decrease of 0-2%. Twietmeyer concluded that both groups were effective in increasing flexibility, but that neither was better.

Ballistic vs Static vs Others

Riddle (40) used the spring stretch, the held stretch and a combination stretch using both techniques. The subjects consisted of college females from eight classes taught by three different instructors. Each instructor had one section using held stretch (n = 101), one section spring stretch (n = 88), and two instructors had sections using a combination stretch method (n = 63). No control group was used. Not a great deal of consistency existed between instructors and what exercises they had their classes perform. Instructors could use any suitable exercise they desired as long as it was in the same category of stretch they were using. Subjects were encouraged to do some stretching outside of class, which further limits the control over the subjects. Subjects were pre- and post-tested using a Leighton Flexometer. No baseline measurements were obtained. She concluded that all three methods increased flexibility ($p < .05$) but that the spring stretch was more effective in increasing trunk and hip joint flexibility (4% increase), while the held-stretch was most effective in increasing hip joint flexibility (8% increase).

Bridell (3) examined the effects of the dynamic, static and combined stretching techniques on hip flexibility. The 92 college male subjects were randomly placed into a static group (n = 23) a dynamic group (n = 23), a combination group (n = 23) and a control group (n = 23). Pre- and post-measurements were taken with a Wells and Dillon Sit and Reach Box. Baseline measurements were not obtained. The three stretching groups met twice a week for nine weeks and performed five different exercises during each session. The static stretch was held in a stable position near the end of the range of motion for each exercise. The dynamic stretch was a bouncing motion continued during the same time period. The combination stretch used the static stretch for the first half of every exercise and a ballistic stretch the last half of every stretch. At the end of the training session the static group had a mean gain of 1.2", the dynamic group 1.3", the combination group 1.2" and the control 0.7". The study concluded that the three training methods improved hip flexibility ($p < .05$) but none of the methods was superior.

Long (34) compared static, dynamic and combined stretching methods in 54 college women on hip joint abduction. A Leighton Flexometer was used before and after a six week training session. The subjects were randomly assigned to one of six groups, a static and dynamic that trained three times a week and a static, dynamic and two combined groups that trained two times a week. All the treatment groups increased in flexibility while none of the methods of training was significantly better than the other.

PNF and Others

More recently studies have been conducted using the proprioceptive neuromuscular facilitation (PNF) technique. This method was first developed by Herman Kabat at Kabat-Kaiser Institute during the years 1946-1951 (26). Working with paralytic patients, Kabat (24) believed to build strength, more motor units needed to be stimulated. To stimulate these motor units in the muscle, one must apply a maximal resistance to the voluntary movement throughout the range of motion (24). Through PNF the resistance of the nerves was diminished and each voluntary movement went through its motion more easily. Knott and Voss (26) continued with the ideas of proprioceptive neuromuscular facilitation and used it as a therapeutic treatment on patients without paralysis.

Holt, Travis and Okita (20) conducted a study comparing the static, ballistic and PNF methods of flexibility. Whereas Kabat (24) and Knott and Voss (26) worked diagonally, or in two planes, Holt worked only in one plane with the PNF treatment. Twenty-four subjects were pre- and post-tested on a sit and reach box. Lower back muscles and hip extensors were the key muscle groups being stretched in this study. The fast stretch group performed two hip flexion exercises, one from a standing position and the other from a sitting position. Each exercise consisted of a bouncing motion for four sets of 20 seconds. The slow stretch group performed the same exercises but held the hip flexion instead of bouncing back and forth like the fast stretch. The PNF group performed two exercises, one in the sitting and one in a standing position. After full flexion of the hip a partner would resist the subject from extending the hip, performing an isometric contraction. From the sitting position two sets of three contractions for both legs were performed. From the standing position four sets of three repetitions were performed. The slow and fast stretch averaged 0.75 inch improvement while the PNF averaged 2.10 inch improvement. Holt concluded that the PNF method increased flexibility significantly greater ($p < .0001$) than either the static or ballistic.

Carr (5) conducted a study comparing the effects of the static stretch and the PNF technique on sprinting velocity. This study also attempted to determine if one method of stretching was more effective than the other. The subjects were 26 male college students who were all pre- and post-tested in hip flexibility. The hip extensors were measured with a toe touch test while the hip flexors were measured with a goniometer. Baseline measurements were not obtained. The subjects reported three days per week for seven consecutive weeks. Carr concluded that both techniques increased flexibility significantly greater ($p < .05$) than the control group. The mean changes in hip extensors for the control, static and PNF were 1.3 inches, 2.6 inches, and 2.6 inches, respectively. The only difference between the techniques was the static group increasing right hip flexors to a greater extent than the PNF method.

Tanigawa (46) using 30 male subjects, ranging in age from 20-48, compared the effects of the PNF and static stretch techniques on tight hamstring muscles. The subjects were divided into a static group ($n = 10$), PNF group ($n = 10$) and a control group ($n = 10$). Measurements were all taken using a right angle triangle. Baseline measurements were not obtained prior to treatment. The subjects in the treatment groups received stretching two days per week for three consecutive weeks. The treatment groups stretched the hamstring muscles the same length of time during each session. After three weeks the PNF group showed 45% increase in hamstring flexibility, the static stretch showed 22% increase, while the control group showed a 4% increase. According to Tanigawa the PNF was significantly better ($p < .05$) than the static method for increasing flexibility in the hamstrings.

Hartley (17) used 119 women to test varying stretching methods on right hip flexion. The subjects were randomly assigned to one of seven groups; a passive lift action hold group, an active PNF group, a ballistic, and hold group, a prolonged stretch and mental relaxation group, a passive PNF group, a passive prolonged stretch, and a control group. The subjects were pre- and post-tested using a Leighton Flexometer. Baseline measurements were not established prior to treatment. The subjects in the treatment groups stretched three times a week for three weeks. Each exercise treatment lasted about ten minutes per session. The control group showed a 20% improvement, passive lift action hold 22% improvement, active PNF 20% improvement, ballistic and hold 20% improvement, relaxation 26% improvement, passive PNF 20% improvement, and the prolonged stretch group 17% improvement. Her results showed that while all groups increased in range of right hip flexion there was no significant difference ($p > .05$) between active and passive techniques nor any difference between static, ballistic or PNF groups.

Cornelius (7) used 30 college males to examine the effects of a passive static stretch, a combination active and passive static stretch, and four varying treatments incorporating a PNF stretch. In an active passive stretch each subject would stretch on his own followed immediately by a passive stretch with the help of a partner. Two of the treatments used a three second isometric contraction, one was followed by a passive contraction the other with a combination of an active passive stretch. The other two PNF treatments were performed exactly the same, only holding for a six second isometric contraction. Cornelius worked with hip flexion muscle groups, and measured the degree of improvement in hip range of motion immediately following the stretch; no training session was involved. All treatments increased hip flexion significantly ($p < .05$). The PNF treatments were significantly better than the passive stretch but not better than the combination active passive stretch.

Turner (47) compared the PNF technique with the static method using 12 females ranging in age from 12 to 14 years. Training sessions were held three times per week for six consecutive weeks. The subjects were divided into a static ($n = 4$), PNF ($n = 4$), and control ($n = 4$) group. A Leighton Flexometer was used to measure the flexibility of the shoulder, knee and ankle. Baseline measurements were not obtained. The same number of sets (8) and duration (10 sec) for each exercise was used in both groups. Turner concluded that while both groups gained in flexibility ($p < .05$) neither group was better.

Rivera (41) used 79 (37 male and 42 female) subjects to compare the static, ballistic and PNF stretching methods. The subjects were randomly assigned to the static group (n = 19), the PNF group (n = 18), the ballistic group (n = 19) and control (n = 23). The training sessions were held five days a week for six weeks. The ballistic and static groups performed nine stretching exercises while the PNF performed seven exercises stretching similar muscle groups. Pre- and post-measurements of the neck, hip, ankle, trunk and shoulder were measured with a Leighton Flexometer. Baseline measurements were not obtained. Rivera concluded that all training techniques improved flexibility ($p < .05$) but that the static and PNF groups were better than the ballistic group.

Summary of Review of Literature

1. The literature reveals that the Leighton Flexometer gives the most valid and reliable scores of flexibility.

2. The literature reveals contradictory results as to which technique is best for increasing flexibility.

3. There are several weaknesses in the previous research comparing flexibility techniques.

a. Many of the studies failed to establish baseline measurements for the subject's flexibility. The normal day-to-day biological variability in flexibility has not been determined. A subject may vary a great deal in flexibility from day-to-day necessitating establishing individual baseline levels to accurately determine improvement.

b. A number of the studies failed to have a control group. Without a control group the experimenter cannot be sure if gains in flexibility are due to the training session or other unknown variables.

c. Many of the studies use different instruments to measure joint flexibility. Often studies are not comparable because of the lack of uniformity in measurement tools and techniques.

d. The use of different muscle groups makes it difficult to compare studies; the concept of specificity of flexibility is well-established (13, 18, 19).

Statement of the Problem

It was the purpose of the present study, therefore, to compare the effects of three stretching techniques (static, ballistic, PNF) for three different muscle groups (shoulder, trunk, hamstring) on the flexibility of college males. Special consideration will be given to the consistency of individual differences in flexibility scores.

Theoretical Predictions

1. All three flexibility training groups will improve in flexibility. Some of the elastic structures providing the resistance to stretch will adapt by allowing an increased range of motion.

2. The group using the proprioceptive neuromuscular facilitation method of stretching will increase more than either the static or ballistic group. PNF diminishes muscular inhibition to stretch allowing greater acute gains in

flexibility and thus a greater long-term increase in range of motion.

3. Some muscle groups will improve in flexibility to a greater degree than others. Flexibility and flexibility training are highly specific in the human body. Different muscle groups act independently to similar stretching programs.

Assumptions

1. Flexibility can be improved over a period of time with a proper stretching program.

2. The Leighton Flexometer gives a valid measure of joint flexibility.

Delimitations

Sixty-five male volunteer college students from the University of Nebraska at Omaha served as subjects. No individual was allowed to participate if he already followed a specific stretching routine using the shoulder, trunk or hamstring muscle groups. No active weight lifters were allowed to participate.

CHAPTER II

METHODS

Subjects

Sixty-five male volunteer college students from the University of Nebraska at Omaha served as subjects. Any individual who followed a specific stretching routine of the same muscle groups that the study examined was not allowed to participate. Also no active weight lifters were allowed to participate. Subjects were free to withdraw from the study at any time and complete anonymity was insured.

Sample Size:

The sample size was reasonably sensitive enough to detect a false null hypothesis. According to Cohen (6), three factors should be considered in sample size estimation: 1) level of significance; 2) the effect size, that is, the difference between values of importance or practical significance to the investigator, and; 3) the power of the statistical analysis.

The level of significance was set at p = .05. The effect size may be determined from previous studies or estimated to be of practical importance. In consideration of the typical 6-12% increase in flexibility through training and an increase or practical importance, a 10% increase for men of college age is taken as the effect size. A sample size of at least ten for each group results in a power of .95 (Cohen (6), table 8.44), clearly acceptable for scientific investigation. Subjects who missed more than one exercise session were dropped from the study. The final sample size was 43 (Control n = 10, Static n = 10, Ballistic n = 11, PNF n = 12).

Measurements

All subjects were pre- and post-tested in their shoulder, hamstring, and trunk flexibility. A gravity-operated Leighton Flexometer (10) was the measuring device. The Leighton Flexometer consists of a round case with a 360° dial. The flexometer is strapped to the body segment being tested and records the number of degrees that the body segment travels in its range of motion. Baseline measures and reliability of flexibility scores were determined by measuring three trials on two separate days for each muscle group of each subject. All measurements pre- and post-training were taken at approximately the same time of day. The muscle groups include the following:

1. Shoulder (Figure 1) - The subject stood with his back to a wall next to a projecting corner. The right shoulder protruded just past the corner allowing the right arm to move freely in a sagittal plane. A Leighton Flexometer was strapped to the lateral side of the right arm. The arm was then flexed at the shoulder joint as far as possible. The palm of the hand was flat against the wall and

elbow kept in the same plane not to allow any abduction to take place. The flexometer was zeroed and the dial locked. The arm was brought downward in an arc and extended behind the body with the palm of the right hand sliding against the wall. When the subject had extended as far as possible the pointer was locked and the reading taken. To insure an accurate reading, the subject's heels, buttocks, shoulder blades and head were kept in contact with the wall during the entire movement.

2. Hamstring (Figure 2) - The subject was in the supine position on a table. It was important that neither the feet nor head extend beyond the length of the table. A Leighton Flexometer was strapped to the lateral side of the right thigh. Both legs remained straight throughout the measurement. The dial was zeroed and locked with the subject resting on the table. The right lower extremity then was flexed as high as possible while the left thigh remained completely in contact with the table. At full flexion the pointer was locked and the reading taken.

3. Trunk (Figure 3) - The subject was in the supine position on a table with his arms positioned above his head. It was important that neither the feet nor head extend beyond the length of the table. A Leighton Flexometer was strapped to the right side of the chest at nipple level. Both knees remained extended with the lower extremities in complete contact with the table during the measurement. The flexometer was zeroed and the dial locked with the subject

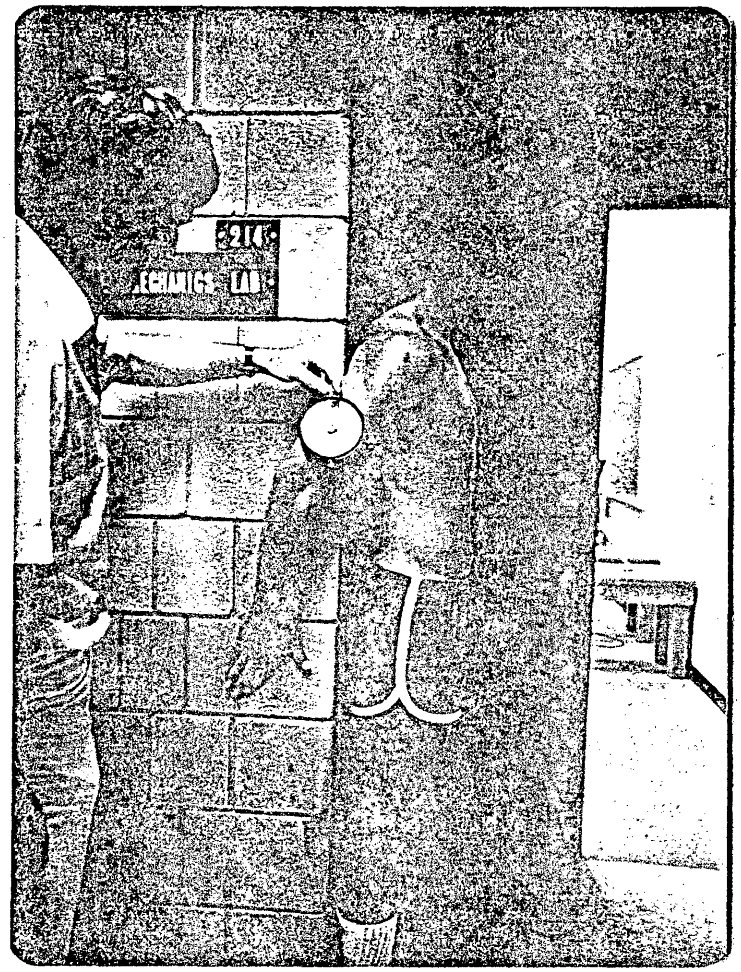

Figure 1. Shoulder Flexibility Measurement with Leighton Flexometer

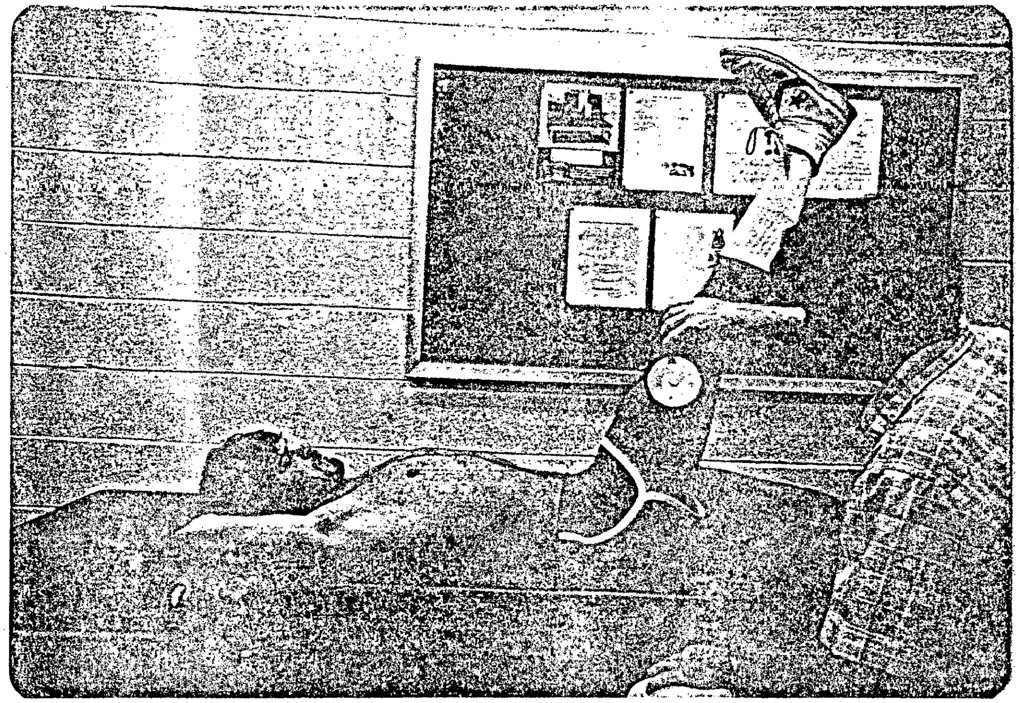

Figure 2. Hamstring Flexibility Measurement with Leighton Flexometer

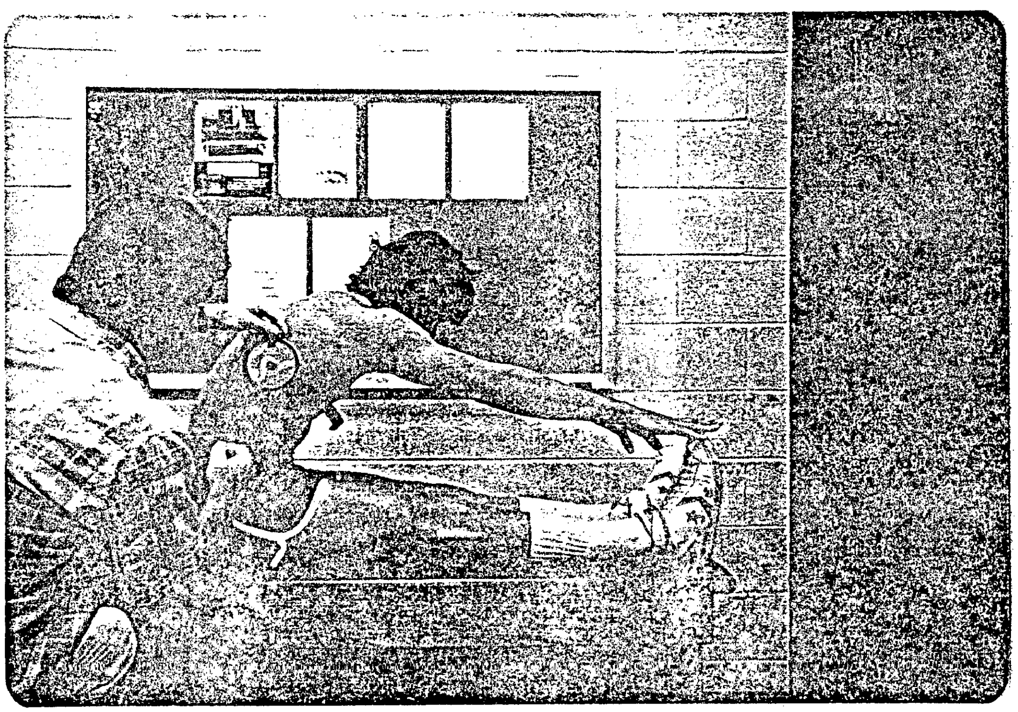

Figure 3. Trunk Flexibility Measurement with Leighton Flexometer

resting on the table. The trunk then was flexed as far as possible. At full flexion the pointer was locked and the reading taken.

Flexibility Training

Each subject was randomly selected into one of four stretching groups: 1) Ballistic (B); 2) Static (S); 3) Proprioceptive Neuromuscular Facilitation (PNF) and; 4) Control (C) group. All the training groups performed stretching exercises specifically geared toward increasing flexibility of the shoulder, trunk and hamstrings.

The following instructions were given to the three different stretching groups:

Ballistic: Repeat each motion rapidly for twenty repetitions.

> Shoulder (Figure 4) - Start in a standing position and swing the right arm forward and upward (in the same plane) as high as possible and then swing downward and behind the body as far as possible.
>
> Hamstring (Figure 5) - Lie on back and swing right leg upward as high as possible and return to floor.
>
> Trunk (Figure 6) - Start from a sitting position and bounce trunk forward as far as possible reaching with both arms.
>
> Return to starting position.

Static: Slowly stretch to the limits of motion and hold for six seconds. Relax, then repeat two more times.

> Shoulder (Figure 7) - Lie on stomach with arms extended above head. Raise right arm as high as possible and hold. Remaining on stomach and with arms straight next to sides, raise right arm as high as possible and hold.

Figure 4. Shoulder Ballistic Stretching

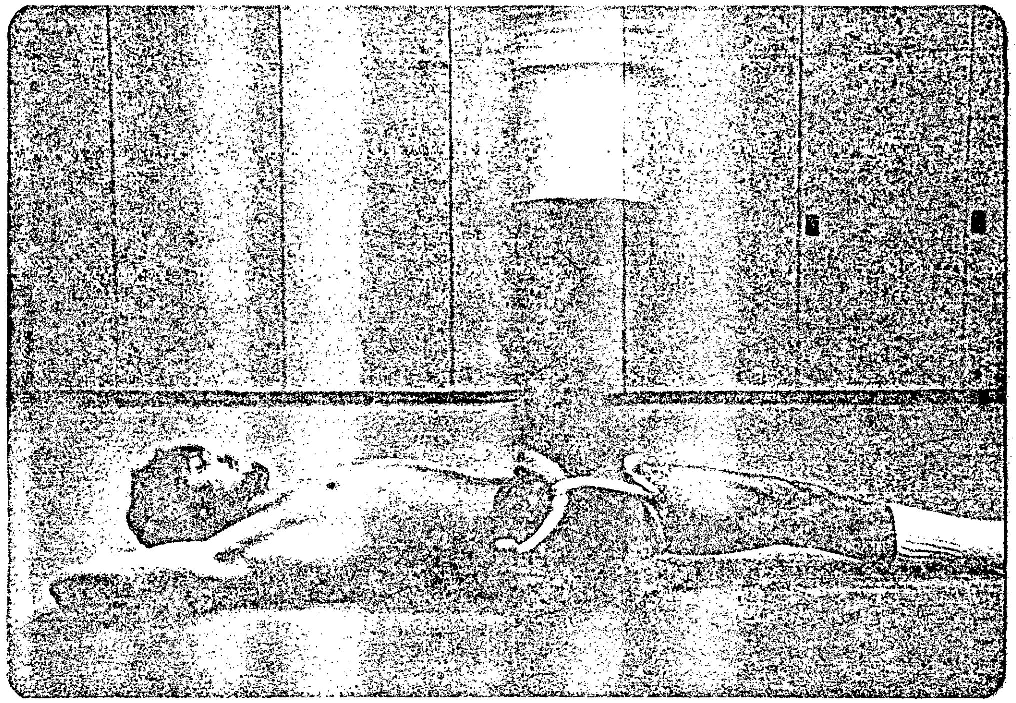

Figure 5. Hamstring Ballistic Stretching

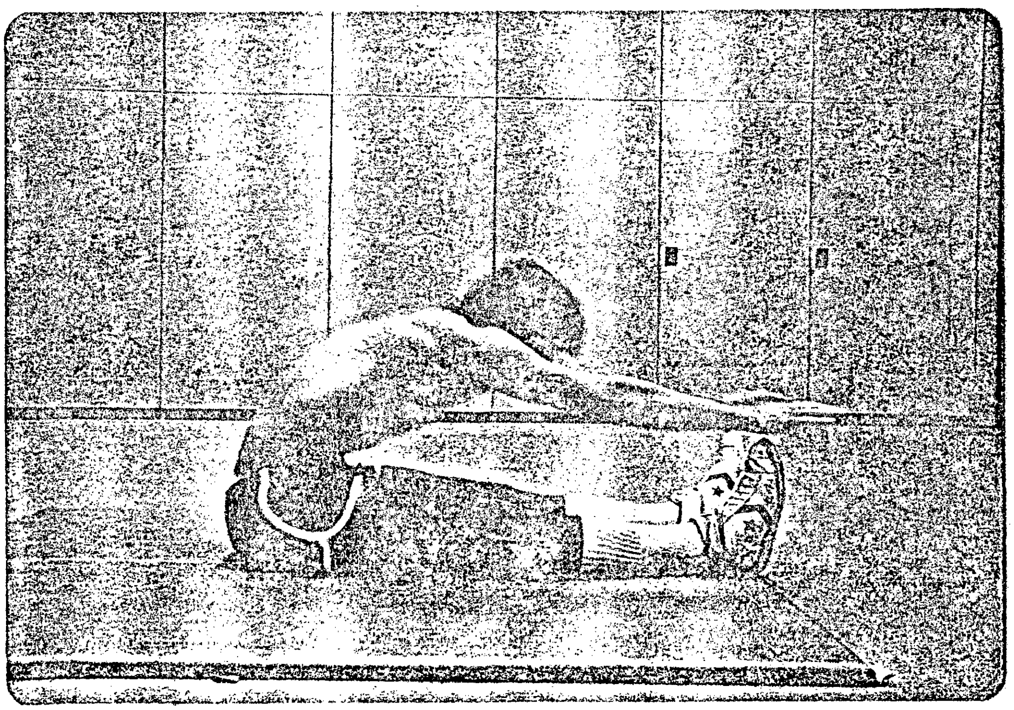

Figure 6. Trunk Ballistic Stretching

Hamstring (Figure 8) - Lie on back and raise right leg as high as possible and hold.

Trunk (Figure 9) - In a sitting position with legs straight bend trunk forward as far as possible reaching with hands and hold.

PNF: There are three steps to any PNF stretch: 1) Slowly stretch to the limits of motion; 2) Have partner support or restrain you as you exert an isometric contraction in the opposite direction for six seconds; 3) Relax and stretch further. Repeat this sequence two more times with partner repositioning to act as a support or restrainer.

Shoulder (Figure 10) - On stomach with arms above head raise right arm as high as possible. A partner will hold forearm in that position while you attempt to pull it back to the floor. Next while on stomach and arms straight next to sides attempt to raise right arm as high as possible. A partner will hold forearm in that position while you attempt to pull it back to the floor.

Hamstring (Figure 11) - Lie on back and raise right leg as high as possible. A partner will hold leg in that position while you attempt to pull it back to the floor.

Trunk (Figure 12) - From a sitting position with the legs straight bend forward as far as possible and reach with your hands. A partner will hold your back in that position while you attempt to straighten your trunk for six seconds.

Control: Just pre- and post-measurements were taken for this group.

Each subject stretched at approximately the same time of day in the Biomechanics Laboratory of the School of Health, Physical Education and Recreation. The investigator supervised the stretching to assure that directions were followed.

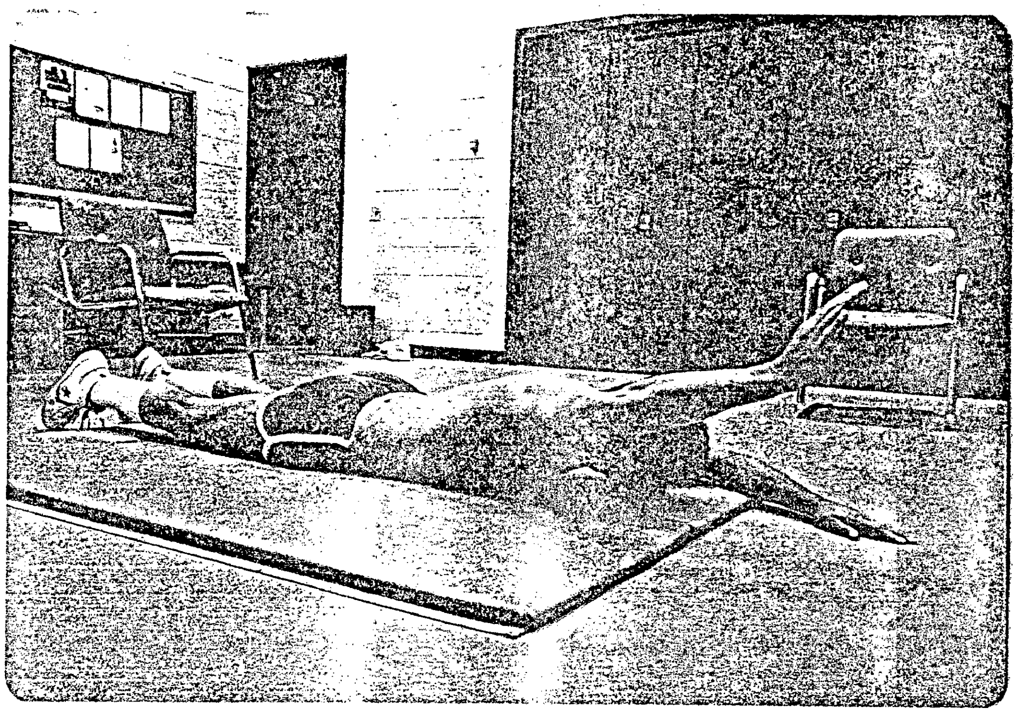

Figure 7. Shoulder Static Stretching

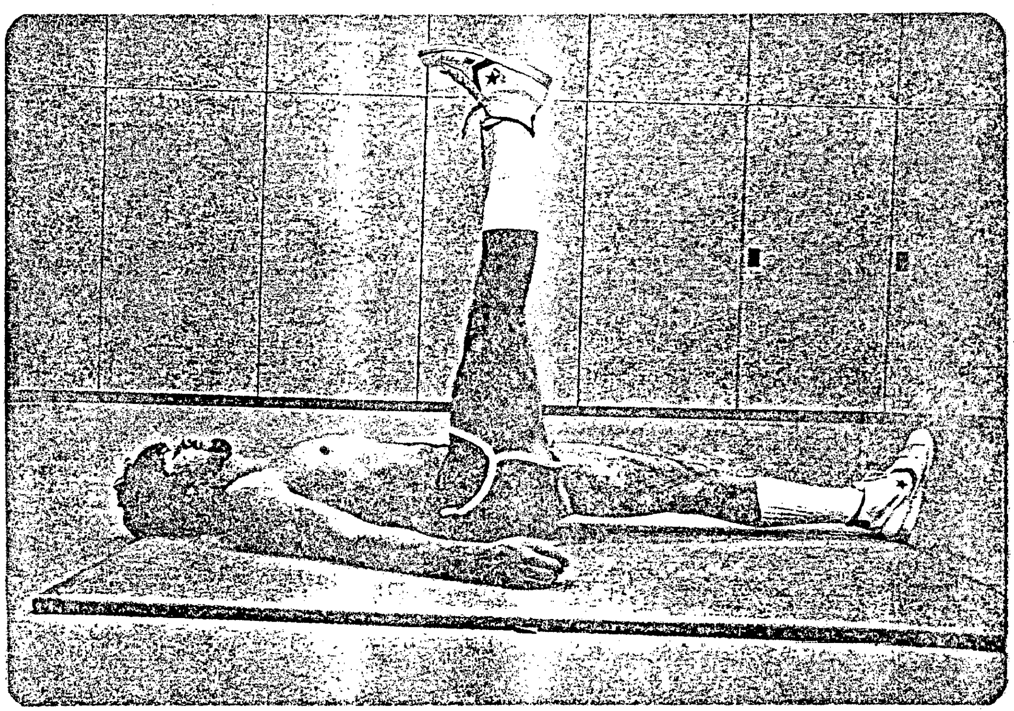

Figure 8. Hamstring Static Stretching

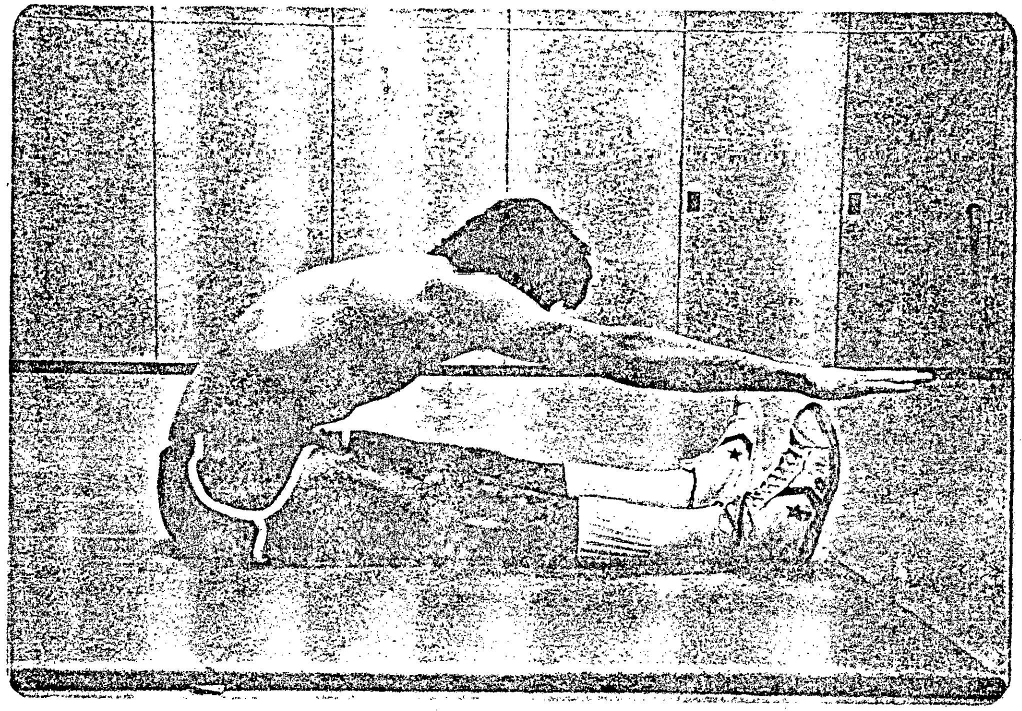

Figure 9. Trunk Static Stretching

Figure 10. Shoulder PNF Stretch - Partner Provides Support

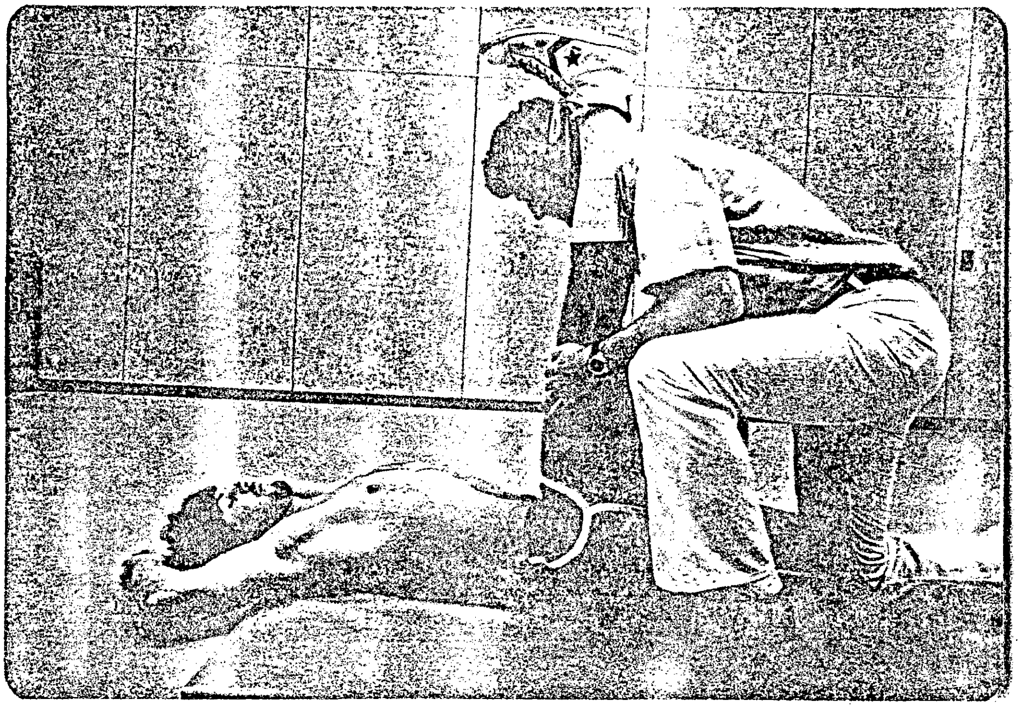

Figure 11. Hamstring PNF Stretch - Partner Provides Support

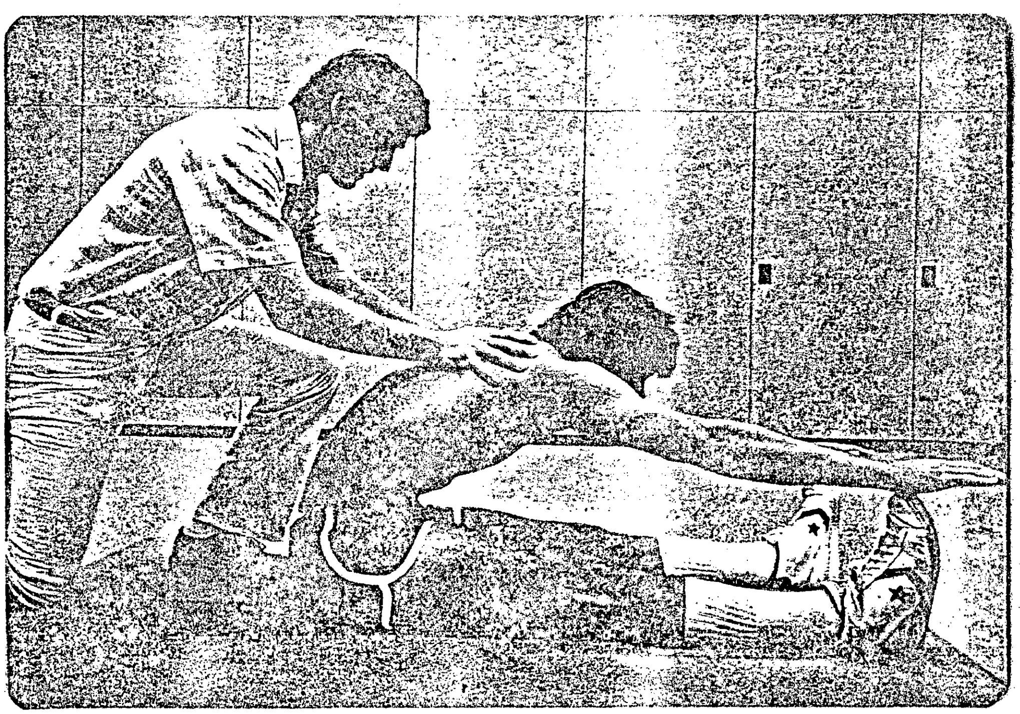

Figure 12. Trunk PNF Stretch - Partner Provides Support

the exercises for the experiment groups took approximately ten minutes to do and were done three days per week for six consecutive weeks.

Statistical Analysis

The reliability of flexibility scores for pre- and post-training was determined by the intraclass correlation using analysis of variance (ANOVA) techniques (32). A 4 X 3 (FlexGroup X Muscle) factorial analysis of variance on the difference scores (post - pre) was used to ascertain differences among flexibility groups and muscle groups. The difference scores were obtained by first averaging the six trials on the two separate days for pre- and post-training. Then each individuals' average pre-training score was subtracted from his average post-training score. Post-hoc tests were preformed according to Tukey "a" procedure (51). Statistical significance was taken at the .05 level throughout.

Summary of Procedures:

	Pre-test	Training	Post-test
Type:	Flexibility Measurements	Stretching	Flexibility Measurements
Time:	2 Days (Baseline)	6 Weeks (3 Days/Week)	2 Days (Baseline)

CHAPTER III

RESULTS

Descriptive characteristics of the 43 subjects are seen in Table 1. As can be seen these values are in the "normal" range for college males commonly used in flexibility studies (3, 5, 7, 10, 48).

Tables 2 and 3 give the reliability for pre- and post-measurements. As can be seen all coefficients are high, ranging from r = .83 for the hamstrings pre-training to r = .95 for the trunk post-training. In general reliability is higher for the post-training scores. Also the variability among trials ($\alpha^2 e_1$) and between days ($\alpha^2 e_2$) is somewhat lower for the post-training scores.

The flexibility socres for each day pre- and post-training for the shoulder, trunk, and hamstrings are presented in Tables 4, 5 and 6 respectively. As can be seen the mean difference between days (Day 2 score minus Day 1 score) pre-training for each muscle group is statistically significant ($p < .05$). However, the hamstrings are the only muscle group that showed an increase while the trunk and shoulder muscle groups both revealed a decrease in flexibility. There are no statistical differences between days for any muscle group on the post-test.

The differences in flexibility scores (post-training avearage minus pre-training average) for the three muscle groups are presented in Tables 7, 8 and 9. The absolute scores and percent changes for each muscle group are depicted in Figures 13, 14 and 15. The 4 X 3 (FlexGroup X Muscle) factorial analysis for these difference scores revealed both main effects to be significant ($p < .05$) (Table 10). However, there was no significant interaction between the flexgroup and the muscle groups.

Further analysis of the significant main effects was done using Tukey's "a" post-hoc procedure. As can be seen in Figure 16 the only difference among the flexibility groups occurred between the PNF (10.6° increase) group and the control group (3.4° increase). For the muscle groups only the hamstrings (9.4° increase) is different from the trunk (5.2° increase).

Table 1. Descriptive Characteristics of Subjects

	Total (n = 43)		Control (n = 10)		Ballistic (n = 11)		Static (n = 10)		PNF (n = 12)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Age, yrs	22.9	3.32	21.6	1.92	22.9	3.60	23.5	2.87	23.3	4.32
Height, cm	178.1	6.74	181.4	6.07	177.5	6.01	179.0	4.47	175.3	8.65
Weight, Kg	74.4	9.83	73.3	10.29	74.3	5.79	78.8	12.96	71.8	9.40

Table 2. Variance Estimates for Intraclass Correlation Reliability Analysis on Pre-Training Scores

Component	MUSCLE GROUP Shoulder (n = 43)	Trunk (n = 43)	Hamstrings (n = 43)
MS Subjects	851.89	589.52	823.23
MS Days Within Subjects	123.85	34.70	139.35
MS Within Cells (trials)	13.90	8.20	4.99
$\alpha^2 e_1$ trials	13.90	8.20	4.99
$\alpha^2 e_2$ days	36.65	8.83	44.79
$\alpha^2 t$ true	121.34	92.47	113.98
R	.85	.94	.83

Table 3. Variance Estimates for Intraclass Correlation Reliability Analysis on Post-Training Scores

Component	MUSCLE GROUP Shoulder (n = 43)	Trunk (n = 43)	Hamstrings (n = 43)
MS Subjects	763.41	533.95	581.74
MS Days Within Subjects	49.26	26.04	50.31
MS Within Cells (trials)	9.83	5.35	4.09
$\sigma^2 e_1$ trials	9.83	5.35	4.09
$\sigma^2 e_2$ days	13.14	6.90	15.46
σ^2 e t true	119.03	84.65	88.57
R	.94	.95	.91

Table 4. Shoulder Flexibility Scores for Each Day Pre- and Post-Training (Degrees)

Pre	Day 1 Mean	Day 1 SD	Day 2 Mean	Day 2 SD	Mean Dif.
Total	206	12.6	203	12.8	-3*
Control	212	11.5	209	7.3	-3
Ballistic	204	10.4	202	15.3	-2
Static	202	16.2	198	12.7	-4
PNF	206	11.7	202	13.0	-4

Post	Day 1 Mean	Day 1 SD	Day 2 Mean	Day 2 SD	Mean Dif.
Total	211	11.7	212	11.6	+1
Control	213	11.1	216	10.7	+3
Ballistic	208	12.9	211	11.7	+3
Static	211	9.8	208	11.1	-3
PNF	214	12.9	213	13.0	-1

*$p < .05$ between days for total group

Table 5. Trunk Flexibility Scores for Each Day Pre- and Post-Training (Degrees)

Pre	Day 1 Mean	Day 1 SD	Day 2 Mean	Day 2 SD	Mean Dif.
Total	149	9.7	147	10.5	-2*
Control	151	8.2	149	6.6	-2
Ballistic	146	6.7	145	6.6	-1
Static	149	7.2	147	7.9	-2
PNF	150	14.4	148	17.0	-2

Post	Day 1 Mean	Day 1 SD	Day 2 Mean	Day 2 SD	Mean Dif.
Total	154	9.3	153	10.1	-1
Control	153	4.9	151	8.3	-2
Ballistic	151	7.7	150	8.3	-1
Static	153	10.0	153	9.3	0
PNF	157	12.4	157	13.1	0

*$p < .05$ between days for total groups

Table 6. Hamstring Flexibility Scores for Each Day Pre- and Post-Training (Degrees)

Pre	Day 1 Mean	Day 1 SD	Day 2 Mean	Day 2 SD	Mean Dif.
Total	79	13.1	84	11.7	+5*
Control	84	14.4	88	9.3	+4
Ballistic	79	10.5	85	11.1	+6
Static	76	17.4	82	14.0	+6
PNF	79	10.6	83	12.6	+4

Post	Day 1 Mean	Day 1 SD	Day 2 Mean	Day 2 SD	Mean Dif.
Total	90	10.3	92	10.2	+2
Control	90	13.7	91	10.6	+1
Ballistic	90	7.1	92	5.2	+2
Static	88	11.2	86	12.7	-2
PNF	94	9.1	98	8.9	+4

*$p < .05$ between days for total groups

Table 7. Shoulder Flexibility Difference Scores for the Various Groups (Post-Pre)

	Min	Max	Mean	SD
Total	-11	29	7	8.5
Control	-11	22	4	8.0
Ballistic	- 4	22	7	6.9
Static	- 6	29	10	12.1
PNF	- 2	22	9	6.7

Table 8. Trunk Flexibility Difference Scores for the Various Groups (Post-Pre)

	Min	Max	Mean	SD
Total	- 7	18	5	5.0
Control	- 7	7	2	4.4
Ballistic	- 3	16	5	5.7
Static	0	12	5	3.8
PNF	1	18	8	4.8

Table 9. Hamstring Flexibility Difference Scores for the Various Groups (Post-Pre)

	Min	Max	Mean	SD
Total	- 8	32	9	8.0
Control	- 5	10	4	4.8
Ballistic	- 8	19	9	8.0
Static	0	22	8	7.3
PNF	4	32	15	7.6

Table 10. Summary of Analysis of Variance

Source	df	m.s.	F
Between Subjects			
FlexGroup	3	284.62	4.09*
Subjects within FlexGroup	39	69.63	
Within Subjects			
Muscle	2	180.07	4.72*
FlexGroup X Muscle	6	33.22	ns
Muscle X Subjects within FlexGroup	78	38.12	

*$p < .05$

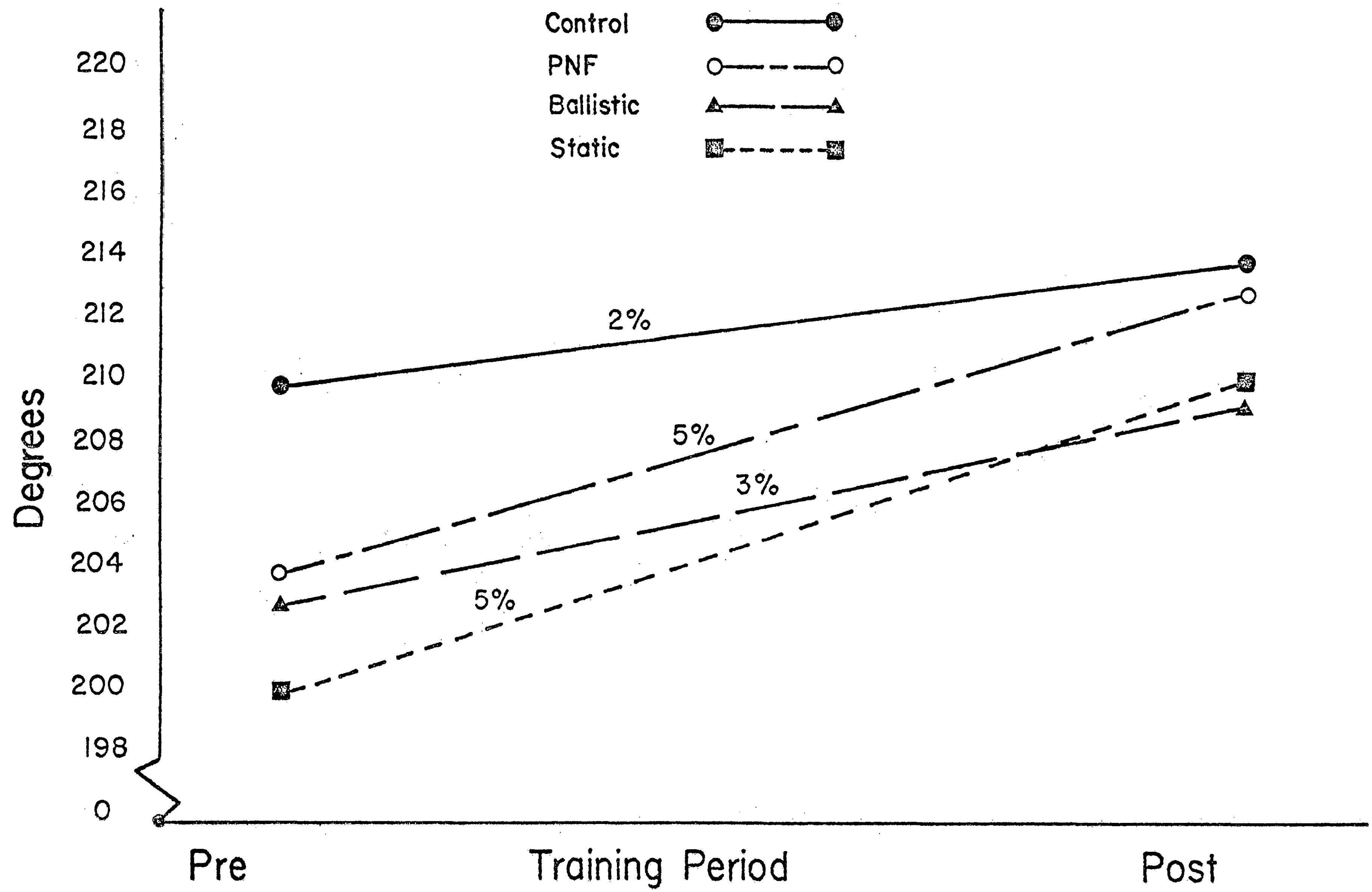

Figure 13. Shoulder flexibility scores for each group pre- and post-training. Percent change is indicated.

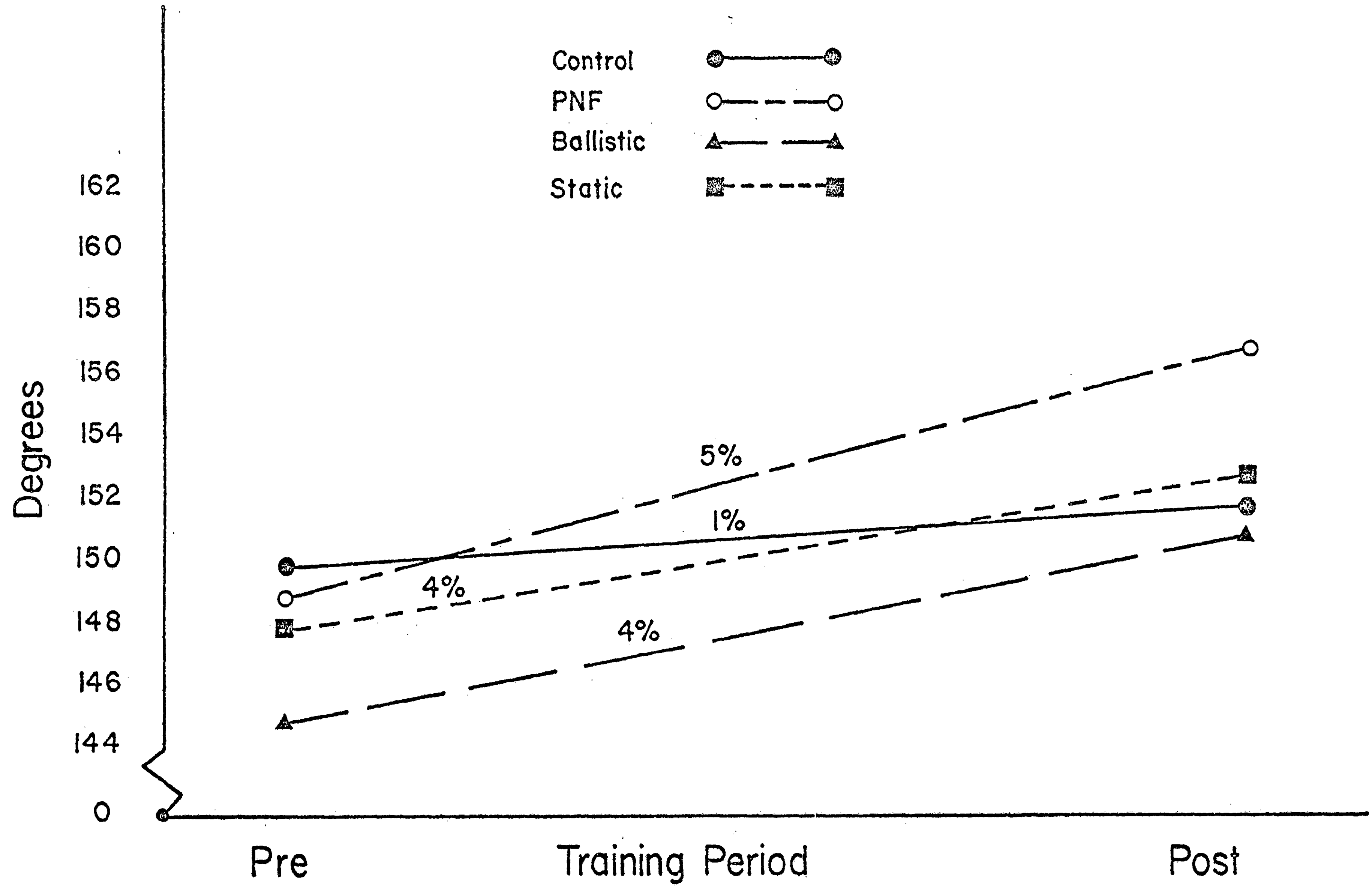

Figure 14. Trunk flexibility scores for each group pre- and post-training. Percent change is indicated.

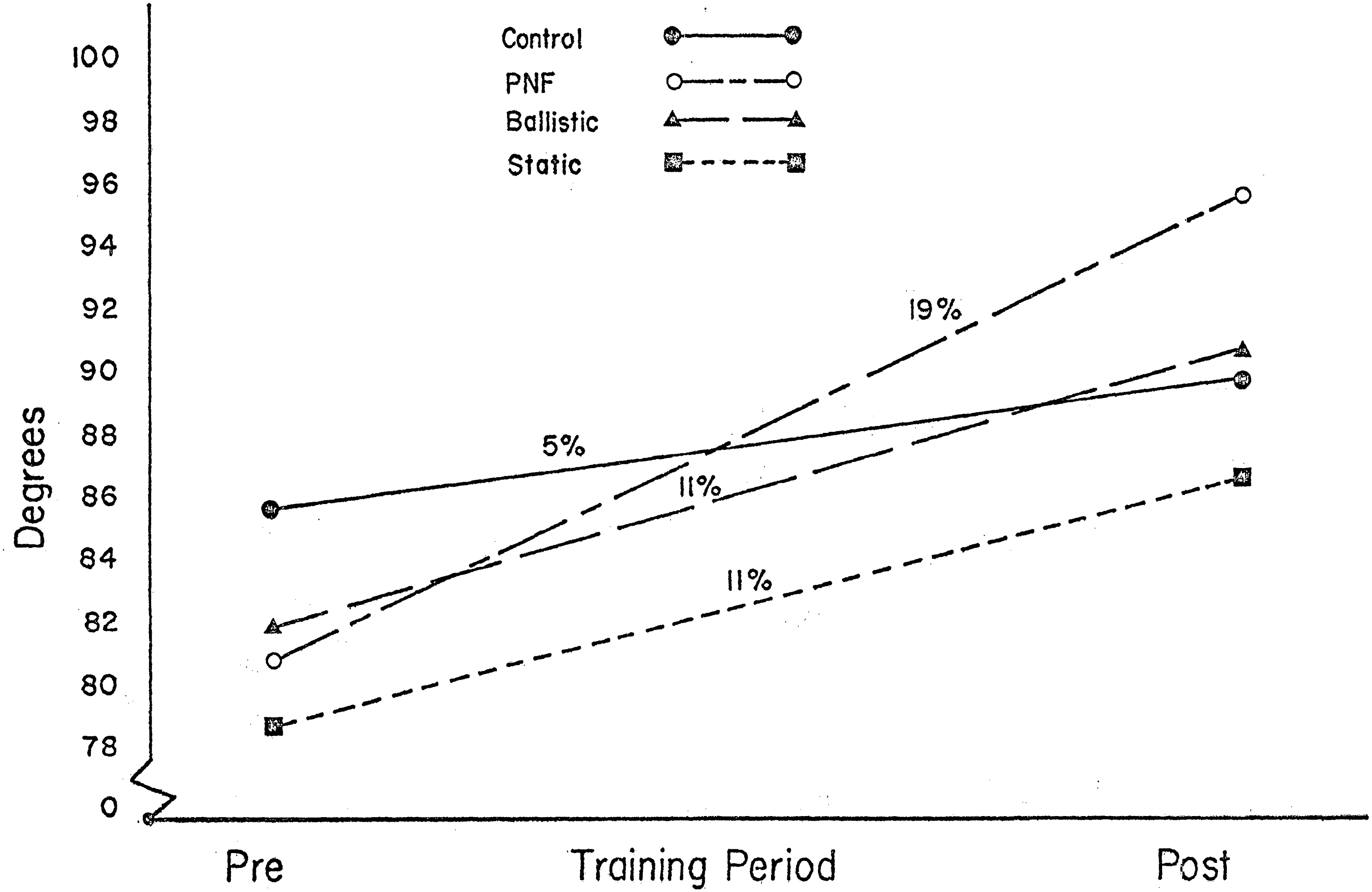

Figure 15. Hamstring flexibility scores for each group pre- and post-training. Percent change is indicated.

Figure 16. Tukey "a" Post-Hoc procedure comparing difference scores (post-pre) among flexibility groups (q = 5.57, .05 level, 39 df) and muscle groups (q = 3.19, .05 level, 78 df).

Flexibility Groups

Control	Ballistic	Static	PNF
3.4	7.0	7.8	10.6

Muscle Groups

Trunk	Shoulder	Hamstring
5.2	7.4	9.4

CHAPTER IV

DISCUSSION

A major finding of the present study is the superiority of PNF stretching. Although there were no significant differences among static, ballistic and PNF groups, only PNF significantly increased flexibility (Figure 16). This occurred despite equating the duration of stretching exercises for all groups. Holt, Travis and Okita (20), and Tanigawa (46) also found the PNF technique to be best. Other studies, however, indicate that while PNF may increase flexibility it is not necessarily better than other methods (5, 17, 41, 47).

There are a number of possible reasons for this discrepancy. Not all studies have used a control group with which to compare treatments. Without adequate control there is no way to ascertain whether the changes observed are due to real changes or are part of biological and/or experimental variability. Additionally no attempt was made to determine normal day-to-day variability in flexibility by means of baseline data. Furthermore, the instrument employed and the exercise prescription, that is, the sets, reps, duration of stretch, and frequency of training varied from study to study. Lastly, the training stimulus was not always equal among groups.

The importance of establishing baseline data for flexibility is evident from the present study. Although high reliability was obtained for the pre-training scores (r = .83 to r = .94), there was a significant day effect for each muscle group (Tables 4, 5, 6). Both shoulder and trunk decreased in flexibility on day two while hamstring increased. Also there was considerable within trial variability (Table 2). Ninety-five percent of the time a subject's flexibility score is expected to vary from trial to trial approximately $\pm$ 7° for the shoulder, $\pm$ 6° for the trunk, and $\pm$ 5° for the hamstrings. Apparently, there is a "reactive effect" to stretching the structures which limit the extent of range of motion. That is, a short-term adaptive response occurs in the joint capsule and/or associated connective tissue and/or muscles (19).

One may speculate why the PNF method is most successful for increasing flexibility. The PNF technique elicits a greater acute stretch from a muscle group during exercise than other techniques (7, 20). This neurologically-based mechanism apparently results in an enhanced training stimulus. That is, one obtains greater increases in flexibility with greater stretching during each exercise session. Although the length of time, sets, and reps were similar for all groups, the acute stretch was probably greater for PNF. These results are in contrast to statements of Falls et al. (14). They believe that since it is likely the primary resistance to flexibility is not in the contractile elements of the muscle, programs using reciprocal innervation and tendon reflexes probably add little to the effect of static stretching exercises. However they fail to consider that whatever the primary resistance to flexibility, it is overcome during a PNF stretch resulting in a greater range of motion.

Another major finding of the present investigation is the enhanced training of the hamstring compared to trunk muscles (Figure 18). An explanation may be sought in the initial level of flexibility for these muscle groups. Flexibility is highly specific in the body (18). It is possible that an individual's daily body mechanics restricts the range of motion of the hamstrings compared to the trunk. The hamstrings are not near full flexion while walking or jogging while the trunk is flexed to a great degree for sitting and lifting activities. Therefore greater room for improvement is available for the hamstrings.

Of further interest is the higher reliability of flexibility scores for the shoulders and hamstrings for post-training compared to pre-training (Tables 2 and 3). Additionally, there were no significant day effects and the within-trial variability was somewhat less following training. These data suggest a training effect of increased consistency of flexibility scores. This information suggests that a "learning" process of the neural circuits takes place resulting in greater consistency.

CHAPTER V

SUMMARY/CONCLUSIONS/IMPLICATIONS

Summary

It was the purpose of this study to compare the effects of three stretching techniques on the flexibility of the shoulder, trunk and hamstring muscles. The subjects were 43 male volunteers attending the University of Nebraska at Omaha. Subjects were randomly placed into either a control group (n = 10), ballistic group (n = 11), static group (n = 10) or a proprioceptive neuromuscular facilitation group (n = 12). Baseline measurements were obtained by taking all measurements on two separate days prior to and following the six week training session. All measurements were taken with a Leighton Flexometer. The subjects reported three days per week for six consecutive weeks. The duration of stretching exercise was equal for each of the flexibility groups.

A 4 X 3 unweighted mean factorial analysis of variance was used to ascertain differences among flexibility groups and muscle types. There were significant ($p < .05$) main effects for both flexibility groups and muscle types. Post-hoc analysis indicated that the PNF method was the only technique significantly better than the control, and the hamstring muscles improved significantly better than the trunk muscles.

Additionally, a greater consistency of flexibility scores is observed following training.

Conclusions

The following conclusions can be justified by the findings of this investigation:

1. Proprioceptive neuromuscular facilitation (PNF) is the best method for increasing flexibility. This is evidenced by the fact that of the three stretching techniques employed (static, ballistic, PNF), the PNF was the only method to significantly increase flexibility.

2. Increases in flexibility are easier to obtain in the hamstrings than in the trunk. Results indicated that a significant difference exists between these two muscle groups.

3. Training results in a greater consistency of flexibility scores. Generally, the reliability coefficients are higher for post-training versus pre-training scores. Moreover, a significant day effect occurred only for the pre-training scores.

Implications

The results of this study have direct application to athletics, rehabilitation, medicine and physical education. The PNF technique could be integrated into any training, personal exercise or rehabilitation situation. Increases in flexibility will occur with relatively little time involvement (a total of only 54 seconds of stretching per week!!).

However, it is not known which combination or reps, sets, duration and frequency of stretching will result in the maximal gains of flexibility. Further studies need to be conducted comparing various permutations of reps, sets, durations and frequency for all stretching techniques. The importance of such investigation can be seen in light of the many time constraints in practice/training of various sports teams and individual exercise and rehabilitation programs.

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