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EFFECTS OF DIFFERENT TRAINING METHODS ON FLEXIBILITY

BY

© ANDREW ALLAN TURNER

A THESIS

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DEDICATION

To my wife, my mother, and my father,
for all their assistance, support,
and love during my years as a student.

ABSTRACT

The purpose of this study was to investigate the effects of six different standardized stretch training methods on active flexibility for shoulder extension and ankle plantar flexion. The different training methods were: 1) 3S (concentric, isometric and concentric contractions with external force), 2) 2S (passive extension), 3) SS (concentric and isometric contractions), 4) ES (eccentric contraction and passive extension), 5) BS (concentric contraction), and 6) CS (concentric, isometric and concentric contractions). Forty-two female volunteer students ranging in age from 12 to 14 years were selected as subjects. They were tested at the beginning of the study (pre-test), after two weeks, four weeks, and six weeks (post-test), and after the two week retention period. The modified Leighton Flexometer was utilized to test active range of motion for the ankle and shoulder joints.

Data was analyzed using two three-way analyses of variance (Greenhouse-Geisser test on repeated measures) and post-hoc Scheffé test ($\alpha = 0.05$). Analysis of data on ankle joints revealed that 3S, 2S, ES, and CS training method increased within-session flexibility when compared to the control ($p < 0.05$). In addition, 3S training was superior to CS training in relation to within-session gains ($p < 0.05$). The data on shoulder joints showed that only the 3S training method increased within-session flexibility when compared to the control group. Also, the 3S training method was

the only one which consistently increased range of motion on both the ankle and shoulder joints for within-session training.

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STATEMENT OF THE PROBLEM

Introduction

Flexibility is defined as "the range of possible movement in a joint (as in the hip joint) or series of joints (as when the spinal column is involved)" (de Vries, 1976, p. 432). This range of motion can further be divided into two phases - the active and the passive. The former refers to the range of motion produced by a voluntary contraction of the muscles, and the latter to the range of motion produced by use of force from outside the joint (e.g., force from a partner) (Hartley, 1976). The distinction is illustrated in Figure 1, which shows Subject A demonstrating active flexibility and in Figure 2, Subject B demonstrating passive flexibility for shoulder joint extension.

Consequently, flexibility can be defined as the degree to which a joint(s) is free to move through its range of motion.

The importance of flexibility was stated by Hartley (1976), listing six aspects of physical activity where flexibility plays a crucial role in enhancing:

1) Injury prevention,
2) Shock absorption,
3) Balance and agility,
4) Aesthetic impression,

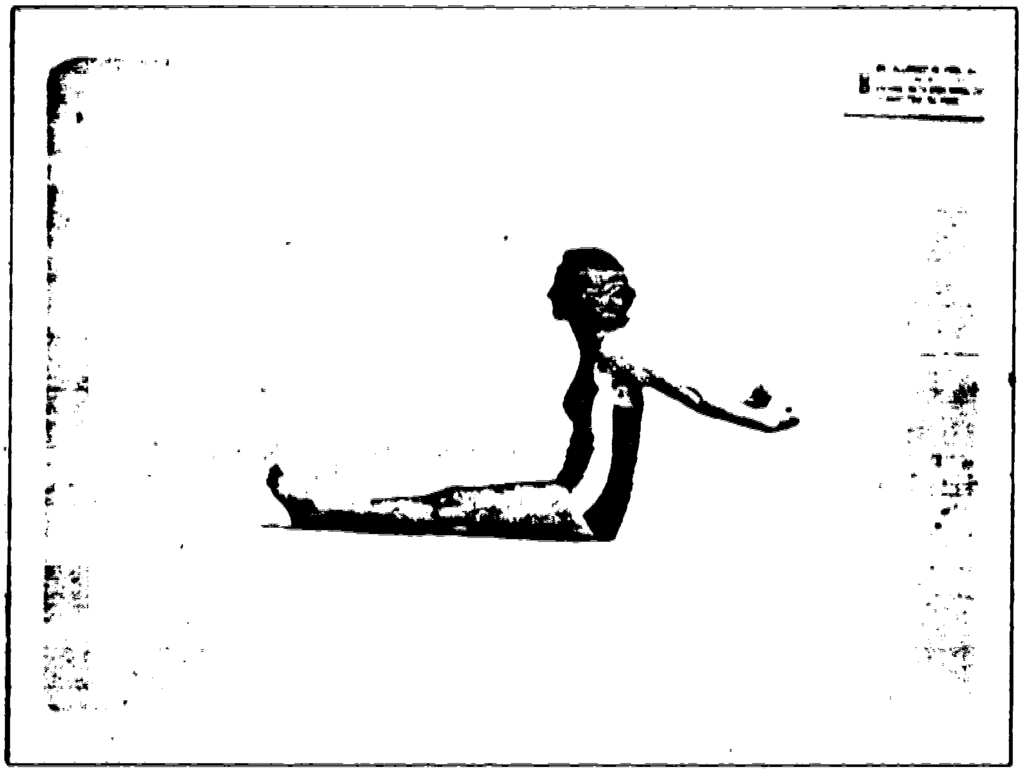

Figure 1. Subject A: Active Flexibility

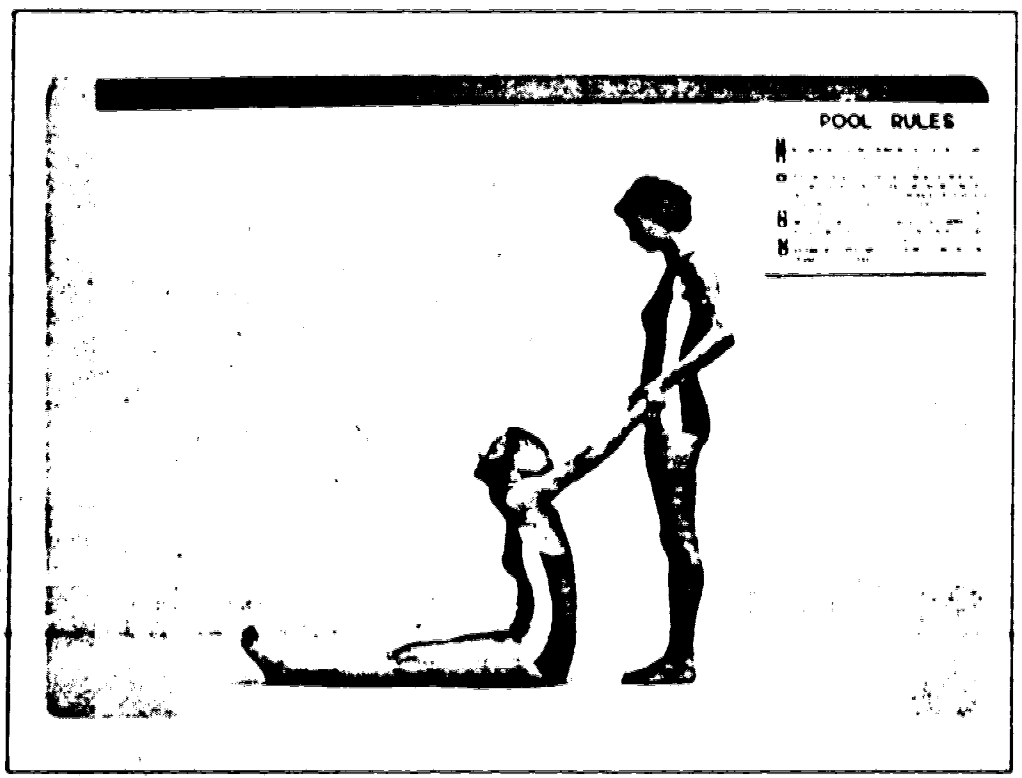

Figure [illegible]ubject B: Passive Flexibility

5) Performance efficiency, and

6) Joint amplitude.

Flexibility has been acknowledged only recently by both the practitioner and researcher to be a centrally important human performance variable (Corbin and Noble, 1980). Schultz (1979) stated that flexibility, for years the overlooked sibling of strength, endurance, and speed, has come to be appreciated for its own virtues. Jesse (1979) drew attention to the misuse of strength training with regards to the loss of specific joint flexibility (e.g., ankle flexibility). A few years earlier, Cooper and Fair (1977) called for stretching exercises to be brought out from under the piles of weight-lifting machine literature, taught properly, and implemented into every athlete's year-round training program.

From a coaching perspective, Hogg (1977) in a comprehensive review of the literature on flexibility training concluded:

> In the area of flexibility for athletes there are few valuable studies. Comparative research into the best stretching methods has been difficult because of the presence of many uncontrolled variables and the limited availability or normative data (p. 37).

From a researcher's perspective, Schultz (1979) stated that de Vries is recognized as one of the foremost investigators on the nature and effects of flexibility training. He finds it unfortunate there is no large body of evidence from other laboratory and clinical studies to support, or reject, the use of specific stretch training methods (e.g., static stretching). From a therapist's perspective, Cherry (1980) called for research to establish which methods are most effective, development of new techniques and a scientific rationale of the most effective methods.

The review of the literature revealed that there were several popular flexibility training methods, each purporting to cause significant improvements in joint range of motion. Scientific Stretching for Sport (i.e., 3S) required a two second concentric contraction, a six second isometric contraction and a two second concentric contraction, with light force from a partner (Holt, 1973). Static Stretching (i.e., 2S) consisted of a two second passive extension and an eight second held passive extension (de Vries, 1962). Slow Active Stretching (i.e., SS) involved a two second concentric contraction and an eight second isometric contraction (Jacobs, 1976). Eccentric Stretching (i.e., ES) entailed a five second eccentric contraction and a five second passive extension. Ballistic Stretching (i.e., BS) required a one second concentric contraction (McCue, 1952). Contract Relax Stretching (i.e., CS) consisted of a two second concentric contraction, a six second isometric contraction and a two second concentric contraction (Moore and Hutton, 1980) (see Appendix A).

Problem

Based on the above considerations, an investigation was undertaken to establish which stretch training methods were superior in attaining the greatest range of active flexibility, within the session and over training weeks, with the most enduring effects, and across different types of joints.

The purpose of this study was to examine active flexibility for:

A) Treatments

1) 3S (Scientific Stretching for Sports),
2) 2S (Static Stretching),
3) SS (Slow Stretching),
4) ES (Eccentric Stretching),
5) BS (Ballistic Stretching),
6) CS (Contract Relax Stretching),
7) Control (receiving no flexibility training);

B) Session

1) before session training,
2) after session training; and

C) Weeks

1) pre-training (pre-test),
2) two-week training,
3) four-week training,
4) six-week training (post-test),
5) two-week retention,

on shoulder extension and ankle plantar flexion.

Limitations of the Study

The study had the following limitations:

1) Extra-curricular activities were not controlled.
2) Subjects were restricted to right hand dominant, junior high school girls.

3) Subjects with joint impairment were excluded from the study.
4) Subjects received two different treatment conditions, one on the shoulder and one on the ankle.
5) The ankle joint (hinge) and shoulder joint (ball-and-socket) may not account for all the range of motion for ankle plantar flexion and shoulder extension.

Delimitations of the Study

The study had the following delimitations:

1) Subjects were confined to 42 female junior high physical education students, ranging from 12 to 14 years of age.
2) Joints selected, the right shoulder (ball and socket) and the left ankle (hinge), were of the synovial classification.

Definitions of the Study

Scientific Stretch for Sport (3S). This is a method of increasing flexibility whereby an isometric contraction of the muscles to be stretched (muscles in a lengthened position to start) is followed by a concentric contraction of the opposite muscle group, together with light force from a partner (external force), performed in a progressively more strenuous series until the range of movement cannot be increased without severe pain (Holt, 1973, pp. 5-7).

Static Stretch (2S). This is a method of increasing flexibility whereby an external force (i.e., hands pulling the segment) is applied in a progressively more forceful manner, until the range of movement cannot be increased, then held for a period of time, without severe pain (de Vries, 1976, pp. 436-437).

Slow Active Stretch (SS). This is a method of increasing flexibility by slow active concentric contraction of the agonist muscles, without additional assistance from an external force (i.e., hands pulling the segment to a greater range of motion), while relaxing the antagonist muscle group (the muscles to be stretched) (Jacobs, 1976, pp. 151-152).

Eccentric Stretch (ES). This is a method of increasing flexibility whereby a slow active eccentric contraction of the muscles to be stretched (muscles in a contracted position to start) is followed by light force from a partner (external force), while the subject relaxes both agonist and antagonist muscles around the joint.

Ballistic Stretch (BS). This is a method of increasing flexibility whereby particular emphasis is placed on training each individual to make all movements in a relaxed rhythmic manner, and to put special effort toward carrying the movement to the limit of the subject's range of motion (McCue, 1952, p. 322).

Contract Relax Stretch (CS). This is a method of increasing flexibility whereby an isometric contraction of the muscles to be stretched (muscle in a lengthened position to start) is followed by a concentric contraction of the opposite muscle group (Moore and Hutton, 1980, p. 323).

Joint. This is a connection between two or more separate segments or parts of the skeleton. Joints are variously classified, with the official classification based on the material which joins the long parts. Classification of joints are: fibrous joint, cartilaginous joint, and synovial joint, with the latter being chosen for this study. This type of joint, which permits a variable amount of movement, consists of a series of investing ligaments, a true joint cavity, and hyaline cartilage over the articulating surfaces of the bones forming the joint. Synovial joints may be subdivided according to the type of movement: gliding, pivot, hinge, biaxial, and ball-and-socket joints (Francis, 1968). For the purposes of this study two sub-types of joints were chosen; shoulder (ball-and-socket) and ankle (hinge).

Shoulder Joint. This is the proximal ball-and-socket joint of the upper limb which controls the movement of the upper arm (humerus). Three basic movements of the shoulder are:

1) flexion and extension,
2) adduction and abduction, and
3) rotation.

Circumduction is merely a rhythmical combination in orderly sequence of flexion, abduction, extension, and adduction (Last, 1978). The present study termed any change in flexibility in shoulder extension, measured by the modified Leighton Flexometer, as occurring in the shoulder joint.

Ankle Joint. This is the distal hinge joint of the lower limb, which controls the movement of the leg relative to the foot, occurring in a sagittal plane. The ankle joint is not the only active joint when ankle plantar flexion becomes extreme; an increase in range is provided by hollowing of the plantar arches (Adams, 1971). The present study termed any change in flexibility in ankle plantar flexion as measured by the modified Leighton Flexometer as occurring in the ankle joint.

Shoulder Extension. This is the movement of the humerus posteriorly, in a sagittal plane (Last, 1978).

Ankle Plantar Flexion. This is the movement of the dorsum of the foot away from the anterior surface of the leg so that the foot tends to fall into line with the leg. This movement occurs through the sagittal plane (Adams, 1971).

CHAPTER II

REVIEW OF LITERATURE

Flexibility is the degree to which a joint(s) is free to move through its range of motion.

Overview of Flexibility

A review of the literature on flexibility revealed that there were several aspects of flexibility, which included: specificity, age, sex, strength, anthropometry, tests, limitations, somatotypes, activity patterns, warmup, motor performance, injury prevention and muscular soreness. The important area pertaining to the present study, flexibility training, will be discussed in greater detail (Song, 1979; Song and Reid, 1979; and Corbin and Noble, 1980).

Flexibility Training

Flexibility has been studied in connection with the science of sport, physical fitness and physical therapy. The following paragraphs review the literature on the effects of different flexibility training methods.

Moore and Hutton (1980) studied the effects of three different stretch techniques on passive hip flexibility for 23 female gymnasts, 17 to 23 years of age. Static stretch (S) required the subject to passively relax the hip extensors, while a pulley and weight system was applied on the lower extremity in order to stretch the hip extensors. Contract-relax stretch (CR), a modified proprioceptive neuromuscular facilitation (PNF) technique, consisted of a five second maximal isometric hamstring contraction followed immediately by hamstring relaxation; the hip extensors were then stretched by the wall pulley apparatus. The contract-relax with agonist (hip flexors) contraction (CRAC) was identical to the CR procedures, with the adduction of a submaximal voluntary contraction of the agonists (hip flexors), while the pulley apparatus stretched the hamstring muscle group. The hip angles were measured with a goniometer and electrogoniometer. During one session, each subject performed three stretch techniques with three consecutive trials per stretch method. The performance order was a randomized latin square design. Data showed CRAC and S were equally superior in improving passive hip flexion over CR, during a one session test.

Medeiros, Smidt, Burmeister, and Soderberg (1977) studied the effects of different training methods on hip flexibility for 30 normal men ranging in age from 21 to 34 years. Subjects were randomly assigned to a control group (n = 10), passive stretch group (n = 10) and an isometric contraction group (n = 10). The training program consisted of eight treatment days. The passive stretch treatment group performed 20 passive stretches each treatment day at their threshold force, with the subject's right leg a total of six degrees beyond the threshold point. This position was maintained for three seconds before the subject's leg was returned to the point where the threshold force was reached. Fifteen seconds of rest was allowed between each passive stretch. The isometric treatment group performed 20 isometric hip extension contractions each treatment day at the limb position where their threshold force was attained. The isometric contraction was held for six seconds with 15 seconds rest between each contraction. The control group received no exercise treatment. Before the first and after the last contraction or stretch on each treatment day the investigators measured the subject's pelvicfemoral angle at the point where the threshold force was attained. Stabilization was applied to the pelvis and lower left extremity. The data showed both treatments significantly increased the range of passive hip flexion compared to the control group. However, comparisons between the two treatment groups indicated that isometric contraction and passive stretch had similar effects.

Turner (1977) examined the effects of two different flexibility training methods, 3S (Scientific Stretching for Sport) and SS (Slow Active Stretching). 3S is a method of increasing flexibility whereby an isometric contraction of the muscles to be stretched (muscles in a lengthened position to start) is followed by a concentric contraction of the opposite muscle group, together with light pressure from a partner (external force) performed in a progressively more strenuous series until the scope of movement cannot be increased without severe pain. SS is a method of increasing flexibility by slow active concentric contraction of the agonist muscles without additional assistance from an external force [redacted], hands pulling the segments to a greater range of motion), while relaxing the antagonist muscle group (the muscles to be stretched). Warm-up effects, different joint responses, and the standardization of training procedures were controlled. Subjects were 12 schoolgirl basketball players, aged 12 to 14. The research design consited of four replications of a 3 x 3 Graeco-latin square. Subjects were assessed for flexibility at the beginning of a six week flexibility training program, at the conclusion of training, and then after two two-week retention periods. Significant results showed that:

1) flexibility trained methods (3S and SS) improved flexibility.
2) the shoulder joint acquired more flexibility than either the knee joint of the ankle joint.
3) neither flexibility training method was superior to the other.
4) within two weeks of training cessation, both 3S and SS effects were lost to a significant degree when compared to control effects.
5) after four weeks of training cessation, there was no difference between changes of the control and two training groups.
6) there was no difference in loss of flexibility between the shoulder, the knee, and the ankle joints.

Song and Garvie (1976) examined 14 international Canadian freestyle wrestlers, ranging from 17 to 28 years of age. The study consisted of an experimental group (n = 8) and a control group (n = 6). The flexibility program required the subjects to train for five weeks, four sessions per week. The 3S method of training involved the muscle group to be passively extended close to the maximum, then this same muscle group was isometrically contracted, against a fixed resistance, while in the extended position, for 5 to 7 seconds. The muscle group was then relaxed, thus making possible further extension of that particular group. With the antagonists relaxed while extended, further joint extension was allowed. Three exercises were performed on the shoulder, eight on the hip, one on the leg, one on the torso, and one on the combined trunk and hip. This program was undertaken in addition to the athletes' regular workout. Pre-post flexibility tests were taken on: trunk flexion, trunk lateral flexion, hip abduction, shoulder extension, hip extension, trunk extension, hip hyperextension, split pike, hip inward rotation, hip outward rotation, shoulder horizontal abduction and trunk rotation (19 tests). The experimental group showed all test results, except shoulder horizontal abduction, improved significantly. The control group showed 11 of the 19 test results improved significantly. However, between groups, only the left hip extension and split pike were significantly different.

Hartley (1976) investigated the effects of six methods of stretch on the active range of hip flexion for 119 women physical education students, ranging in age from 17 to 31 years. The program ran over a four week period with a total of 11 sessions. All subjects were tested before and after the study as well as before and after exercise on the first day of each week. The treatment conditions were: passive lift and active hold, active PNF, ballistic and hold, relaxation method, passive PNF, and prolonged stretch. Passive lift and active hold required the subject's right leg to be lifted by the partner and taken slowly to the end-point (six seconds). The subject, at the end-point, held this position for the next six seconds by actively contracting the hip flexors. Passive pressure and active holding alternated every six seconds for one minute (five times). Active PNF required the subject to voluntarily lift the right leg as far into flexion as possible in six seconds. The subject, in the next six seconds, eased into a maximum isometric contraction down against the manual resistance of the partner. The subject alternated voluntary lift and maximum isometric extensor contractions so that each exercise occurred five times in one minute. Ballistic and hold required the subject to start at a 45 degree angle with four leg bounces made to flex the hip. On the fourth bounce an active hold was made to stop the leg at the end-point. Each leg bounce took one second, and the "hold" was maintained for six seconds. The whole combination was repeated five times in one minute. The relaxation method required the subject to use prolonged stretching with mental relaxation and mind-set techniques. Passive PNF required the right leg to be taken passively to the end-point in six seconds. Over the next six seconds, the subject eased into a maximum isometric contraction of the extensors against the maximal resistance of the partner. The passive lift and extensor contraction alternated so that each was performed five times in one minute. The prolonged stretch required the right leg to be lifted passively and taken slowly to the end-point. The end position was held passively for one minute just below the pain threshold. The subjects were tested on the Leighton Flexometer for right hip flexibility. The data showed all methods increased flexibility significantly, but no one method was superior.

Tanigawa (1972) studied the effects of PNF hold-relax procedures, and passive mobilization on tight hamstring muscles for 30 normal subjects, ranging from 20 to 48 years of age. Subjects were randomly selected and assigned to a control group, a passive mobilization group, and a hold-relax group. Subjects were selected based on passive straight-leg-raising of less than 70 degrees in the right limb. The test measurement was a mathematical method involving the calculation of the sine of a right-angle triangle. Subjects were seen two days per week for four consecutive weeks with days one to six for attaining flexibility and days six to eight (one week) for retention of flexibility. All subjects were measured before and after treatment sessions. The passive mobilization technique required the stretching force (i.e., normally by the therapist) to be applied independently of any active movement by the subject. The hold-relax technique was used to increase joint range of motion and was based on an isometric contraction of the shortened muscle performed against maximal resistance. The results showed subjects receiving mobilization increased passive flexibility more than control subjects. The hold-relax procedure was superior to the passive mobilization for developing and retaining flexibility. In addition, the hold-relax method increased flexibility at a faster rate than the passive mobilization.

Holt, Travis and Okita (1970) examined the effects of training on the hip extensor and lower back flexibility of 24 male college students. The investigation compared three methods - fast stretch (ballistic), slow stretch, and a modified version of PNF (IA-CA). This method required isometric contraction (5-6 seconds) of the agonist IA, followed by a concentric contraction of the antagonists, CA. Instead of diagonal patterns a simpler, unidimensional approach (movement and exercise in one plane) was adopted. This technique was based on the principles of successive induction, muscle relaxation, and reciprocal innervation. Six groups of four subjects each were formed and each group received all the treatments in different orders to control for treatment order effects. The program consisted of three weeks, three sessions per week. All methods were performed sitting and standing with a 30 second rest interval between positions, with the exception of IA-CA which was performed lying down instead of sitting. Each exercise was performed for 20 seconds, followed by rest for 10 seconds, for a duration of two minutes, with only one technique performed per week. The trunk flexion flexibility test was administered before and after each training session. The test designed by the author measured the distance subjects would reach forward while in a long sitting position. The data revealed the IA-CA method for increasing flexibility yielded significantly higher improvement scores than both fast and slow stretch methods.

Fieldman (1966) examined the effects of selected extensibility exercises on the flexibility of the hip joint on 33 college students. The subjects were tested once a week for five weeks, with the exception of the first week, when tests one and two were performed. Each person was permitted one trial per test with the second test performed immediately after the first, the first serving as a warm-up. The third test was performed after the completion of four exercises and the fourth test was performed after the completion of six exercises. The fifth test followed the completion of eight exercises and the sixth test was performed within pre-exercise. All subjects were tested on a toe-touch test. The analysis showed all differences between tests were significant, with the exception of tests two and six, which showed that exercise improved the range of motion. The greatest gain occurred between tests two and three. The smallest gain was shown between tests four and five, suggesting subjects were reaching their maximum flexibility, but these tests still indicated greater total gain.

de Vries (1962) investigated the effects of seven 30-minute training sessions, over a five week period, with two training sessions per week, on the flexibility of 57 male college students. Subjects were randomly assigned to static and ballistic training groups. Static stretch involved a held position with no movement, slow or fast, in which the body segments to be stretched were locked into a position of greatest length. Ballistic stretch involved quick movements characterized by quick jerks and pulls upon the body segments to be stretched. Static exercises (derived from Hatha Yoga exercises) started with a 30-second period and increased to one minute by the fourth workout. Ballistic exercises (derived from swim exercises) and static exercises started with 20 repetitions and increased to 40 repetitions by the fourth workout. Each group performed a total of eight exercises. Cureton's flexibility tests were employed: trunk flexion, trunk extension, and shoulder elevation. The pre-post test gains in flexibility for static and ballistic stretch methods showed trunk flexion, trunk extension, and shoulder elevation increased. The difference between static and ballistic flexibility gains revealed no significant difference.

Logan and Egstrom (1961) examined the relative effectiveness of slow and fast stretching techniques on the sacro-femoral angle for 12 female and 13 male university physical education students. Each sex group was randomly sub-divided into slow and fast groups. The slow-stretch method used the active contraction of the anterior muscle groups bent at the hips with the legs straight, maximally, and held the position momentarily. The fast-stretch method used momentum developed by a forced bobbing movement in which the weight of the trunk was bounced, against the resistance encountered at the range of motion. The test procedure required lines corresponding to the sacral indication and those formed by marks on the femur were then drawn on the photographs and the angle was measured with a protractor. The angle created reflected the flexibility score. All subjects performed 20 repetitions per day. The subjects were measured again at the conclusion of the ten day exercise program. The results showed both slow and fast-stretch sub-groups had significantly increased the range of motion at the sacral-femoral angle. The females had increases significant at the 1% level for the fast-stretch sub-group and at the 5% level for the slow-stretch sub-group. The males had increased significantly at the 1% level for both sub-groups. There was no significant difference between the mean difference of the final measurement of the fast and slow-stretch for either the males or the females. The conclusion drawn was that there was no difference between slow and fast-stretching.

McCue (1952) determined the effects of three weeks of stretch exercises on the flexibility for the lower quartile of 130 college women, ranging in age from 17 to 26 years (mean age 19.5 years). The bounce technique was performed in a relaxed rhythmic manner, to the limit of range of motion. The exercises and tests involved the following joints: hip flexion, hip rotation, ankle flexion and extension, trunk flexion and total back and neck extension. The measurements were taken with the goniometer just before the exercise program, immediately following the three-week series, and again eight weeks following the series. All mean differences between all pre-post test scores on the three-week training period were significant. In addition, hip flexion, total back and neck extension, and hip rotation retained significant amounts of flexibility eight weeks following the exercise program.

Weber and Kraus (1949) investigated the effects of the spring stretch method (bobbing) on group one (n = 25 cases) and plain stretch method (control) on group two (n = 25 cases) for the toe-touch and leg-lift from supine position tests and exercises. The passive spring stretch of hamstring muscles was described as a "bobbing" motion caused by the physical therapist at the point where it is felt that the muscle has reached its fullest length. The active spring stretch is done with the patient standing erect, knees straight, bending over to touch the floor with fingertips. The subject bobs up and down with a spring-like motion, exerting power in the downward direction, thus decreasing the distance from fingertips to the floor. The plain stretch applied was the same exercise, but without the bobbing or spring-like rhythmical motion. The maximum range of motion was held for a few seconds. The rate of improvement per month in regaining normal length of these muscle groups was computed in 50 unselected cases. The technique of measurements was both degree (protractor) and linear (inches) for the leg-lift and toe-touch respectively. The authors reported the spring stretch method showed an average improvement of 3.0 degrees in the hamstring muscles (leg-lifts) and 2.0 inches in the back-hamstring-gastrosoleus muscles (toe-touch) per month. The plain stretch improved by an average of 1.0 degree and 1.0 inch per month respectively. The final conclusion was that spring stretch method showed 200 percent more efficiency in the hamstring muscle (leg-lift) stretch and 100 percent more efficiency in the back-hamstring-gastrosoleus muscle (toe-touch) stretch.

Summary

Table 1 shows a summary of the results of different studies conducted on flexibility training.

The major generalizations from these studies are:

1) Flexibility training, regardless of method, has increased active and passive flexibility within one training session and over weeks of training.
2) Active and passive flexibility retention have been retained for at least one week following cessation of flexibility training.

The generalizations across different flexibility training studies are few, due to the following limitations:

1) Researchers employing the same stretch technique have not followed standard procedures.
2) Test methods utilized by different investigators (i.e., linear and degree) may not be comparable, since linear change may be shown without a change in degrees.
3) Immediate training effects and long term training effects are different; generalizations made should be specific to each effect. Research papers examining both effects have failed to report the results in this manner.
4) Active flexibility and passive flexibility are distinctly different; information about one type should not be transferred to the other. Some research papers investigating different joint flexibility measurements have not

TABLE 1

EFFECTS OF DIFFERENT STRETCH TRAINING METHODS ON FLEXIBILITY

Author	Subjects	Sex	Weeks	Sessions	Method	Flexibility Type	Test B	Test A	Flexibility Test	Results: Training	Results: Retention
[illegible] et al. 1980	12	F		1	CS CRAC S	Passive	No	Yes	Goniometer (°)	Improvement CRAC and S superior	No data
[illegible] 1977	30	M		6	Passive Isometric contraction	Passive	Yes	Yes	Goniometer (°)	Improvement No difference bet. methods	No data
[illegible] 1977	12	F	10	20	RS SS	Active	No	Yes	Leighton Flexometer (°)	Improvement No difference	Retention No difference
[illegible] 1980	112	F	4	12	Passive lift and active hold Ballistic hold Active PNF Relaxation Passive PNF Prolong stretch	Active	Yes	Yes	Leighton Flexometer (°)	Improvement No difference bet. methods	No data
[illegible] et al. 1978	10	M	6	30	RS	Active (?)	No	Yes	Leighton Flexometer (°) (?)	Improvement Left hip extension and split rite superior to control	No data
Tanigawa 1972	30	M	4	8	Hold-relax Passive	Passive	Yes	Yes	Moth method (°)	Improvement Hold-relax superior	Retention Hold-relax superior
[illegible] et al. 1970	24	M	3	9	Ballistic Slow IA-CA	Active	Yes	Yes	Sit and Reach (in)	Improvement IA-CA superior	No data
Fieldman 1966	33	M	3	6	Smoothness	Active	Yes	Yes	Toe touch Test (in)	Improvement	No data
de Vries 1962	57	M	1	7	Static Ballistic	Active	No	Yes	Cureton's method (in)	Improvement No difference bet. methods	No data
[illegible] et al. 1961	25	F/M	1 1/3	10	Slow Fast	Active	No	Yes	Goniometer (°)	Improvement No difference	No data
[illegible] 1962	130	F	3	9	Bounce	Active	No	Yes	Goniometer (°)	Improvement	Retention
[illegible] et al. 1949	50	M/F	8		Spring Plain	Passive Active	No	Yes	Goniometer (°) Toe-touch Test (in)	Improvement Spring superior	No data

Test B: before and after test within the training session
Test A: tests over weeks
(?): incomplete
(°): degrees

clearly indicated which type of flexibility was studied.

5) Studies examining a treatment effect without the use of a control group seriously affect the interpretation of the results.

6) Training programs without proper supervision may not guarantee the performance of the program.

7) Joint tests with significantly higher reliability than other joint tests have greater power to detect treatment changes; comparison between these joint tests may not be justified.

8) Since joints are unique within the across-joint-classification, the response to treatment may be different. Consequently, pooling results across joints may prove meaningless.

9) Research has yet to examine a number of standard stretch techniques in one study. An attempt has been made to investigate a number of combined methods (i.e., ballistic - hold versus passive lift - active hold). The superiority of one method cannot be claimed.

10) Since men and women have both physiological and anatomical differences within joints (i.e., hips), their response to treatment may not be the same.

11) The presence or absence of a pre-test warm-up in different studies makes the results among studies difficult to compare (Atha-Wheatley, 1976).

12) Little attention has been given to equalize time in training from one method to the next. Perhaps one method may prove more or less effective only because it requires more

or less time in training.

13) The subject's initial flexibility score can affect the rate and magnitude of flexibility change. Researchers have neglected to allow for this important variable. If the study had blocked on initial flexibility scores, their results were not reported in this manner.

14) The frequency and duration of training sessions over days and/or weeks are extremely different from one study to the next. Training programs have little in common for cross comparisons.

It may therefore be concluded that previous investigations were not able to discern which flexibility training method(s) was superior in developing both immediate and long term flexibility across different joints, with the most enduring effects. Consequently, a major comprehensive investigation on flexibility training was designed and undertaken with a view to minimize the effects of the limitations cited above.

CHAPTER III

METHODOLOGY

Subjects

Forty-nine volunteer female, right hand dominant, junior high students, ranging from 12 to 14 years of age, at Lakewood Intermediate School, Kenora, Ontario were selected as subjects. Permission to test the subjects was received from the principal of the school (Appendix C). The preferred writing hand was used to categorize the subjects as right-handed.

Forty-nine shoulder joints and 49 ankle joints were studied, each subject contributing both joints. Subjects with any history of joint injury or disease (e.g., broken ankle) were excluded from the study.

Randomization

Selection. Two classes totalling forty-nine female subjects were selected from a school population of 350 females.

Assignment. Following the initial flexibility tests, each subject was rank-ordered on her joint flexibility scores, from high to low, for each joint. Blocks of seven subjects were formed by ranking successive students on flexibility. Subjects in each block were then randomly assigned to one of the seven conditions. Assignments to the six treatment and control conditions were done independently for ankle and shoulder joints except that in the case of the control conditions, no subject was allowed to be in the control group for both the shoulder and ankle studies.

Modification. Three subjects dropped out of the study, leaving six subjects in each of three treatment groups and seven subjects in each of the remaining four treatment groups. Since this occurred, one subject's joint was randomly selected from each of the remaining four groups and discarded from the analysis. This procedure was performed independently for both the ankle joint and the shoulder joint. Subsequently, a one-way analysis of variance among treatments was conducted on pre-test flexibility scores (Cook and Campbell, 1979, p. 152). The analysis was performed independently for both the ankle and shoulder joints. The results showed no significant difference among treatment groups for the pre-test flexibility scores for each ankle and shoulder joint analysis ($p > 0.05$).

Experimental Design

The experimental design consisted of two 7 x 5 x 2 (treatment, week and session) factorial designs with repeated measures on the last two factors.

The first factor (factor A) was the treatment variable. The seven levels of this factor were:

A_1 3S training

	Subjects	Weeks: B_1		B_2		B_3		B_4		B_5	
		Sessions: C_1	C_2	C_1	C_2	C_1	C_2	C_1	C_2	C_1	C_2
A_1	1 2 6										
A_2	1 2 6										
A_3	1 2 6										
A_4	1 2 6										
A_5	1 2 6										
A_6	1 2 6										
A_7	1 2 6										

Treatment Conditions

- A_1 3S training (n = 6)
- A_2 2S training (n = 6)
- A_3 SS training (n = 6)
- A_4 ES training (n = 6)
- A_5 BS training (n = 6)
- A_6 CS training (n = 6)
- A_7 Control (n = 6)

Week in Experiment

- B_1 pre-training
- B_2 two-week training
- B_3 four-week training
- B_4 six-week training
- B_5 two-week retention

Session

- C_1 pre-session
- C_2 post-session

Figure 3. Design of the study.

A_2 2S training

A_3 SS training

A_4 ES training

A_5 BS training

A_6 CS training

A_7 control

The second factor (factor B) involved repeated measures. The five levels of this factor were:

B_1 pre-training (pre-test)

B_2 two-week training

B_3 four-week training

B_4 six-week training (post-test)

B_5 two-week retention

The third factor (factor C) also involved repeated measures. The two levels of this factor were:

C_1 pre-session training

C_2 post-session training

Testing Apparatus

The Leighton Flexometer was developed for measuring the shoulder joint and ankle joint for active flexibility. The flexometer is comprised of a weighted 360 degree dial and a weighted pointer housed in a case. The dial and pointer function freely and independently of each other, though each is controlled by gravity. The flexometer, when positioned within 20 degrees off the horizontal, will record accurate angular movement. Independent locking mechanisms are furnished for the dial and the pointer which stop angular movement of either at any position. The flexometer must be strapped to the segment next to the joint being tested. The dial will be locked at one position (e.g., full flexion of the ankle); the angular movement will be performed and the pointer locked at the opposite extreme position (e.g., full extension of the ankle). The exact reading of the pointer on the dial will be the angular movement through which motion will have taken place (Leighton, 1966).

The Leighton Flexometer test demonstrated the correlation coefficient between the first and second measurement to be 0.913 and 0.996 (thirty measures on 120 boys) (Leighton, 1966, p. 86). Joint tests with significantly higher reliability than other joint tests have greater power to detect treatment changes; comparison between these joint tests may not be justified. Consequently, the author developed the modified Leighton Flexometer test method for ankle plantar flexion and shoulder extension to alleviate this problem.

The reliability of two different flexibility test methods, the traditional Leighton Flexometer method and a modified Leighton Flexometer method was investigated. Twenty-four female volunteer physical education students, ranging in age from 18 to 25 years, were selected as subjects. Twelve of these subjects were assigned to the traditional flexometer method and 12 to the modified Leighton Flexometer testing method. Following the orientation session, in which subjects were familiarized with the testing technique, three tests were conducted during the second session. The results of the last two tests were analyzed statistically using the Pearson product moment correlation coefficient and the difference between two correlation coefficients for independent samples was tested.

Analysis of data revealed that the traditional Leighton Flexometer method gave correlation coefficient values of .914 for shoulder extension ($p < 0.01$) and .990 for ankle plantar flexion ($p < 0.01$). The modified Leighton Flexometer method on the other hand revealed correlation values of .992 and .993 respectively ($p < 0.01$). Differences between the methods for the correlation coefficients for the shoulder joint were significant ($p < 0.01$) and for the ankle joint the difference was not significant ($p > 0.05$). The modified Leighton Flexometer was used in this study because it showed a reliability of .99 across both joints.

Modified Leighton Flexometer. The original cloth strap was removed from the Flexometer. A lightweight (28.35 g) preshaped, plastic brace (foam lined) with adjustable elastic-velcro strap (195.5 to 241.3 mm) was attached to the back of the instrument. This modification allowed for the instrument to fit any size arm or foot comfortably (Figures 4 and 5).

The modified Leighton Flexometer method was consistently more reliable for shoulder extension and ankle plantar flexion tests than the traditional Leighton Flexometer method. This has allowed for better comparison across joints, when detecting

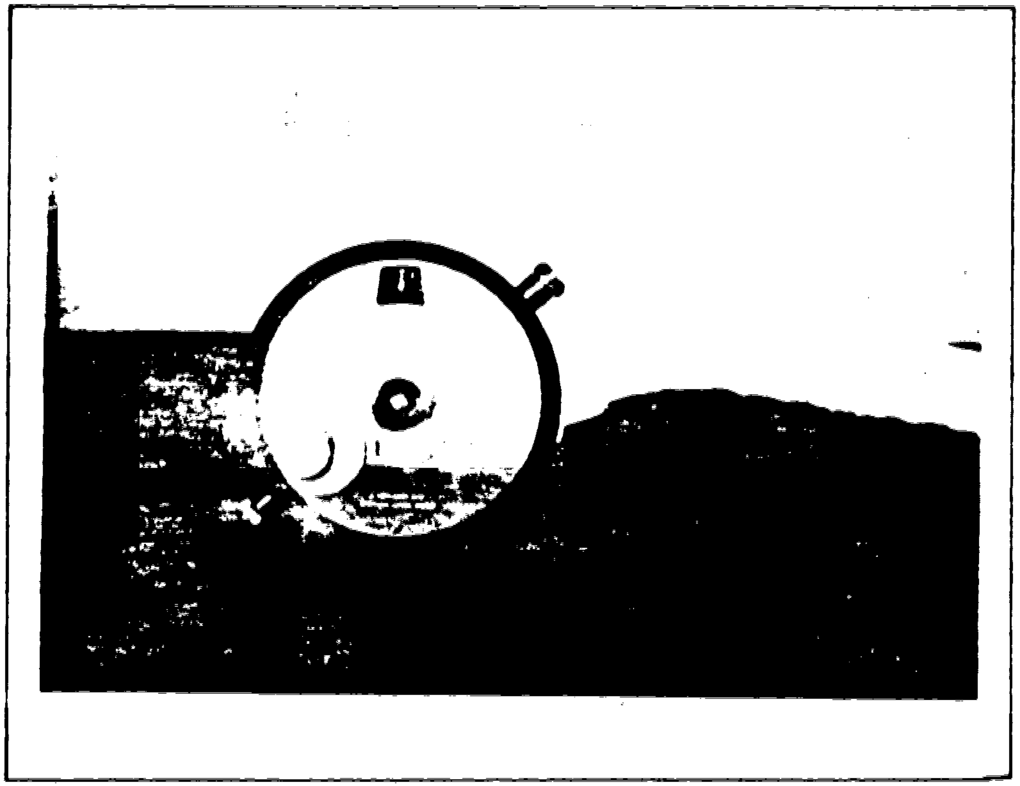

Figure 4. Front view of the modified Leighton Flexometer.

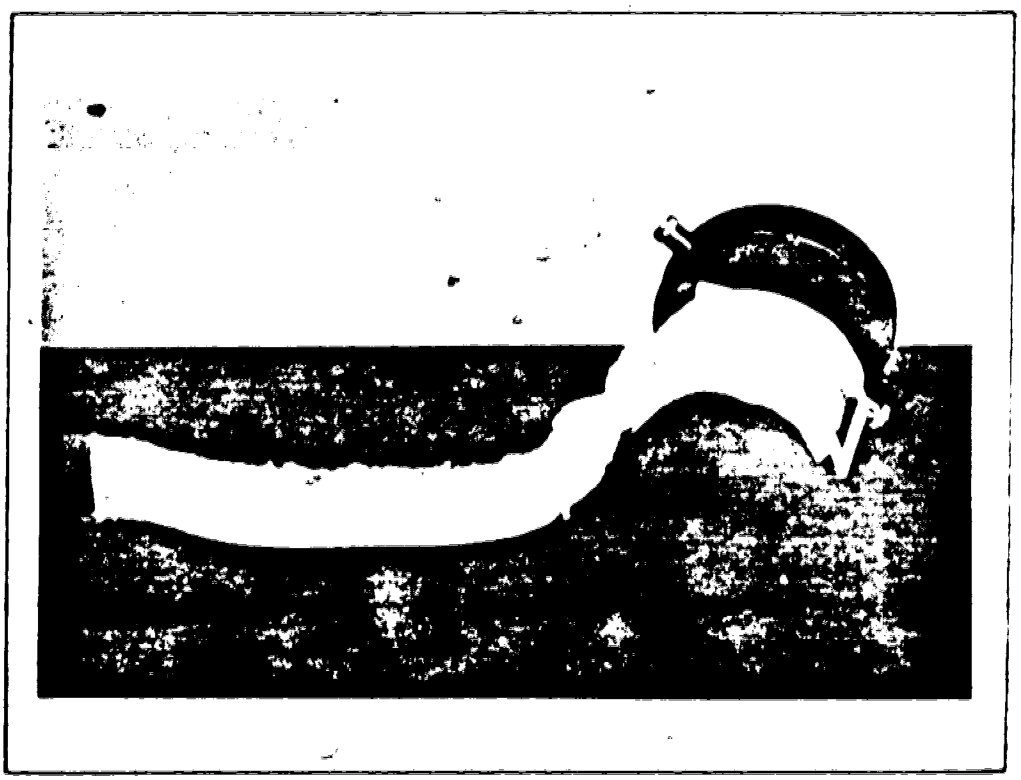

Figure 5. Back view of the modified Leighton Flexometer.

treatment changes.

Apparatus. All testing was carried out in a centrally heated gymnasium. The testing room was at a temperature between 18 and 22°C on all testing days. The room was equipped with two portable tables for testing the shoulder (Figure 6) and ankle joints (Figure 7). One adjustable strap and one cylinder were used for securing subjects into the proper ankle joint test position (Appendix B). Subjects wore standard physical education clothing (e.g., a pair of shorts, a T-shirt, and bare feet).

Testing Procedures

Leighton's rules for flexibility testing (Leighton, 1966) were followed, with modification, as a standard procedure for each test. All tests were conducted in the sagittal plane, in one direction per joint: shoulder extension and ankle plantar flexion. The flexometer's dial was permanently locked, by horizontally positioning the instrument on the table, since only one direction of flexibility was to be measured.

The initial flexibility testing was undertaken within one week before the first flexibility training session. A post-training test was given during the last training session. The retention test occurred two weeks after the post-training test. The flexibility training tests were held on regular school days between 8:30 a.m. and 4:30 p.m.

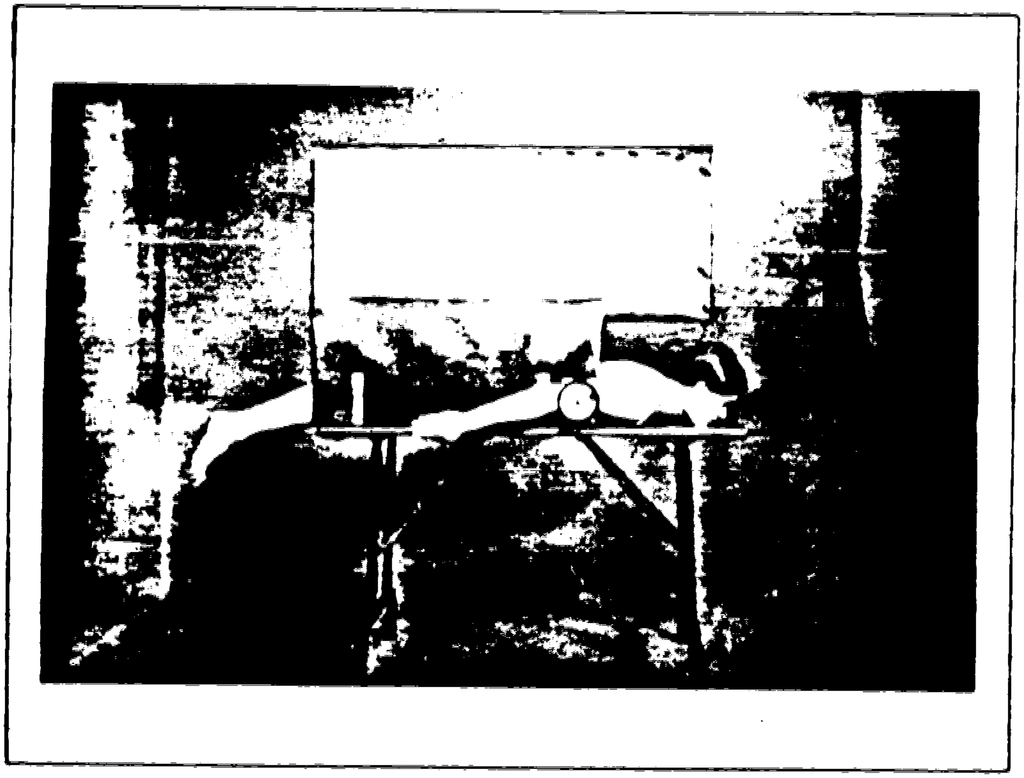

Figure 6. Shoulder extension table.

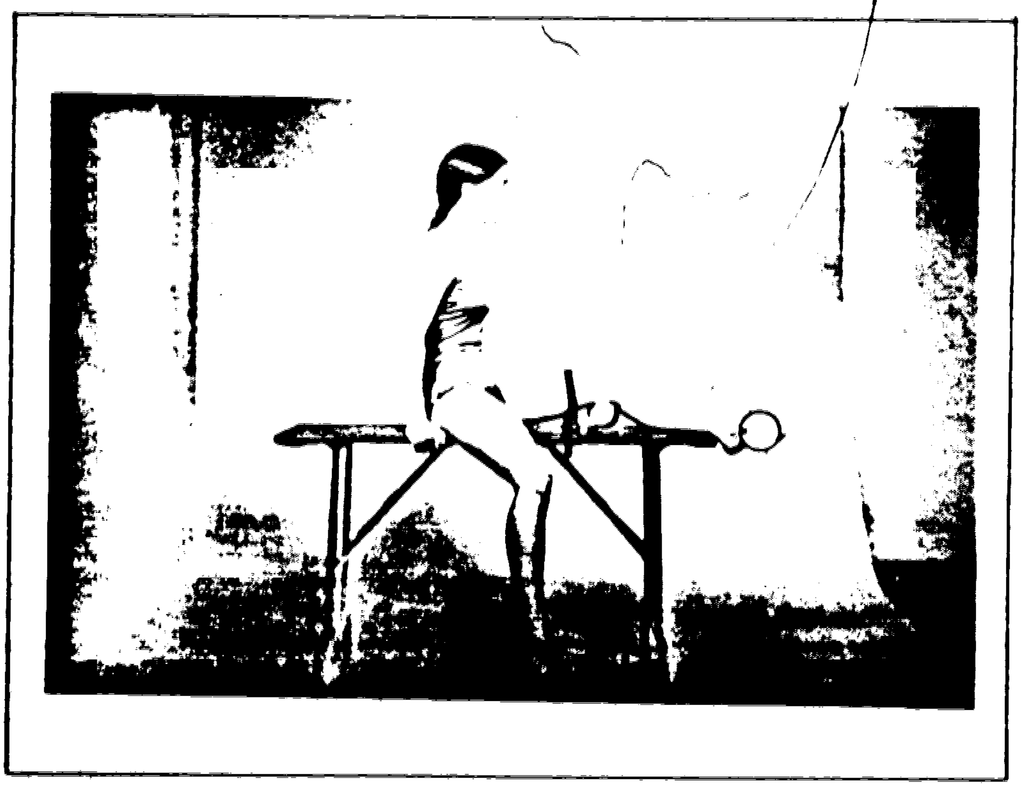

Figure 7. Ankle plantar flexion table.

The pre-training, training, post-training and retention tests all followed the same procedures. In each test session two subjects were randomly called for testing. They changed into their physical education clothing and moved directly to the testing room. Upon completion of the shoulder and ankle tests, the subjects left the testing room and two more subjects were called. This pattern was continued until all subjects had been tested.

The investigator collected all the data for this study. The tester was helped by an assistant who recorded the subjects' flexibility scores for each joint being tested. All subjects performed three consecutive maximum movements for each specific joint to be tested, as instructed by the tester. Each test trial was three seconds in duration. Each subject was given fifteen seconds rest between test trials.

The flexometer was checked before each test session to ensure it was in working order.

Flexibility Tests

The shoulder extension test (Figure 8) and ankle plantar flexion test (Figure 9) were administered to each subject. For a further explanation on each test see Appendix B.

Training Apparatus

All training was carried out in a large centrally heated school gymnasium. The temperature of the training gymnasium

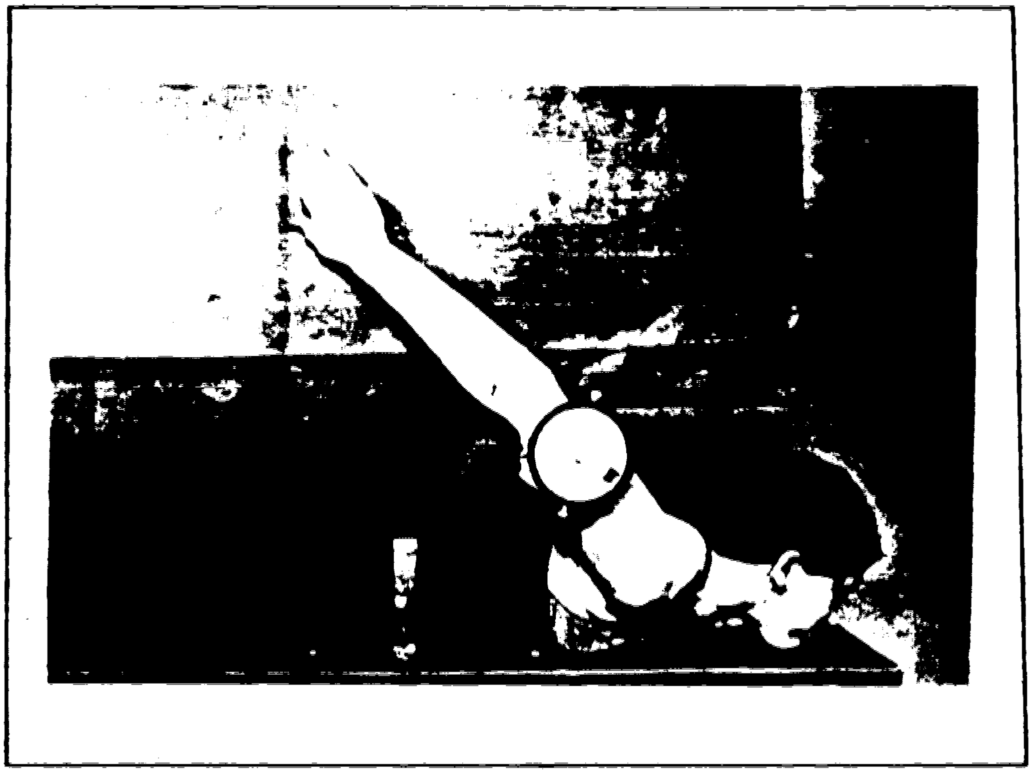

Figure 8. Shoulder extension test.

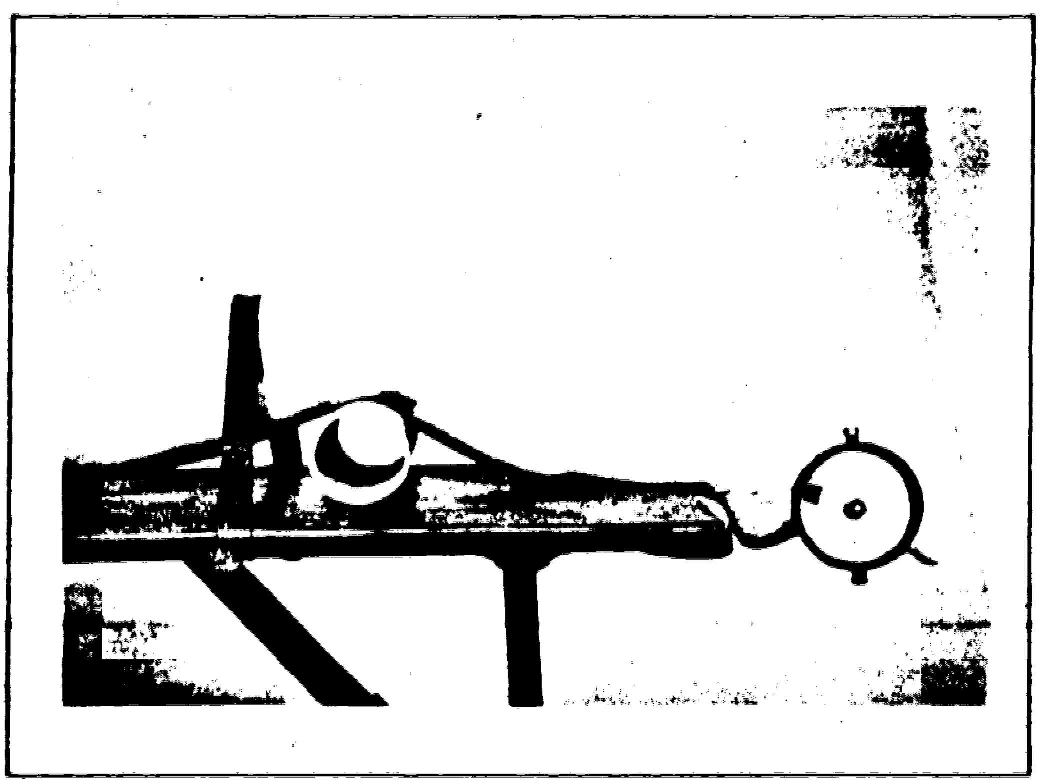

Figure 9. Ankle plantar flexion test.

was between 18°C and 22°C during all training sessions. Subjects wore standard physical education clothing (e.g., a pair of shorts, a T-shirt, and stockings, or bare feet).

Training Procedures

The specific joint training method was followed as a standard procedure. Subjects were encouraged to perform only the joint method assigned. During the study, the subjects were asked to refrain from any flexibility training other than that associated with the experiment. A reward system was implemented to provide motivation for subjects to meet this instruction. A movie and lunch (Big Mac, apple and milk) was provided for all students and staff members involved after the fourth week of the training study. In addition a plaque from the University of Alberta was presented to the principal of Lakewood Intermediate School in appreciation for his school's full co-operation during the course of the experimental research.

The flexibility training program consisted of 24 training sessions. Each exercise was performed three consecutive times during the session. Each subject chose one permanent partner to assist when necessary in the exercises. The order of the joints to be exercised was changed in each series.

The workload for each subject was standardized:

1) thirty seconds training per session(s), and
2) fifteen seconds rest intervals.

Each subject received two treatment conditions:

1) on the shoulder joint, and

2) on the ankle joint.

The exercises were performed during each physical education class. The gymnasium was divided into six stations: 3S, 2S, SS, ES, BS, and CS. The distance between the stations was great enough so that subjects exercising at each station did not distract one another. During each training session, the instructor supervised the training to further ensure that the exercise was performed properly. The instructor accomplished this by moving from station to station, observing, assisting, and encouraging the subjects.

Flexibility Training

The present study developed standard procedures for the six different flexibility training methods (3S, 2S, SS, ES, BS, and CS) for shoulder extension and ankle plantar flexion. The following is an explanation on each standardized flexibility training method. For further explanation see Appendix A.

Scientific stretch for sport training (3S). A maximal range of motion is attained by actively and passively flexing or extending a segment nearest to the joint being trained, in an arc, as far as possible. Repetitions of the exercise are performed, without severe pain. One repetition consists of:

a) two second concentric contraction,

b) six second isometric contraction, and

c) two second concentric contraction, with light force from a partner.

Subject repeats the above exercise (rest optional). The contractions performed by the exercise subject must be gradually, not explosively, increased in effort.

Static stretch training (2S). A maximal range of motion is attained by passively flexing or extending a segment nearest to the joint being trained, in an arc, as far as possible. Repetitions of the exercise are performed without severe pain. One repetition consists of:

a) two second passive extension, and

b) eight second held passive extension.

Subject relaxes for fifteen seconds before repeating each exercise. The external force applied to extend the segment is gradually, not explosively, increased in effort.

Slow active stretch training (SS). A maximal range of motion is attained by actively flexing or extending a segment nearest to the joint being trained, in an arc, as far as possible. Repetitions of the exercise are performed, without severe pain. One repetition consists of:

a) two second concentric contraction, and

b) eight second isometric contraction.

Subject relaxes for fifteen seconds before repeating each exercise. The contractions performed by the subject must be gradually, not explosively, increased in effort.

Eccentric stretch training (ES). A maximal range of motion is attained by actively flexing or extending a segment nearest to the joint being trained, in an arc, as far as possible. Repetitions of the exercise are performed, without severe pain. One repetition consists of:

a) five second eccentric contraction, and

b) five second passive extension.

Subject relaxes for fifteen seconds before repeating each exercise. The contraction and passive extension performed by the subject must be gradually, not explosively, increased in effort.

Ballistic stretch training (BS). A maximal range of motion is attained by actively flexing or extending, in a relaxed rhythmic manner, a segment nearest to the joint being trained, in an arc, as far as possible. Repetitions of the exercise are performed, without severe pain. One repetition consists of one second concentric contractions. Subjects will perform 10 consecutive repetitions, then relax for fifteen seconds before repeating each exercise. The series of ten concentric contractions is performed in a rhythmic manner, explosive in effort.

Contract relax stretch training (CS). A maximal range of motion is attained by actively flexing or extending a segment nearest to the joint being trained, in an arc, as far as possible. Repetitions of the exercise are performed, without severe pain. One repetition consists of:

a) two second concentric contraction,

b) six second isometric contraction, and

c) two second concentric contraction.

Subject immediately repeats the above exercise (rest optional). The isometric contraction performed by the exercise subject must be gradually, not explosively, increased in effort.

All subjects who performed flexibility training on the shoulder joint were required to flex at the knee about 90 degrees (Figure 10) and any partner who assisted a subject was required to stay on her feet or buttocks (Figure 11). This procedure was followed to avoid stretching of the ankle joint, thereby causing a training effect.

Summary of Test and Training Format

Pre-test orientation. The subjects were familiarized with both the training and test methodology. Test and training methods were presented on slides for subjects to follow standard procedures. An information sheet pertaining to shoulder or ankle injury was completed by the students.

Initial test. The initial flexibility test was one week before the first training session.

Training program. The flexibility training sessions were held three times per week (i.e., Monday, Wednesday, and Thursday) for six consecutive weeks, in conjunction with the physical education classes.

Training tests. Two tests were administered per joint, one before and one after the training session. The subjects

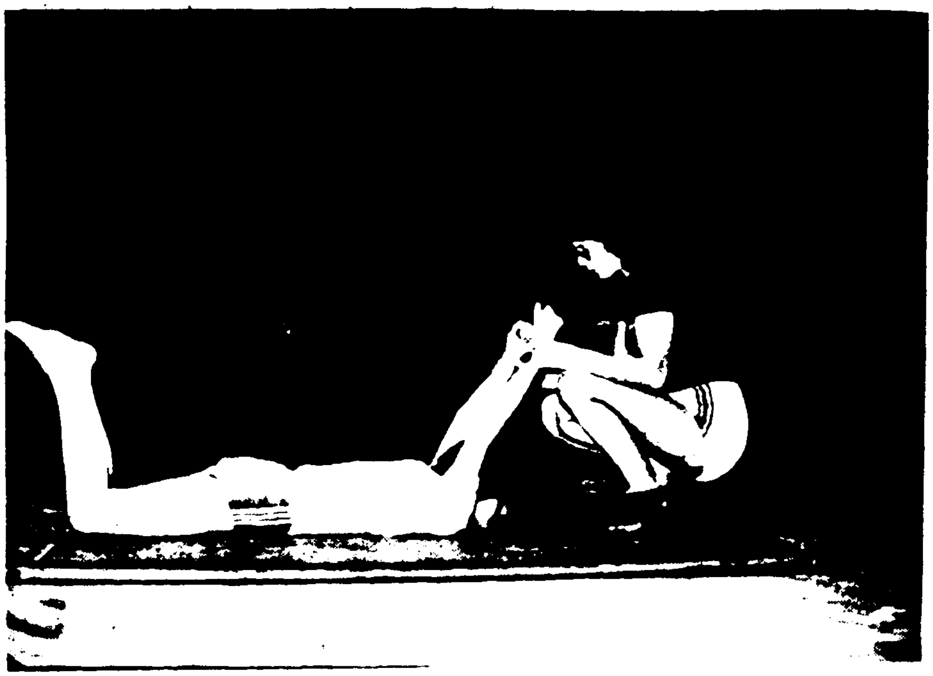

Figure 10. Subject is flexed at knee.

Figure 11. Partner is supported by feet.

were assessed for active flexibility at the first, sixth, twelfth, eighteenth and twenty-fourth session of the training program.

Post-training period. The subjects did not receive any flexibility training during the seventh and eighth week of the study. The physical education classes continued as usual.

Post-training test. The subjects were assessed after a two-week retention period (no flexibility training) (Figure 12).

Week	Session	Test
0		Pre Post T_0
1	1	T_1
	2	
	3	
2	4	
	5	
	6	T_2
3	7	
	8	
	9	
4	10	
	11	
	12	T_3
5	13	
	14	
	15	
6	16	
	17	
	18	T_4
7	19	
	20	
	21	
8	22	
	23	
	24	T_5
9		

Figure 12. Schematic diagram of testing and training format.

CHAPTER IV

RESULTS AND DISCUSSION

The ankle data and shoulder data were analyzed separately using a three-way analysis of variance with repeated measures on the last two factors (Winer, 1971, pp. 539-559). A computer program ANOV34 developed by the Division of Educational Research Services at the University of Alberta was used (DERS, 1979). For both analyses, the training factor (factor A) had seven levels:

A_1 3S training

A_2 2S training

A_3 SS training

A_4 ES training

A_5 BS training

A_6 CS training

A_7 Control

The first repeated measure (factor B) consisted of the five sessional measurements made over the training period.

B_1 pre-training (pre-test)

B_2 two-week training

B_3 four-week training

B_4 six-week training (post-test)

B_5 two-week retention

The second repeated measure (factor C) consisted of pre- and post-session measures taken at each of the measurement sessions in factor B.

C_1 pre-session training

C_2 post-session training

In testing effects involving repeated measures, the Greenhouse-Geisser procedure was used (Winer, 1971, p. 523). This procedure guards against potential violations of the homogeneity of covariance assumptions.

Ankle Plantar Flexion

The summary analysis of variance for ankle plantar flexion is shown in Table 2. The cell means are displayed graphically in Figure 13. Significant main effects were found for B (week) and C (within-session). A significant treatment by within-session-interaction was also noted. Application of the Greenhouse-Geisser conservative test yielded conclusions identical to those in the regular test. Neither the treatment main effect nor any other interaction was significant.

Scheffé comparisons were conducted on the ankle joint data. In the case of factor B (Table 3 and Figure 14), flexibility significantly increased between the fourth and sixth week and then decreased after the two week retention period. Subjects' mean range of motion after the retention period was not significantly different from the pre-test scores.

In the case of factor C, the average post-session mean was significantly higher than the average pre-session mean ($\bar{X}$ pre = 106.3 and $\bar{X}$ post = 107.9).

The differential treatment effect as revealed by the AC interaction showed that 3S, 2S, ES and CS significantly increased within-session flexibility when compared to the control (Table 4 and Figure 15). In addition, 3S training was superior to CS training in relation to within-session gains (Table 5).

Shoulder Extension

The summary of analysis of variance for shoulder extension is shown in Table 6 with cell means displayed in Figure 16. As in the ankle data only B (week), C (within-session) and AC (treatment by within-session) were significant. Application of the Greenhouse-Geisser test did not change the conclusions.

Scheffé comparisons were conducted on the shoulder joint data. In the case of factor B (Table 7 and Figure 17), flexibility significantly increased between the beginning and second week, between the fourth and sixth week and then decreased after the two week retention period. Subjects' mean range of motion after the retention period was significantly different from the pre-test scores.

In the case of factor C, the average post-session mean was significantly higher than the average pre-session mean ($\bar{X}$ pre = 161.6 and $\bar{X}$ post = 162.5).

The differential treatment effect as revealed by the AC interaction showed that only 3S significantly increased within-session flexibility when compared to control (Table 8 and

TABLE 2

SUMMARY OF ANALYSIS OF VARIANCE ON THE ANKLE DATA

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Squares	F Ratio
Between Subjects	24869.00	41		
Factor A (treatment)	1023.00	6	170.50	0.25
Subject Within Group	23846.00	35	681.31	
Within Subjects	3159.00	378		
Factor B (week)	1237.00	4	309.25	41.59**
Factor A x Factor B (AB)	203.00	24	8.46	1.14
Factor B x Subjects Within Group	1041.00	140	7.44	
Factor C (session)	277.00	1	277.00	277.00**
Factor A x Factor C (AC)	232.00	6	38.67	38.67**
Factor C x Subjects Within Group	35.00	35	1.00	
Factor B x Factor C (BC)	8.00	4	2.00	2.35
Factor A x Factor B x Factor C (ABC)	7.00	24	0.29	0.34
Factor B x Subjects Within Group	119.00	140	0.85	

Greenhouse-Geisser Conservative Test

* Significant at 5% level ($p < 0.05$)
** Significant at 1% level ($p < 0.01$)

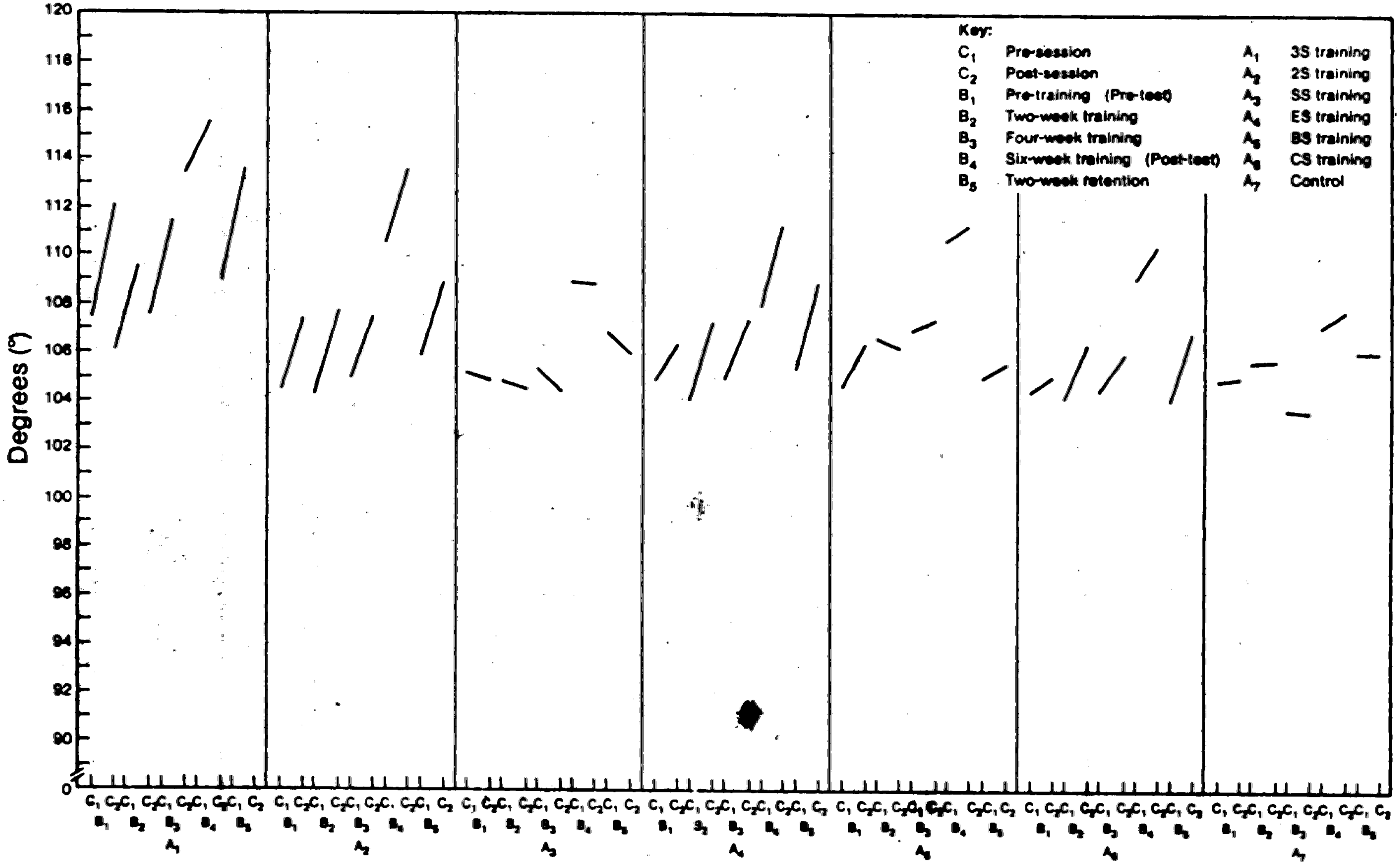

Figure 13. Mean flexibility scores for each treatment, week, and session on the ankle joint.

TABLE 3

SCHEFFÉ POST-HOC CONTRASTS AMONG LEVELS OF FACTOR B (WEEK) ON THE ANKLE DATA

Comparison	F Ratio
B_1, B_2 (Week 1, Week 2)	0.00
B_1, B_3	0.09
B_1, B_4	56.95*
B_1, B_5	2.77
B_2, B_3	0.10
B_2, B_4	57.20*
B_2, B_5	2.83
B_3, B_4	52.48*
B_3, B_5	1.85
B_4, B_5	34.61*

* Significant ($p < 0.05$)

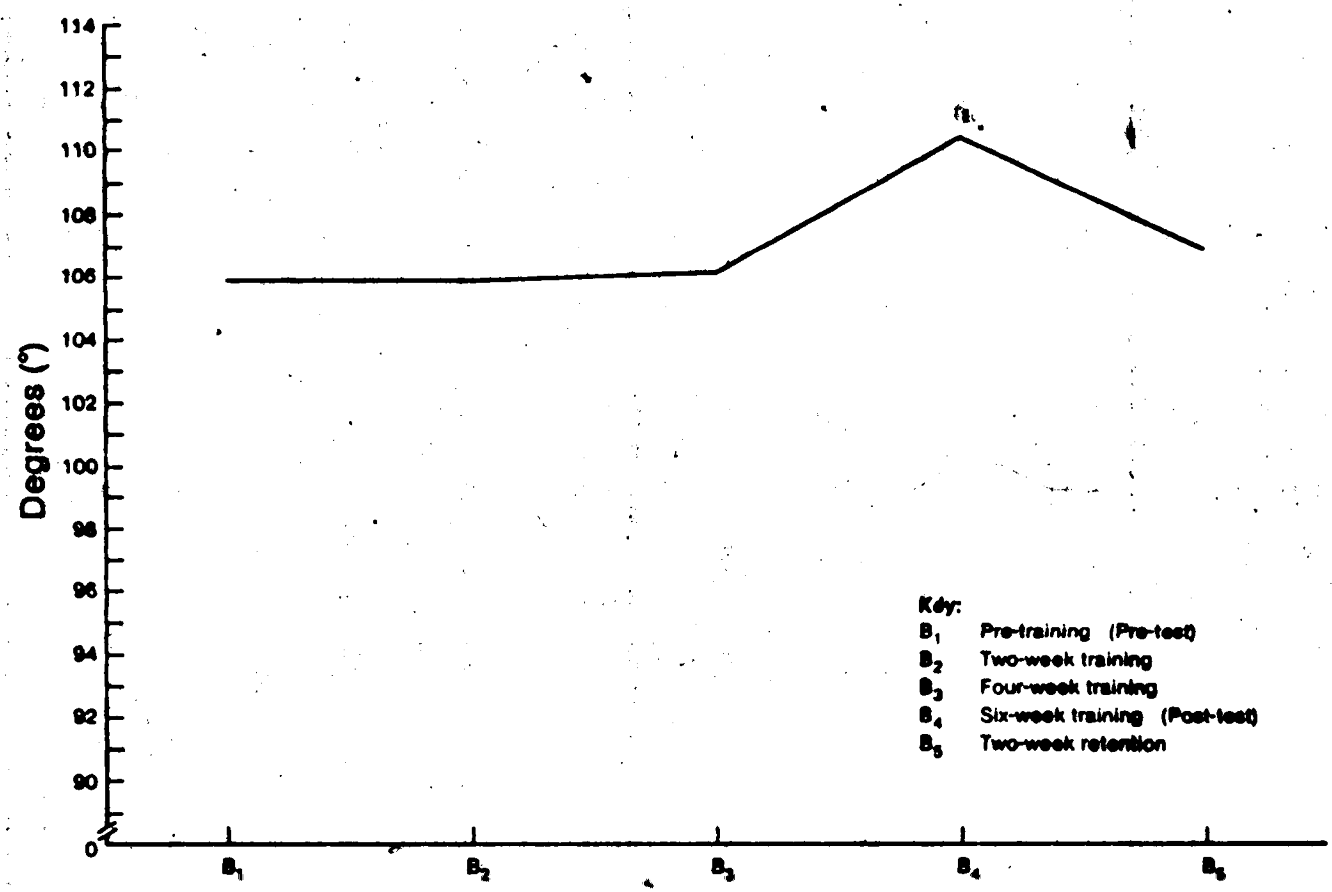

Figure 14. Mean flexibility scores for each week on the ankle joint.

TABLE 4

SCHEFFÉ POST-HOC CONTRASTS AMONG LEVELS OF FACTOR C (SESSION) FOR GIVEN LEVELS OF FACTOR A (TREATMENT) ON THE ANKLE DATA

Treatment	Comparison	F Ratio
A_1 (3S training)	C_1, C_2 (pre- and post-session)	81.40*
A_2 (2S training)	C_1, C_2	53.40*
A_3 (SS training)	C_1, C_2	1.71
A_4 (ES training)	C_1, C_2	48.17*
A_5 (BS training)	C_1, C_2	2.04
A_6 (CS training)	C_1, C_2	17.00*
A_7 (control)	C_1, C_2	0.14

* Significant ($p < 0.05$)

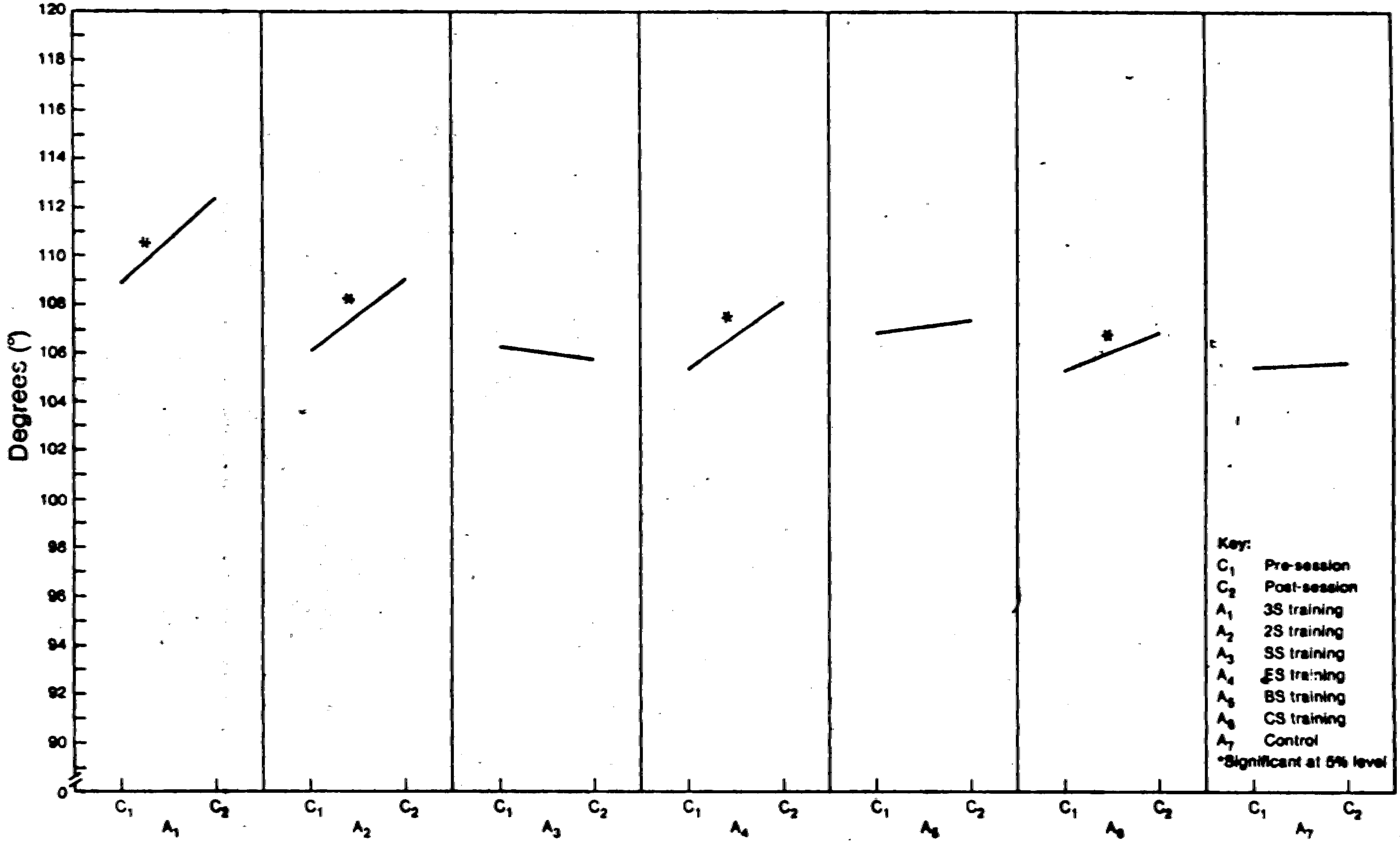

Figure 15. Mean flexibility scores within-session for each treatment on the ankle joint.

TABLE 5

SCHEFFÉ POST-HOC CONTRASTS AMONG LEVELS OF FACTOR A (TREATMENT) FOR SIGNIFICANT C_1 AND C_2 DIFFERENCES ON THE ANKLE DATA

Comparison	F Ratio
A_1 (C_2-C_1), A_2 (C_2-C_1) (3S, 2S)	5.25
A_1 (C_2-C_1), A_4 (C_2-C_1) (3S, ES)	6.38
A_1 (C_2-C_1), A_6 (C_2-C_1) (3S, CS)	15.00*
A_2 (C_2-C_1), A_4 (C_2-C_1) (2S, ES)	1.13
A_2 (C_2-C_1), A_6 (C_2-C_1) (2S, CS)	9.75
A_4 (C_2-C_1), A_6 (C_2-C_1) (ES, CS)	8.63

* Significant ($p < 0.05$)

TABLE 6

SUMMARY OF ANALYSIS OF VARIANCE ON THE SHOULDER DATA

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Squares	F Ratio
Between Subjects	26823.00	41		
Factor A (treatment)	5435.00	6	905.83	1.48
Subject Within Group	21388.00	35	611.09	
Within Subjects	33144.00	378		
Factor B (week)	21864.00	4	5466.00	82.71**
Factor A x Factor B (AB)	784.00	24	32.67	0.49
Factor B x Subjects Within Group	9252.00	140	66.09	
Factor C (session)	77.00	1	77.00	13.08**
Factor A x Factor C (AC)	204.00	6	34.00	5.78**
Factor C x Subjects Within Group	206.00	35	5.89	
Factor B x Factor C (BC)	42.00	4	10.50	2.15
Factor A x Factor B x Factor C (ABC)	58.00	24	2.42	0.49
Factor B x Subjects Within Group	685.00	140	4.89	

Greenhouse-Geisser Conservative Test

* Significant ($p < 0.05$)
** Significant ($p < 0.01$)

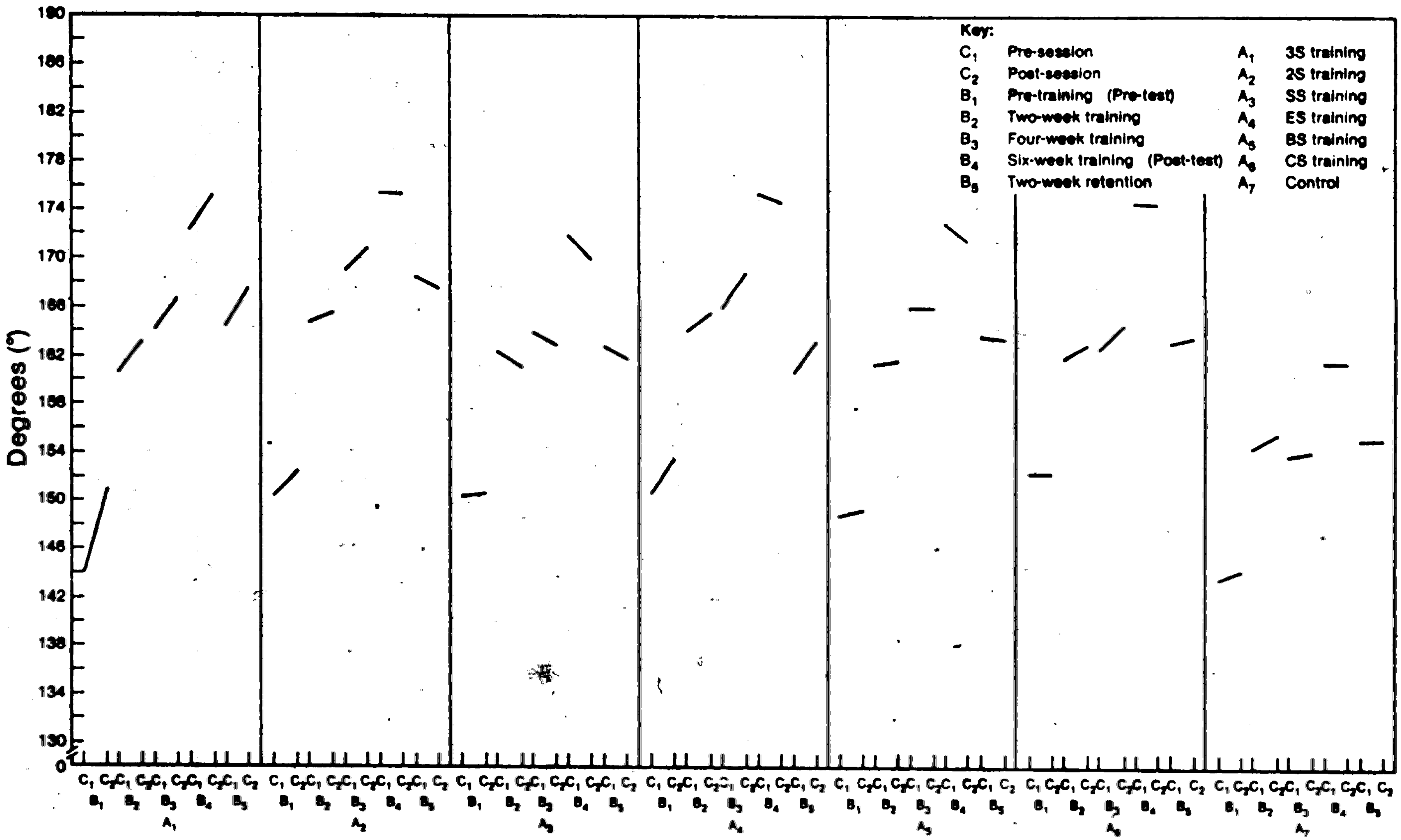

Figure 16. Mean flexibility scores for each treatment, week, and session on the shoulder joint.

TABLE 7

SCHEFFÉ POST-HOC CONTRASTS AMONG LEVELS OF FACTOR B (WEEK) ON THE SHOULDER DATA

Comparison	F Ratio
B_1, B_2 (Week 1, Week 2)	47.93*
B_1, B_3	69.25*
B_1, B_4	159.49*
B_1, B_5	56.74*
B_2, B_3	1.95
B_2, B_4	32.55*
B_2, B_5	0.37
B_3, B_4	18.55*
B_3, B_5	0.62
B_4, B_5	25.98*

* Significant ($p < 0.05$)

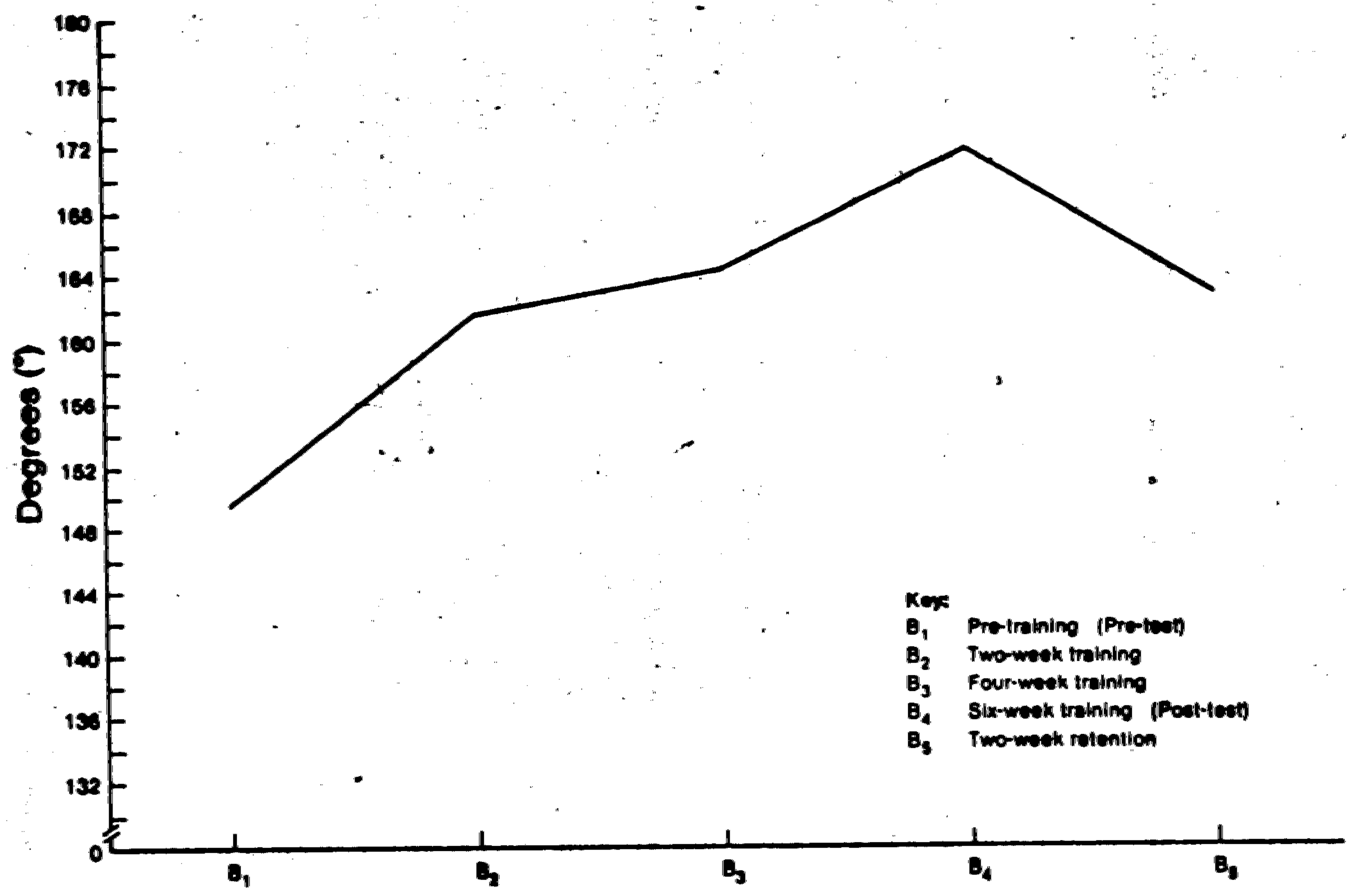

Figure 17. Mean flexibility scores for each week on the shoulder joint.

TABLE 8

SCHEFFE POST-HOC CONTRASTS AMONG LEVELS OF FACTOR C (SESSION) FOR GIVEN LEVELS OF FACTOR A (TREATMENT) ON THE SHOULDER DATA

Treatment	Comparison	F Ratio
A_1 (3S training)	C_1, C_2 (pre- and post-session)	13.46*
A_2 (2S training)	C_1, C_2	0.63
A_3 (SS training)	C_1, C_2	1.02
A_4 (ES training)	C_1, C_2	3.49
A_5 (BS training)	C_1, C_2	0.07
A_6 (CS training)	C_1, C_2	0.50
A_7 (control)	C_1, C_2	0.08

* Significant ($p < 0.05$)

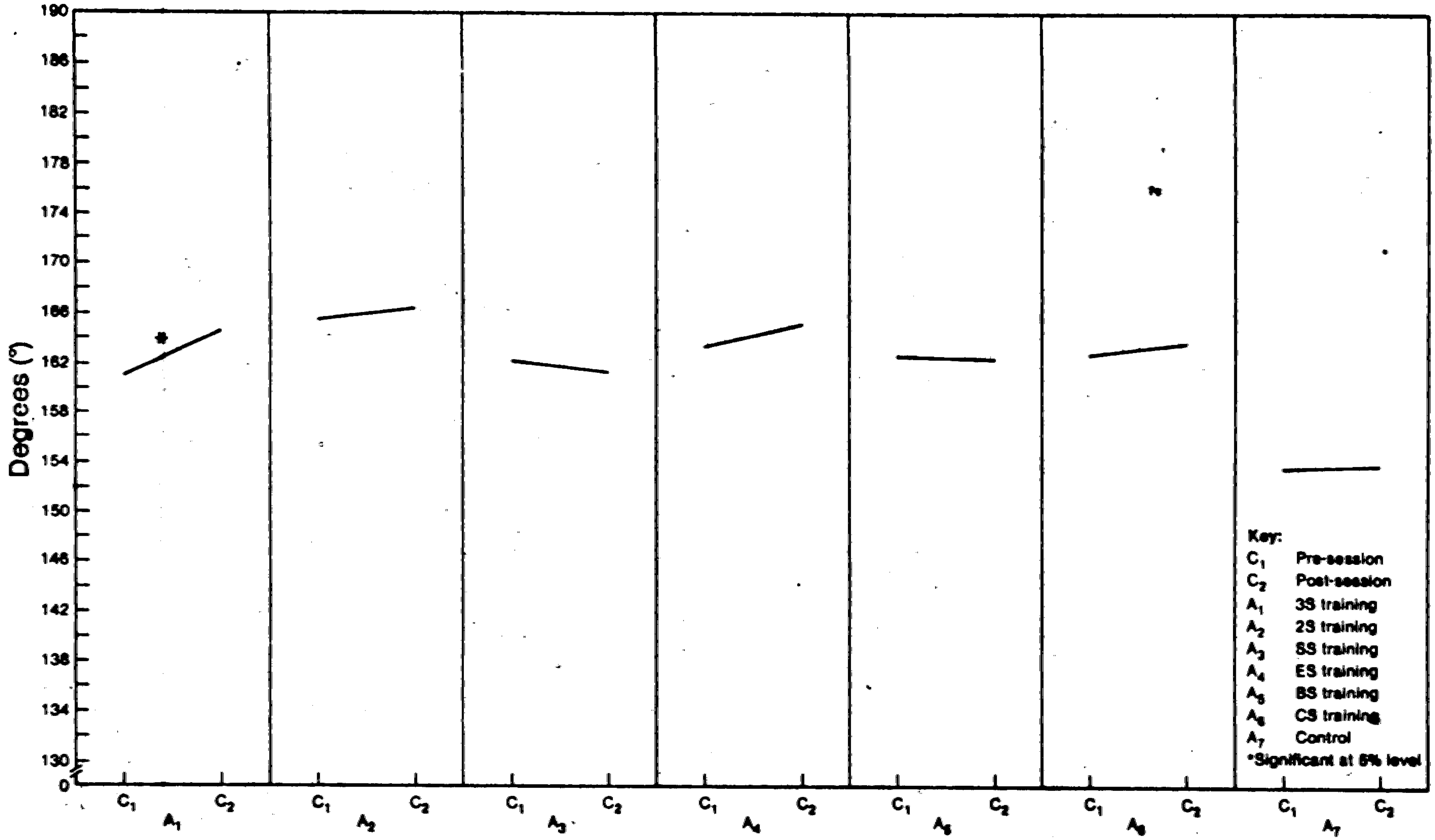

Figure 18. Mean flexibility scores within-session for each treatment on the shoulder joint.

Figure 18).

Discussion of Treatment Over Time

Analysis of the data on both the ankle and shoulder joints revealed no differential effect of treatments over the weeks of training when compared to the control group. There can be several explanations for this. First, control subjects training on one joint may have had a learning effect on the control joint; that is, the subject, after having worked on the other joint may have realized that she could extend the control joint even further. Second, the flexibility test itself may have had an effect on the control subjects' joints, since the control subjects received nine seconds of stretching on both joints within each test session. Third, all subjects including control subjects received 40 minutes of physical education per day during which volleyball classes were introduced between the beginning and second weeks and gymnastics classes between the fourth and sixth weeks. These physical activities required subjects to stretch the shoulder joint during the volleyball sessions (i.e., underhand bump skill) and increased both shoulder and ankle joint flexibility during the gymnastics sessions (i.e., floor routines). This may have had an effect on flexibility. The results showed that all groups increased in shoulder extension during the first two weeks and increased both shoulder extension and ankle plantar flexion for the last two weeks of training. During the fourth and fifth weeks there was no effect. Fourth, some control members were involved in an intramural program (e.g., volleyball), extramural program (e.g., gymnastics), or extra-curricular activities (e.g., competitive swimming). The nature of these activities again required subjects to stretch both ankle and shoulder joints maximally and this may have caused increased flexibility in the control group. Fifth, the amount of training each joint received may not have been of sufficient magnitude to cause major flexibility development. Each joint received 30 seconds of training per session, one-and-a-half minutes per week, three minutes every two-week test interval for a total of 12 minutes of training, over the entire six week training program. Perhaps both the ankle and shoulder joints needed sufficiently more time in flexibility training to allow for the mechanisms underlying change in range of motion to have a sustaining effect. Unfortunately, "there are no research studies which specify the minimal amount of time required for effective stretching" (Trombly and Scott, 1980, p. 226).

Past research revealed other studies which have shown that the control group increased joint range of motion over weeks of investigation. Tanigawa (1972) showed the control group increased in hip flexion. He attributed this result to the halo effect. Tanigawa explained this effect as being the result of passively extending the hip joint on each test occasion and that flexibility became a major concern of the control. Song and Garvie (1976) reported that the control group increased in flexibility on a number of tests, over four weeks of wrestling training. The control groups' gains in flexibility was attributed to regular stretching and wrestling training. Hartley (1976) showed improved range of motion for the hip joint for the control group. She believed the conditioning activities that the subjects underwent during daily physical education and test sessions influenced the control's joint scores. Turner (1977) observed control increased in flexibility throughout the entire study. He suggested the nature of the sport activity and athletes' active lifestyles influenced the control subjects' flexibility scores.

From present and past research, the control group's range of motion could have easily been affected by a number of extraneous variables. In addition, the time in joint sessional training may not have been of sufficient duration to cause a differential effect of treatments over the weeks of training when compared to the control group. The author suggests that future research on this area make two major adjustments. First, use different durations of time for training with none less than 30 seconds. Second, subjects chosen should have very little physical activity (e.g., sedentary 25-30 year olds). Moreover, research studies showing changes in range of motion, without comparison to a control group, cast serious doubt as to the effectiveness of the methods (e.g., de Vries, 1962 and McCue, 1952).

Joint differences for within-session training. The analyses on the ankle and shoulder data for factor C (within-session training) were not identical. A comparison of the ankle (Figure 13) and the shoulder (Figure 16) showed the responses for within-session training at each repeated measure were similar, with the exception of the fourth repeated measure on the shoulder joint. The graph (Figure 16) on the shoulder suggested that the subjects involved in the 2S, ES and CS methods reached a ceiling effect (175 degrees), while the 3S subjects did not encounter this problem. The ceiling effect may have accounted for some of the dissimilar results for the ankle and shoulder for within-session flexibility training.

Since the 3S method seemed to produce the greatest within-session flexibility increase in both the ankle and shoulder studies it is worthwhile to examine it a little more closely.

The following is a review of the scientific investigations pertaining to 3S training and a theoretical explanation on neural mechanisms underlying stretch training which may help explain the findings of the present study.

Scientific Investigations on 3S

Holt (1973) supported the effectiveness of increased range of motion for the 3S training method based on two research studies: Holt, Travis and Okita (1970) and Tanigawa (1972).

Holt, Travis and Okita (1970) studied the effects of three stretching techniques for increasing hip extension and low back flexibility. Fast-stretch (ballistic), slow-stretch, and IA-CA - a modified version of PNF. IA-CA is defined as an isometric contraction of the agonist (IA), followed by a concentric contraction of the antagonist (CA). Results showed that the IA-CA stretch technique had maximum effect on flexibility.

Tanigawa (1972) examined the effects of PNF and passive mobilization on passive range of motion for tight hamstring muscles. The investigation revealed that the PNF method of therapeutic exercise resulted in a significant increase in flexibility along with rate of increase compared to passive mobilization.

A close examination of the above procedures revealed these methods were distinctively different from the 3S procedure defined by Holt (1973). Holt et al. (1970) described the IA-CA method as

> E [partner] when assisting, did not push or apply force to the leg in any direction, but served merely as a stationary object against which S could apply force for contraction of the hip extensors (p. 614).

The 3S training method states that the partner, after a six second isometric contraction is to assist the subject with light force in the direction the subject is concentrically contracting the opposite muscle group to be stretched.

Tanigawa (1972) described the PNF technique as the therapist passively lifting the patient's limb through multiple plane and joint movements. The therapist served as an immovable object so that the patient could perform isometric contractions, followed by only passive extension of the joint. This method is not in accordance with Holt's 3S procedures.

Based on the above considerations, the methods described by Holt et al. (1970) and Tanigawa (1972) are very different from the procedures defined as 3S training. The relative effectiveness of IA-CA training and the PNF techniques respectively, cannot be generalized to the 3S training method.

Since the claims made by Holt (1973), additional research on 3S training methods has been undertaken (Song and Garvie, 1976 and Turner, 1977).

Song and Garvie (1976) compared the flexibility of wrestlers using the 3S flexibility method, with that of a control group receiving no 3S training. The experimental group significantly increased in range of motion for two of 19 tests, when compared to control. The description of the 3S training procedures revealed the omission of an important step - concentric contraction of the opposite muscle group together with light pressure from partner. Song and Garvie's method was:

> . . . method of increasing range of motion involves passively extending a muscle group close to the maximum and then, against a fixed resistance, isometrically contracting this muscle group while in the extended position for 5 to 7 second period. Following the contraction the muscle group is relaxed and once relaxed, further extension of the particular group is possible (p. 18).

Turner (1977) examined the effects of two flexibility methods, 3S and SS. The results showed flexibility training increased flexibility over weeks of training and flexibility decreased following post-training, when compared to control. There was no difference between the 3S and SS training methods during the course of the study. The 3S method employed accurately followed Holt's 3S standard procedures.

A comparison of the past research to the present study showed that only one study (Turner, 1977) followed Holt's

(1973) 3S training procedures. Since Turner did not examine within-session training, comparison was not made. Moreover, the present study found almost identical methods (e.g., 3S and CS training) did not produce the same significant effect. Based on this finding, comparison of similar methods in past research with dissimilar procedures was not warranted.

Theoretical Explanation

Herman Kabat, a medical doctor, originally drafted the proprioceptive neuromuscular facilitation (PNF) principles followed by techniques and methods of exercise to restore strength, endurance and range of motion in muscles of patients suffering from paralysis (e.g., poliomyelitis). The central goal of the PNF techniques was to maximally activate all functional motor units of the affected muscle during a voluntary muscular contraction (motion). The PNF techniques were defined by Kabat as being the following:

1) manual resistance,
2) stretch,
3) mass movement patterns,
4) reflexes, and
5) reversal of antagonist.

A number of PNF methods were combined in various ways for summation of facilitation effect. Kabat utilized the following PNF methods:

1) rhythmic stabilization,
2) isometric reversal of antagonist,

3) isometric reversal of antagonists with isometric contraction, and

4) quick reversal of antagonists.

Kabat pointed out that specific methods may prove more or less effective depending on the nature of the paralysis. For example, rhythmic stabilization is effective in patients with lower motor neuron lesions and lesions of the corticospinal tracts and basal ganglia. However, patients with cerebellar involvement were not affected by rhythmic stabilization.

In specific reference to the development of greatest flexibility, Kabat recommended that the therapist move the joint beyond the active range of motion and the subject perform a maximal isometric contraction (Kabat, 1952).

Following Kabat's work, Voss, D. and Knott, M., a team of physical therapists inspired by Kabat, extended the application and procedures of the PNF technique to patients suffering from non-paralytic dysfunction (e.g., arthritic patients) as well as paralytic dysfunction. Voss herself became a living example of the effectiveness of the PNF therapeutic exercise, as she successfully treated her own disability (Knott, 1973).

Voss (1967), with Knott's assistance standardized a method of therapeutic exercise derived from Kabat's earlier work. The new PNF method contained a number of factors:

1) manual contact,

2) vocal tones,

3) maximal contraction against resistance, and

4) passive and active extension.

Voss supported the use of the PNF technique(s) as they were based on well-grounded information from motor learning, neurophysiology, and motor behavior - research and clinical findings.

Subsequently, Holt appealed to individuals requiring increased range of motion to use the 3S flexibility training method. He suggests it is the only sport training method based on Herman Kabat's PNF (proprioceptive neuromuscular facilitation) therapeutic principles, and as a result is a firmly accepted neurophysiological fact.

Recently, researchers have begun to doubt Kabat's theoretical explanation of the advantages of PNF methods over other procedures which are entrenched in classical Sherringtonian views concerning successive inductive and reciprocal inhibition (Moore and Hutton, 1980). Furthermore, they stated, "the simplistic notion concerning reciprocal inhibition during muscle stretch should be discarded" (p. 327).

A review of selected literature suggested there are three major neural mechanisms (reciprocal inhibition, clasp knife reflex and successive induction) which may underlie the different flexibility training methods.

Reciprocal inhibition causes the antagonists (muscles opposing the contraction) to relax and lengthen, while the agonists (muscles contracting) shorten. For example, to move the forearm the biceps must contract, simultaneously the triceps must relax (Eccles, Fatt, and Landgren, 1956).

Clasp knife reflex causes the collapse of the muscles when various muscles or tendons are subjected to extensive force. For example, when a subject's arm becomes hyperextended during a football tackle, the muscles surrounding the shoulder joint collapse to help protect against injury (Rymer, Houk, and Crago, 1979).

Successive induction is the contraction of the muscles to be stretched (antagonists). Following successive induction, the muscles will be able to be further stretched, due to increased relaxation of the stretched muscle (Moore and Hutton, 1980) and a more forceful agonist contraction is facilitated (Holt, Kaplan, Okita, and Hoshika, 1969).

The present study revealed that the 3S training method was the most effective in increasing range of motion, across the ankle and shoulder joints, for within-session training. A comparison of almost identical methods (3S and CS training) on neural muscular mechanisms helped to explain the results.

The 3S and CS are identical, with one exception. In step four, 3S required both a concentric contraction with external force from a partner; while CS required only concentric contraction (Table 9). The 3S method activated both the reciprocal inhibition and clasp knife reflex, while CS method activated only reciprocal inhibition. The neural mechanisms underlying 3S training (reciprocal inhibition, clasp knife reflex and successive induction) suggested a possible explanation for the superiority of the 3S flexibility training method.

Within the scope of this study, it cannot be accurately determined which underlying neural mechanisms or other mechanisms caused the change in range of motion for each training method.

TABLE 9

NEURAL MECHANISMS UNDERLYING TRAINING METHODS

Method	Procedures	Neural Mechanisms	Effective Ankle	Effective Shoulder
3S	1. 2 sec concentric contraction	(RI)	*	*
	2. 6 sec isometric contraction	(SI)		
	3. 2 sec concentric contraction and external force	(RI & CK)		
2S	1. 2 sec passive extension	(CK)	*	
	2. 8 sec held passive extension	(CK)		
SS	1. 2 sec concentric contraction	(RI)		
	2. 8 sec isometric contraction	(RI)		
ES	1. 5 sec eccentric contraction	(SI)	*	
	2. 5 sec passive extension	(CK)		
BS	1. 1 sec concentric contraction (x 10)	(RI)		
CS	1. 2 sec concentric contraction	(RI)	*	
	2. 6 sec isometric contraction	(SI)		
	3. 2 sec concentric contraction	(RI)		

RI: reciprocal inhibition
CK: clasp knife reflex
SI: successive induction
*: significant ($p < 0.05$)

Future Research

It is recommended that future research be conducted on the mechanisms affecting range of motion. Once this is undertaken, a clearer understanding as to why particular methods enhance, retard, or do not affect flexibility will emerge. In addition, training methods superior to the 3S training technique used in the present investigation may also emerge.

Summary

The major finding and contributions of this study were as follows:

1) Scientific Stretching for Sport (3S) was the only training method that consistently increased range of motion on both ankle plantar flexion and shoulder extension for within-session training.
2) Six different standardized flexibility training methods (3S, 2S, SS, ES, BS, and CS) for ankle plantar flexion and shoulder extension were developed.
3) A modified Leighton Flexometer test method for ankle plantar flexion and shoulder extension was developed.

CHAPTER V

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Summary

Even though flexibility has been recognized as being important in training and conditioning, and many years have been spent in examining the various joint flexibility responses to different stretching techniques, it is apparent from the literature that there is no universally accepted method of stretch training. This study investigated the effects of six different standardized stretch training methods on active flexibility for shoulder extension and ankle plantar flexion. The different training methods were: 1) 3S (concentric, isometric and concentric contractions with external force), 2) 2S (passive extension), 3) SS (concentric and isometric contractions), 4) ES (eccentric contraction and passive extension), 5) BS (concentric contraction), and 6) CS (concentric, isometric and concentric contractions). Forty-two female volunteer students ranging in age from 12 to 14 years were selected as subjects. Test-orientation and training-orientation sessions were followed by a six week flexibility training program and a two week post-training retention period. The modified Leighton Flexometer was utilized to test active range of motion for the ankle and shoulder joints.

The research design consisted of two 7 x 5 x 2 (treatment, week, and session) factorial designs with repeated measures on the last two factors. Data was analyzed using two three-way analyses of variance (Greenhouse-Geisser test-on repeated measures) and post-hoc Scheffé test ($\alpha = 0.05$). The ankle and shoulder data were analyzed independently.

Conclusions

Within the scope of this study, the following conclusions were reached for ankle plantar flexion and shoulder extension.

Ankle plantar flexion. 1) The 3S, 2S, ES and CS flexibility training methods significantly increased ankle plantar flexion within-session training ($p < 0.05$).

2) The 3S training method increased ankle plantar flexion significantly more than CS training for within-session training ($p < 0.05$).

Shoulder extension. 1) The 3S training method significantly increased shoulder extension for within-session training ($p < 0.05$).

Comparison across joints. 1) The 3S training method consistently increased range of motion in both ankle plantar flexion and shoulder extension for within-session training ($p < 0.05$).

2) The SS and BS training methods consistently showed no increase in range of motion in both ankle plantar flexion and shoulder extension for within-session training ($p > 0.05$).

3) The changes in range of motion for ankle plantar flexion were not identical to changes in shoulder extension, over

the eight week period of time.

Recommendations

For further investigation, it is recommended that the present study be replicated using:

1) different age levels, ability levels, and sport and fitness groups (e.g., sedentary 25 to 30 year olds),
2) different numbers of repetitions, sets and frequencies,
3) different amounts of time for work and rest intervals,
4) an investigation on the immediate retention effects of flexibility (e.g., 30 seconds, one minute, and fifteen minutes), and
5) an examination of specific factors underlying all flexibility methods (e.g., external and internal forces).

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APPENDIX A

FLEXIBILITY TRAINING METHODS

SCIENTIFIC STRETCH FOR SPORT TRAINING

(3S)

Definition

This is a method of increasing flexibility whereby an isometric contraction of the muscles to be stretched (muscles in a lengthened position to start) is followed by a concentric contraction of the opposite muscle group, together with light force from a partner (external force), performed in a progressively more strenuous series until the range of movement cannot be increased without severe pain (Holt, 1973, pp. 5-7).

Explanation

A maximal range of motion is attained by actively and passively flexing or extending a segment nearest to the joint being trained, in an arc, as far as possible. Repetitions of the exercise are performed, without severe pain. One repetition consists of:

a) two second concentric contraction,

b) six second isometric contraction, and

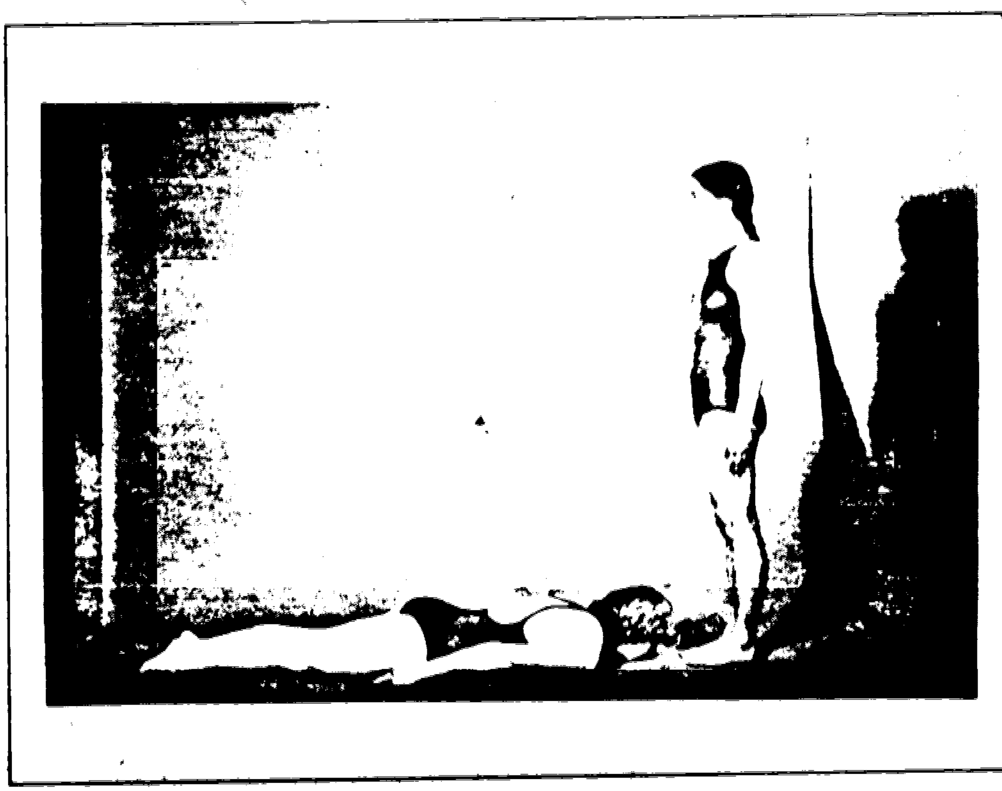
c) two second concentric contraction, with light force from a partner.

Subject repeats the above exercise (rest optional). The contractions performed by the exercise subject must be gradually, not explosively, increased in effort.

(3S)

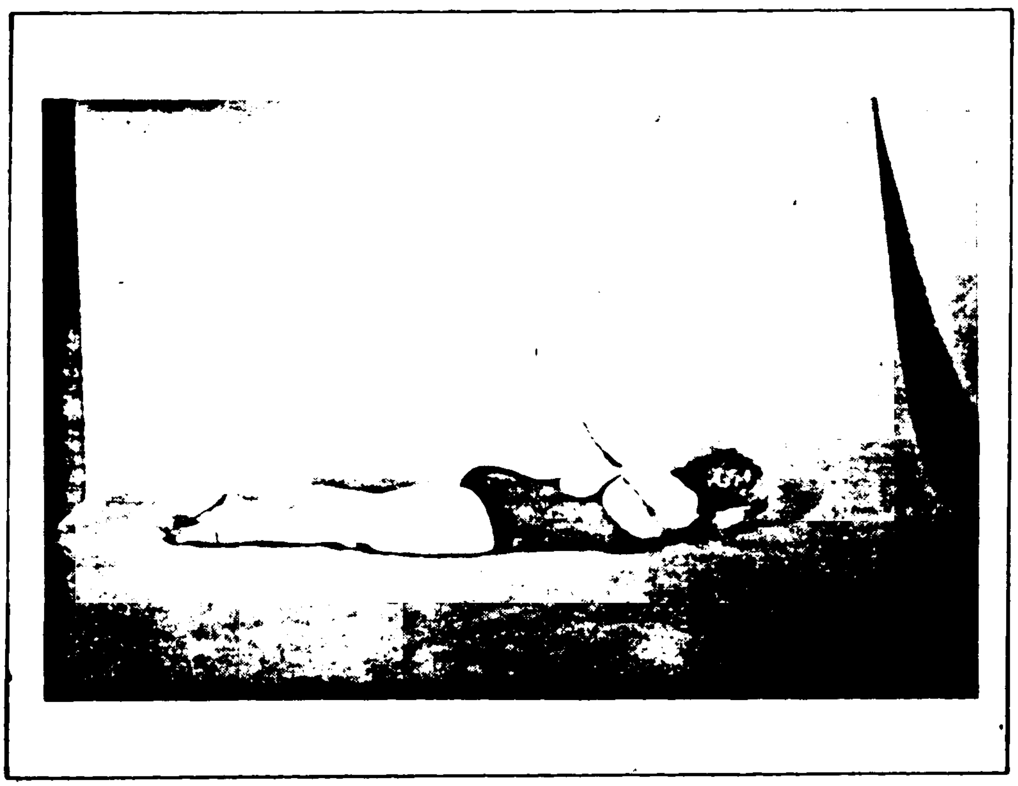
Shoulder Extension Exercise (Stretching Shoulder Flexors)

Step 1. Subject (S) assumes a prone position on the floor, legs and back straight, arms down at sides, with hands supinated. Partner (P) stands in front of S, in an anatomical position.



(3S)

Step 2. Subject's (S's) training arm is extended, in an arc, at the shoulder joint as far as possible, with hand in a neutral position, for a vocal count of two (seconds).



(3S)

Step 3. Partner (P) flexes at the hips, holding S's arm proximal to the wrist. S attempts to flex the arm, while keeping the elbows straight. P resists S's movement. P holds S's position for a vocal count of six (seconds) to produce an isometric contraction.

(3S)

Step 4. Subject (S) again fully extends the arm for a vocal count of two (seconds) keeping the elbow straight (1st), together with light force from P (2nd), so that S attains the maximum extended range of motion in the shoulder joint, without severe pain.

(3S)

<u>Step 5.</u> Subject (S) relaxes for a vocal count of fifteen (seconds) (step 1), then repeats steps two, three, and four. The exercise is performed three consecutive times.

(3S)

Ankle Plantar Flexion Exercise (Stretching Ankle Flexors)

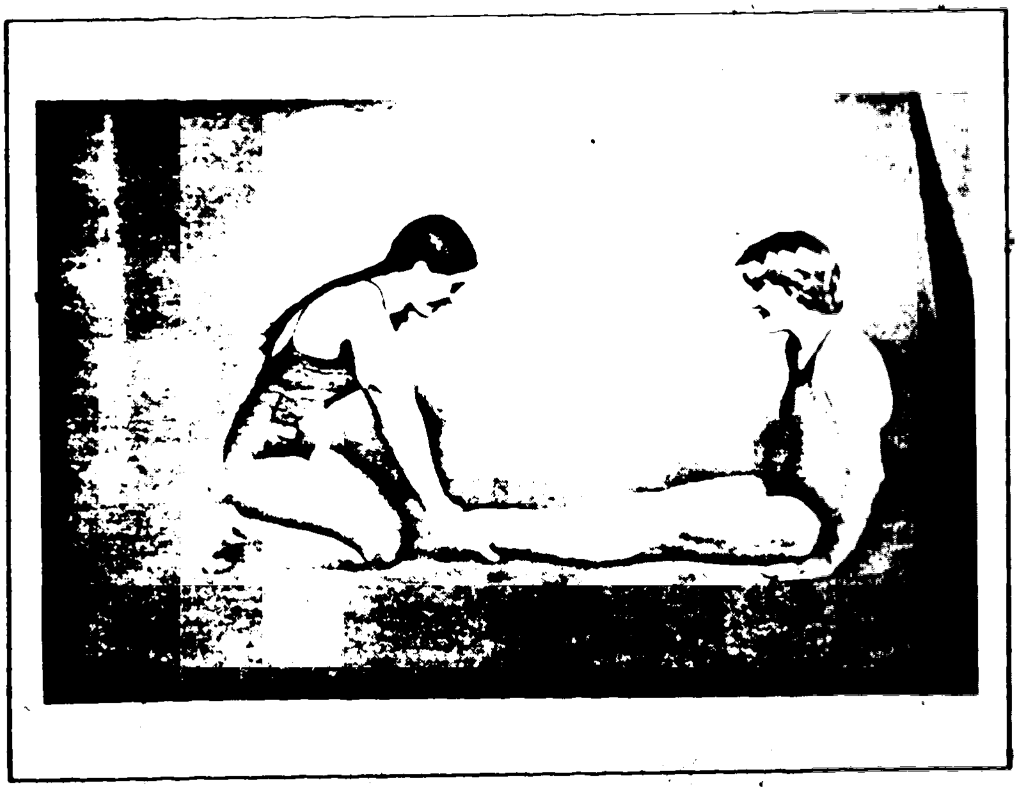
Step 1. Subject (S) assumes a sitting position on the floor, legs and back straight, arms at sides, with hands pronated. Partner (P) kneels in front of S, in a partial anatomical position.

(3S)

Step 2. Subject's (S's) training feet are plantar flexed, in an arc, at the ankle joint, as far as possible, for a vocal count of two (seconds).

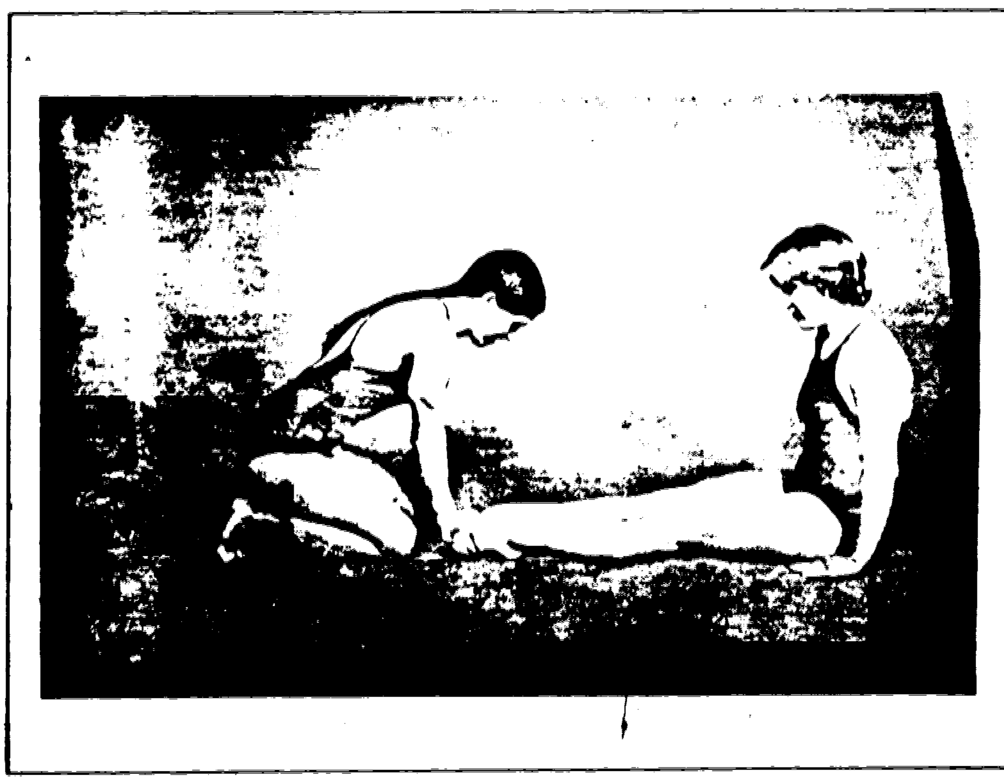
(3S)

<u>Step 3.</u> Partner (P) flexes at the hips, holding S's feet distal to the ankles. S attempts to dorsi-flex the feet, while keeping the knees straight. P resists S's movement. P holds S's position for a vocal count of six (seconds) to produce an isometric contraction.



(3S)

Step 4. Subject (S) again fully plantar flexes the feet for a vocal count of two (seconds) keeping the knees straight (1st), together with light force from P (2nd), so that S attains the maximum flexed range of motion in the ankle joint, without severe pain.



(3S)

Step 5. Subject (S) relaxes for a vocal count of fifteen (seconds) (step 1), then repeats steps two, three, and four. The exercise is performed three consecutive times.

STATIC STRETCH TRAINING

(2S)

Definition

This is a method of increasing flexibility whereby an external force (i.e., hands pulling the segment) is applied in a progressively more forceful manner, until the range of movement cannot be increased, then held for a period of time, without severe pain (de Vries, 1976, pp. 436-437).

Explanation

A maximal range of motion is attained by passively flexing or extending a segment nearest to the joint being trained, in an arc, as far as possible. Repetitions of the exercise are performed without severe pain. One repetition consists of:

a) two second passive extension, and

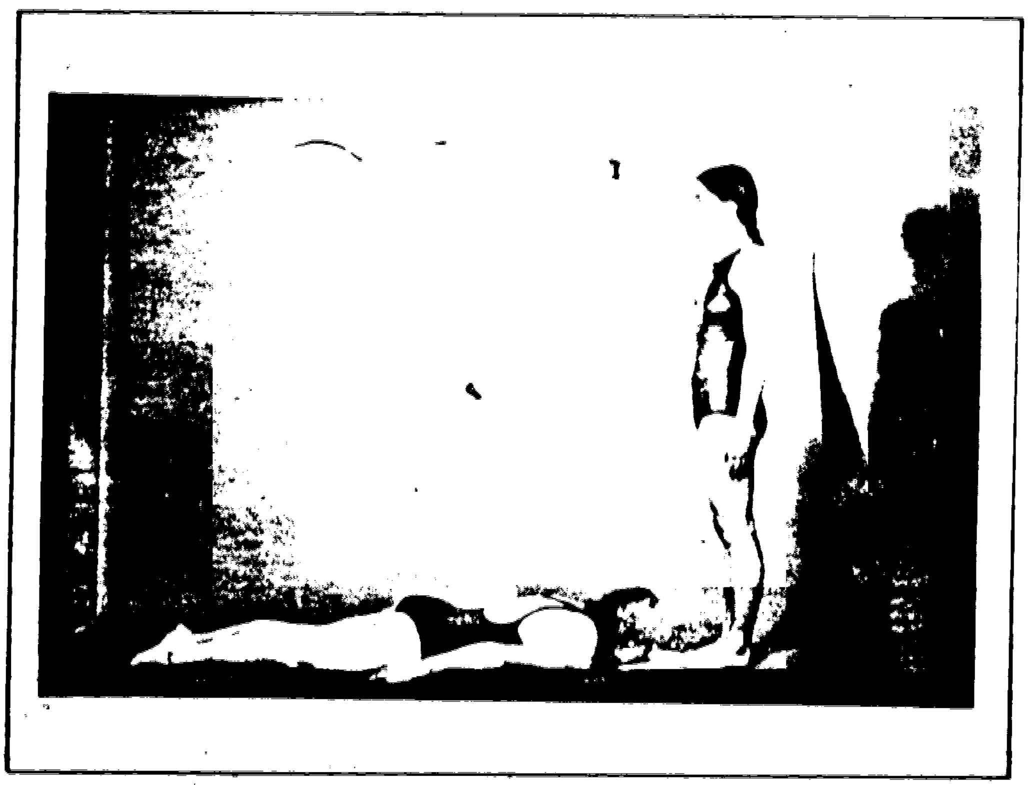
b) eight second held passive extension.

Subject relaxes for fifteen seconds before repeating each exercise. The external force applied to extend the segment is gradually, not explosively, increased in effort.

(2S)

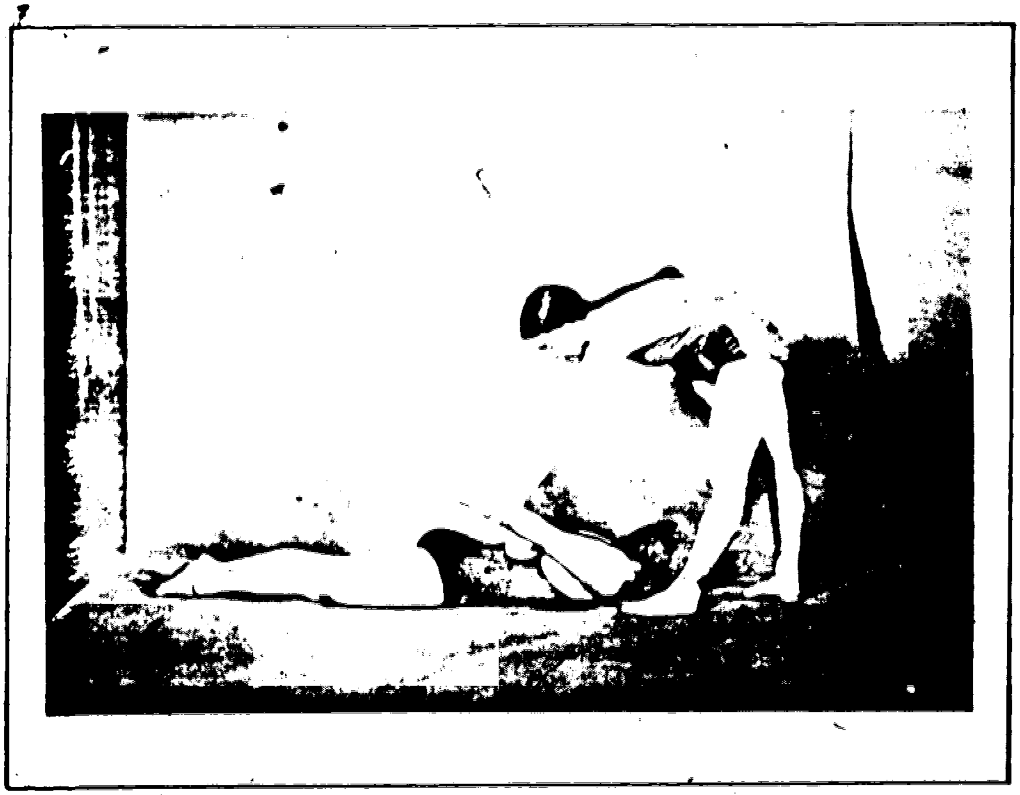
Shoulder Extension Exercise (Stretching Shoulder Flexors)

Step 1. Subject (S) assumes a prone position on the floor, legs and back straight, arms down at sides, with hands supinated. Partner (P) stands in front of S, in an anatomical position.



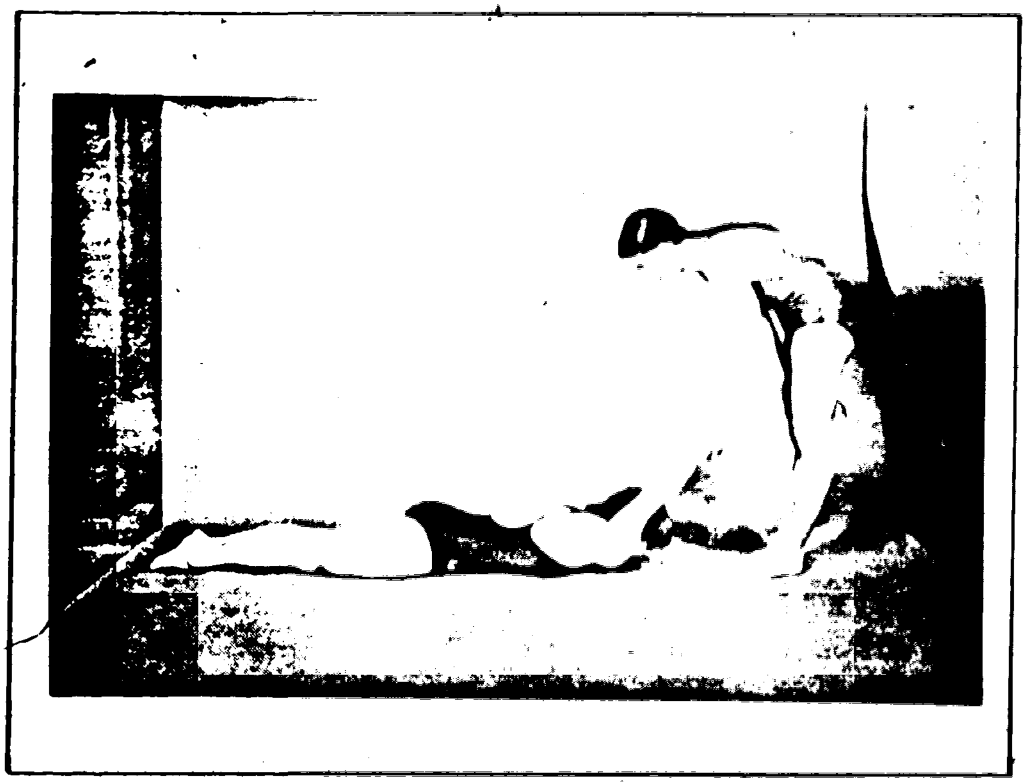
(2S)

<u>Step 2.</u> Partner (P) flexes at the hips, holding S's arm proximal to the wrist. S relaxes the shoulder, keeping the elbow extended, hand in a neutral position, while P passively extends the arm for a vocal count of two (seconds).



(26)

Step 3. Partner (P) fully extends the arm, without severe pain, and this position is held for a vocal count of eight (seconds).



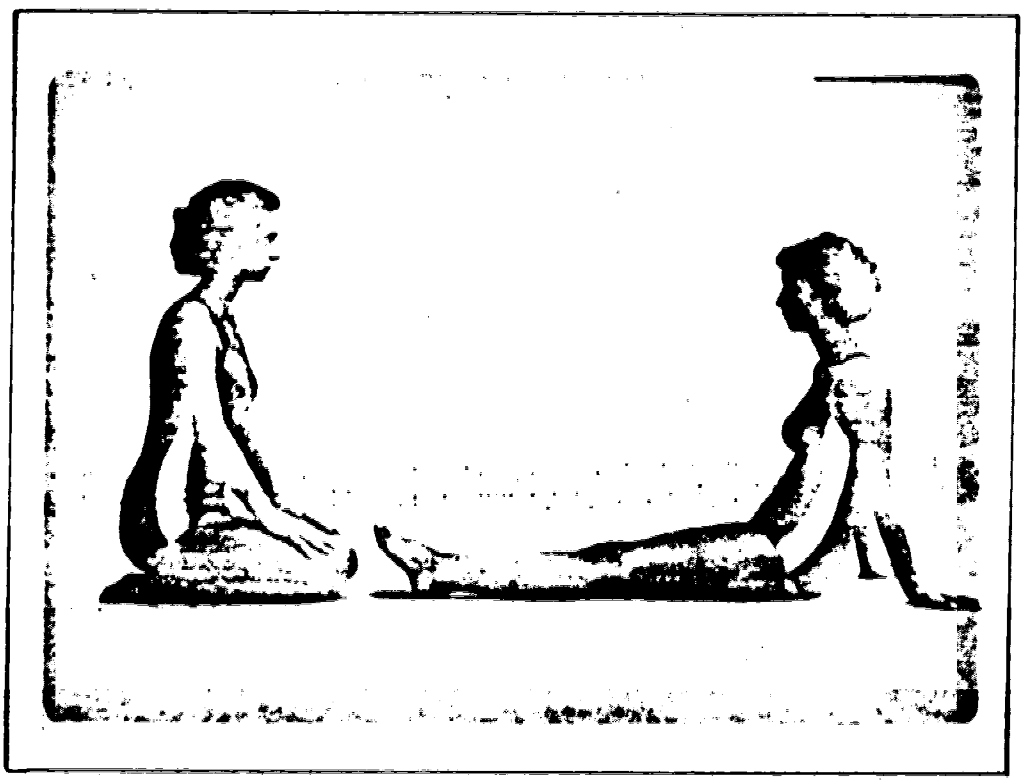
(2S)

<u>Step 4.</u> Subject (S) relaxes for a vocal count of fifteen (seconds) (step 1), then repeats step two and three. The exercise is performed three consecutive times.

(2S)

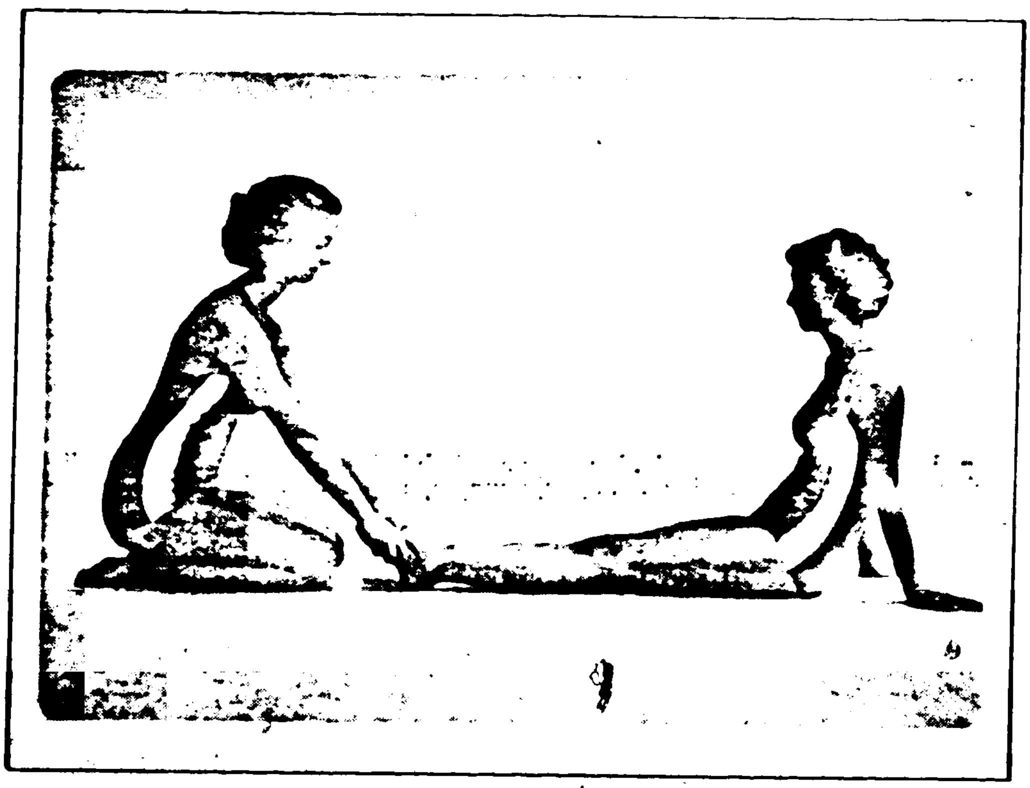
Ankle Plantar Flexion Exercise (Stretching Dorsal Flexors)

Step 1. Subject (S) assumes a sitting position on the floor, legs and back straight, arms at sides, with hands pronated. Partner (P) kneels in front of S, in a partial anatomical position.



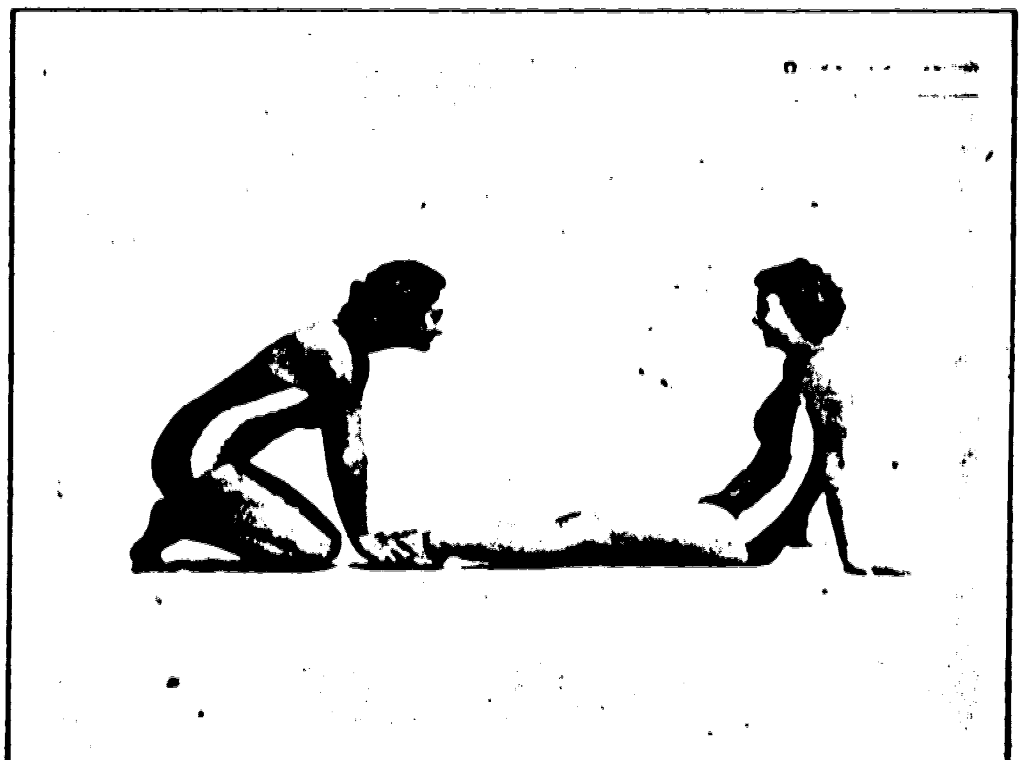
(2S)

Step 2. Partner (P) flexes at the hips, holding S's feet distal to the ankle. S relaxes the ankle, keeping the knees extended, while P passively extends the feet for a vocal count of two (seconds).



(2S)

Step 3. Partner (P) fully extends the feet, without severe pain, and this position is held for a vocal count of eight (seconds).



(2S)

Step 4. Subject (S) relaxes for a vocal count of fifteen (seconds) (step 1), then repeats steps two and three. The exercise is performed three consecutive times.

SLOW ACTIVE STRETCH TRAINING

(SS)

Definition

This is a method of increasing flexibility by slow active concentric contraction of the agonist muscles, without additional assistance from an external force (i.e., hands pulling the segment to a greater range of motion), while relaxing the antagonist muscle group (the muscles to be stretched) (Jacobs, 1976, pp. 151-152).

Explanation

A maximal range of motion is attained by actively flexing or extending a segment nearest to the joint being trained, in an arc, as far as possible. Repetitions of the exercise are performed, without severe pain. One repetition consists of:

a) two second concentric contraction, and

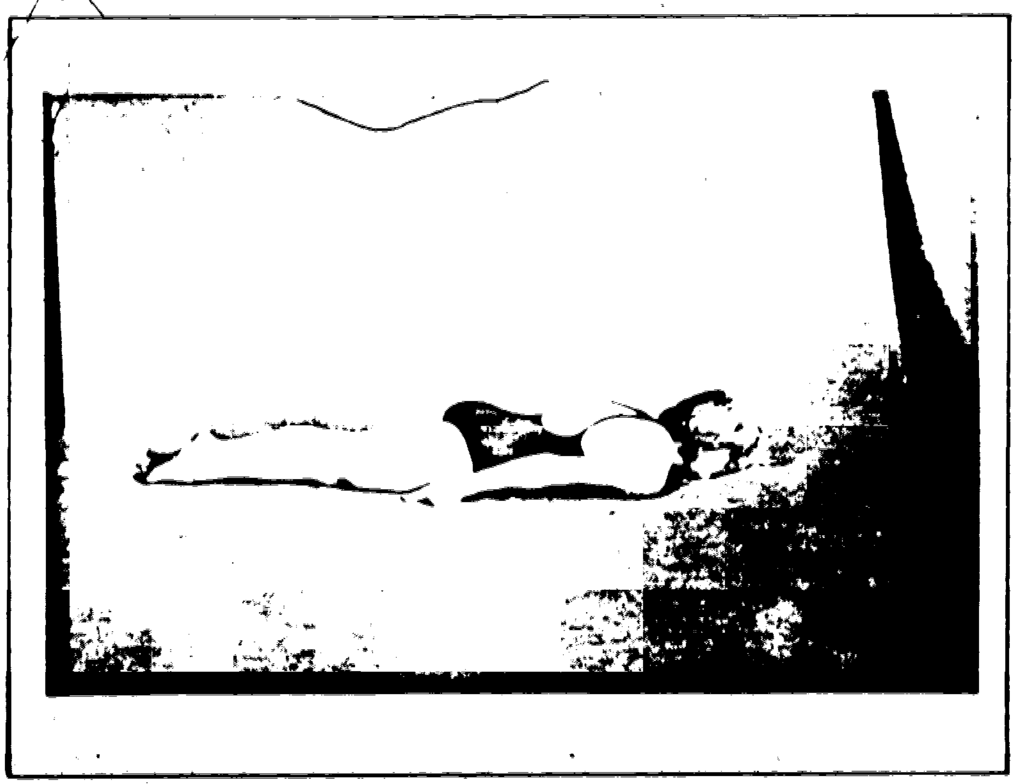
b) eight second isometric contraction.

Subject relaxes for fifteen seconds before repeating each exercise. The contractions performed by the subject must be gradually, not explosively, increased in effort.

(SS)

Shoulder Extension Exercise (Stretching Shoulder Flexors)

Step 1. Subject (S) assumes a prone position on the floor, legs and back straight, arms down at sides, with hands supinated.



(SS)

Step 2. Subject's (S's) training arm is extended, in an arc, at the shoulder joint, as far as possible for a vocal count of two (seconds), then this position is held for a vocal count of eight (seconds). The subject's elbow is extended, with hand in a neutral position.

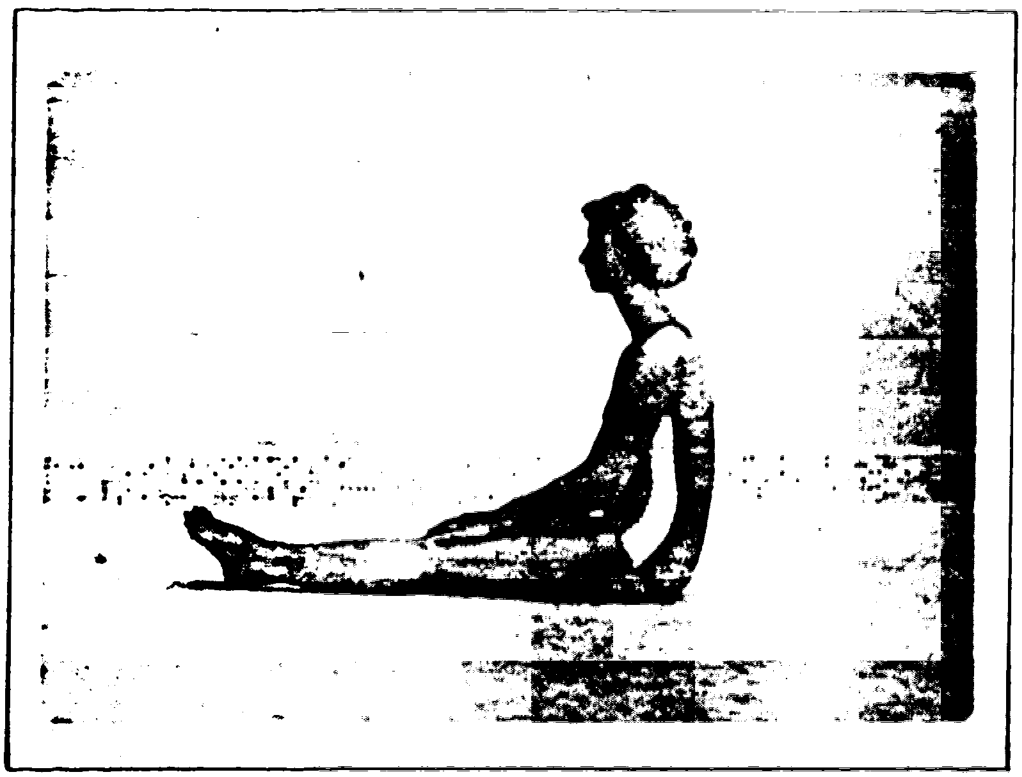
(SS)

<u>Step 3.</u> Subject (S) relaxes for a vocal count of fifteen (seconds) (step 1), then repeats step two. The exercise is performed three consecutive times.

(SS)

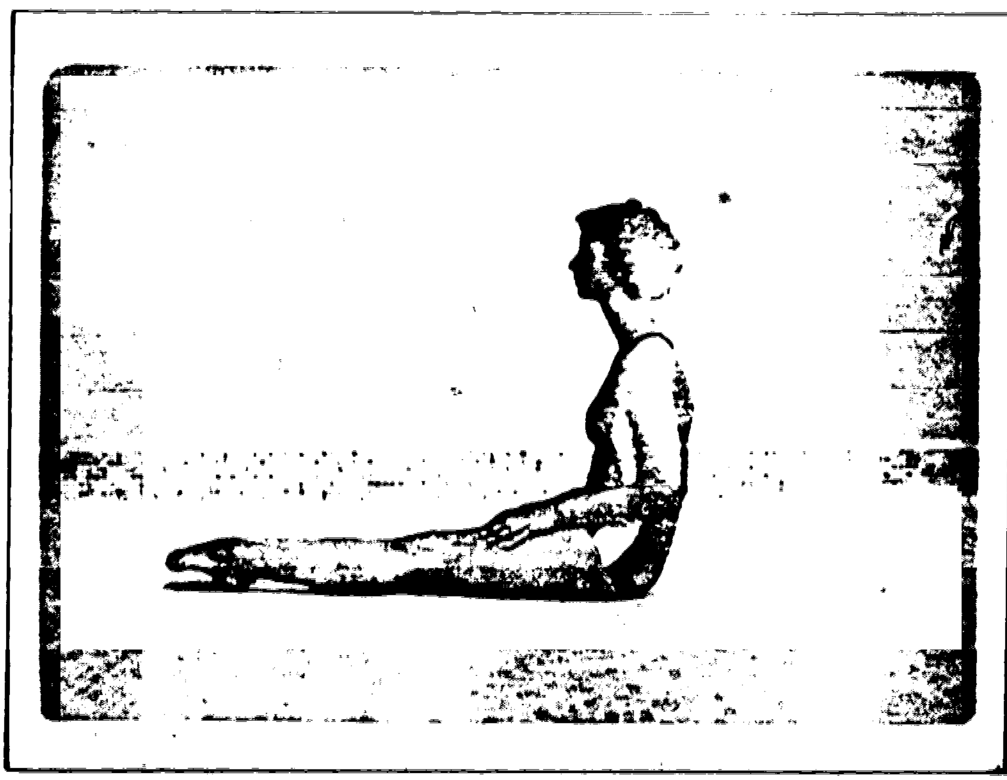
Ankle Plantar Flexion Exercise (Stretching Dorsal Flexors)

Step 1. Subject (S) assumes a sitting position on the floor, legs and back straight, arms at sides, with hands pronated.



(SS)

Step 2. Subject's (S's) training feet are plantar flexed in an arc, at the ankle joint, as far as possible, for a vocal count of two (seconds), then this position is held for a vocal count of eight (seconds).



(SS)

Step 3. Subject (S) relaxes for a vocal count of fifteen (seconds) (step 1), then repeats step two. The exercise is performed three consecutive times.

ECCENTRIC STRETCH TRAINING

(ES)

Definition

This is a method of increasing flexibility whereby a slow active eccentric contraction of the muscles to be stretched (muscles in a contracted position to start) is followed by light force from a partner (external force), while the subject relaxes both agonist and antagonist muscles around the joint.

Explanation

A maximal range of motion is attained by actively flexing or extending a segment nearest to the joint being trained, in an arc, as far as possible. Repetitions of the exercise are performed, without severe pain. One repetition consists of:

a) five second eccentric contraction, and

b) five second passive extension.

Subject relaxes for fifteen seconds before repeating each exercise. The contraction and passive extension performed by the subject must be gradually, not explosively, increased in effort.

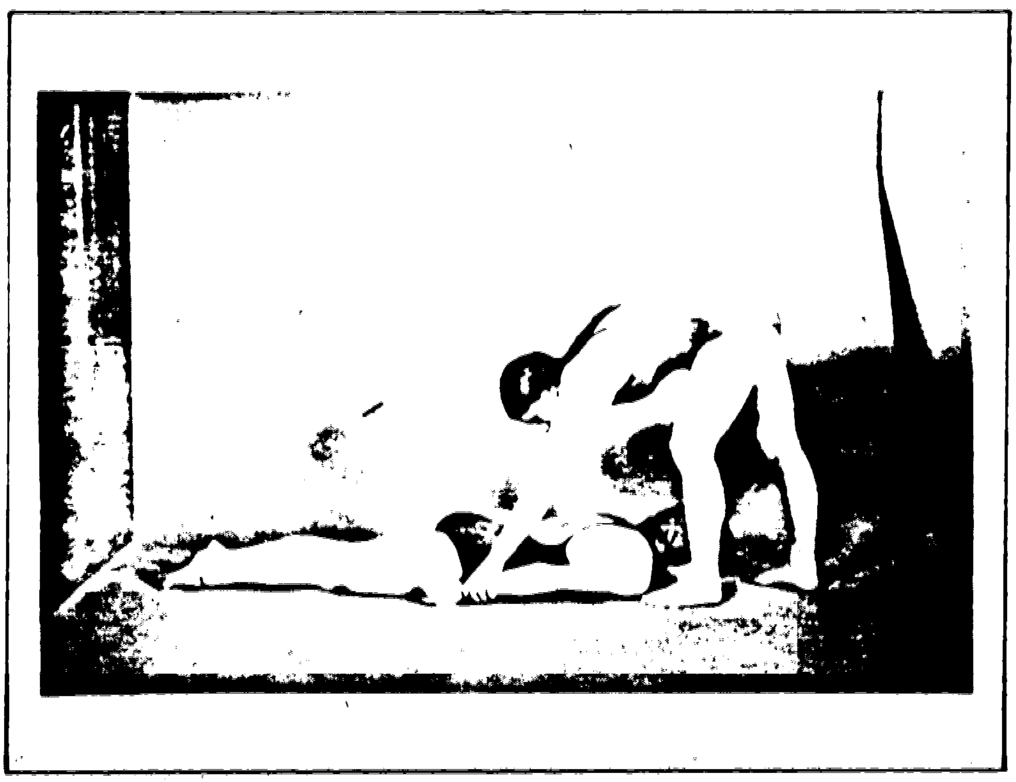
(ES)

Shoulder Extension Exercise (Stretching Shoulder Flexors)

Step 1. Subject (S) assumes a prone position on the floor, legs and back straight, arms at sides, with hands supinated. Partner (P) stands in front of S, in an anatomical position.

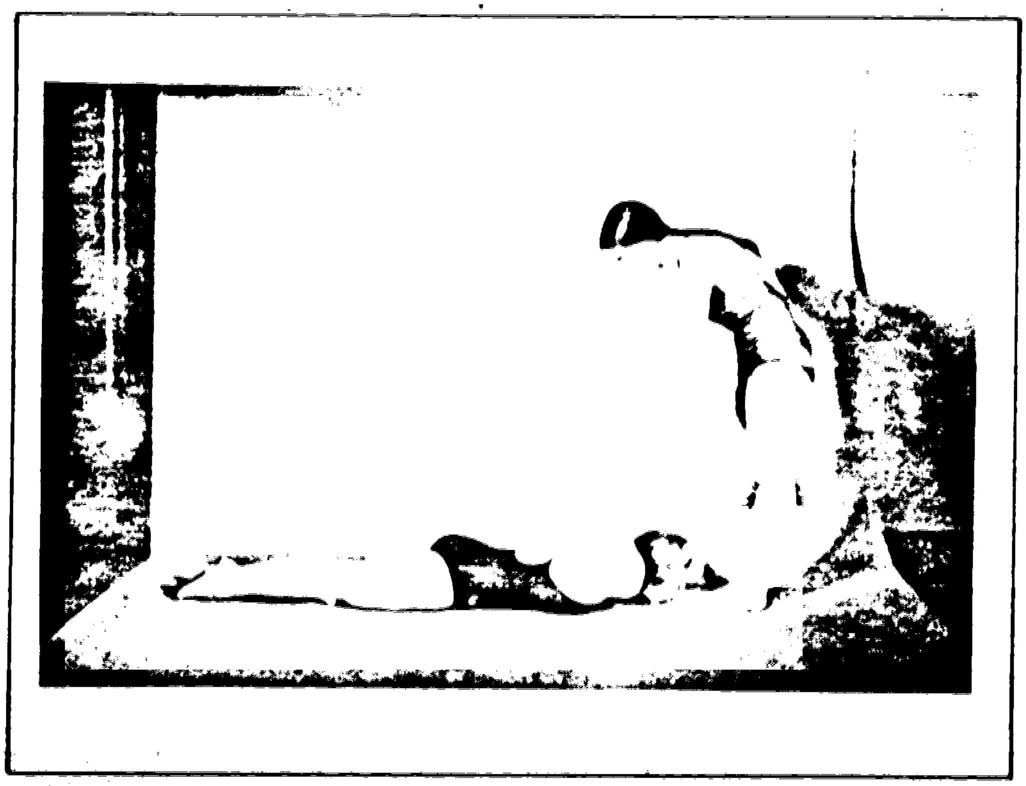
(ES).

Step 2. Partner (P) flexes at the hips, holding S's arm proximal to the wrist.



(ES)

Step 3. Subject (S) attempts to flex the arm, while keeping the elbow straight, with hand in a neutral position. P, with greater force, extends S's arm, in an arc, as far as possible, without severe pain, for a vocal count of five (seconds).



(ES)

<u>Step 4.</u> Subject (S) relaxes, while P passively extends S's arm, as far as possible, keeping the elbow straight, with hand in a neutral position, for a vocal count of five (seconds).

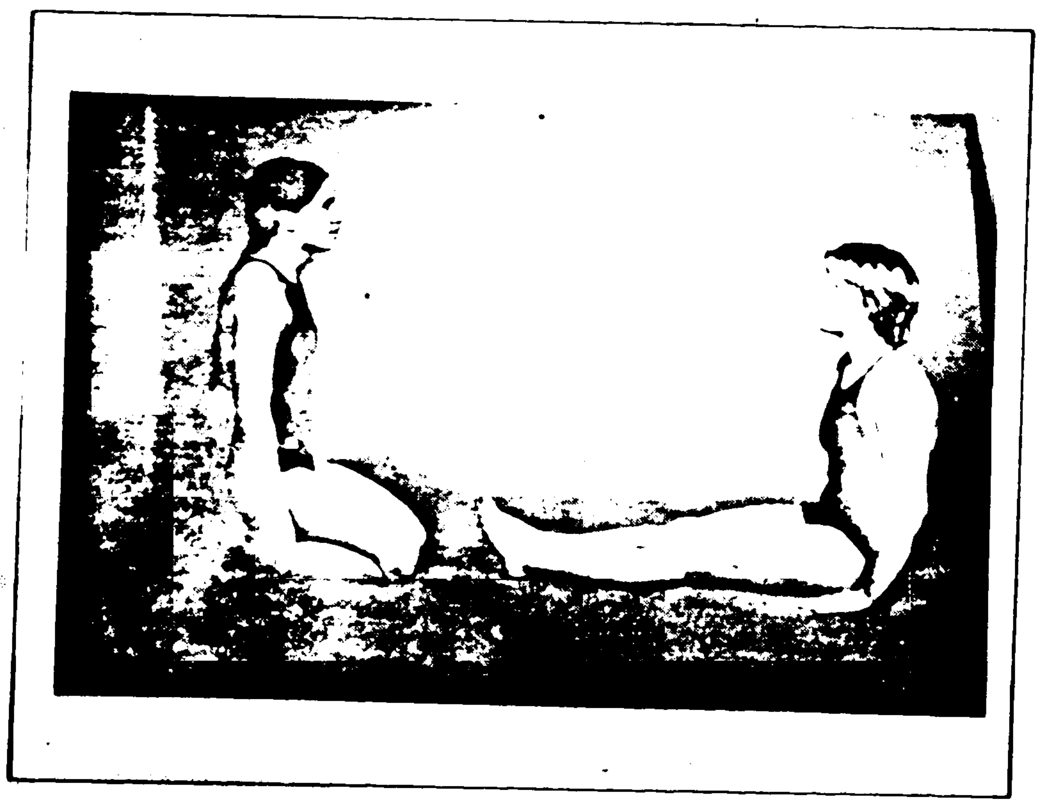
(ES)

Step 5. Subject (S) relaxes for a vocal count of fifteen (seconds), then repeats steps two, three and four. The exercise is performed three consecutive times.

(ES)

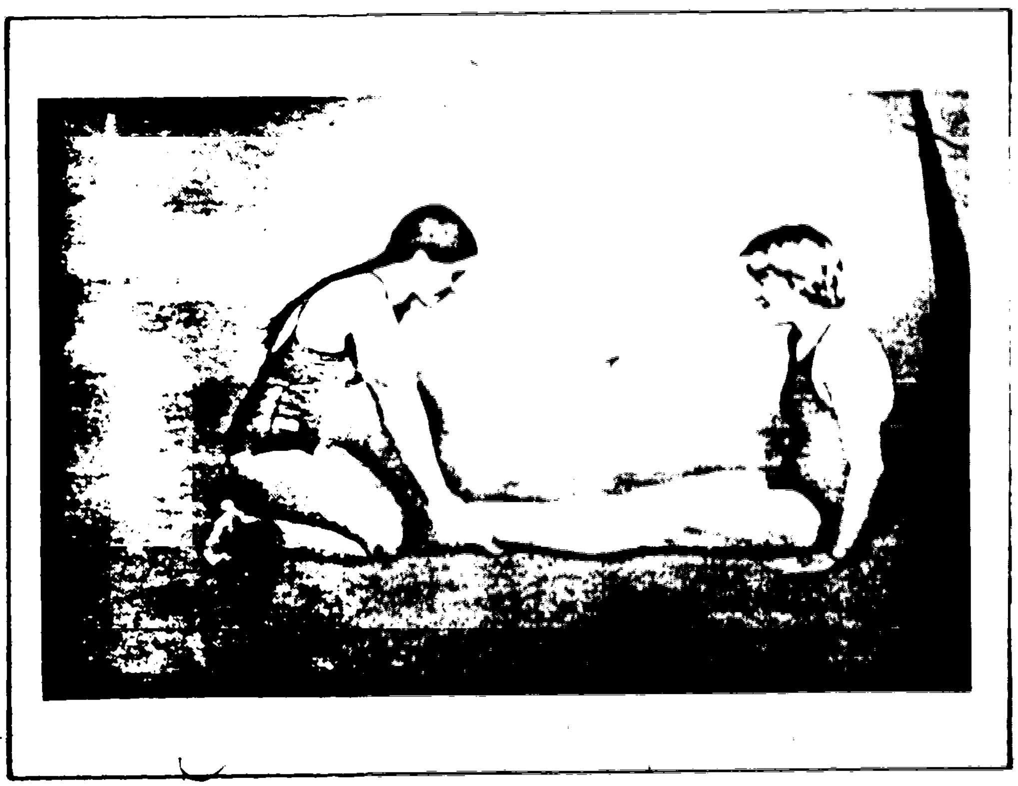
Ankle Extension Exercise (Stretching Ankle Flexors)

Step 1. Subject (S) assumes a sitting position on the floor, legs and back straight, arms at sides, with hands pronated. Partner (P) kneels in front of S, in a partial anatomical position.



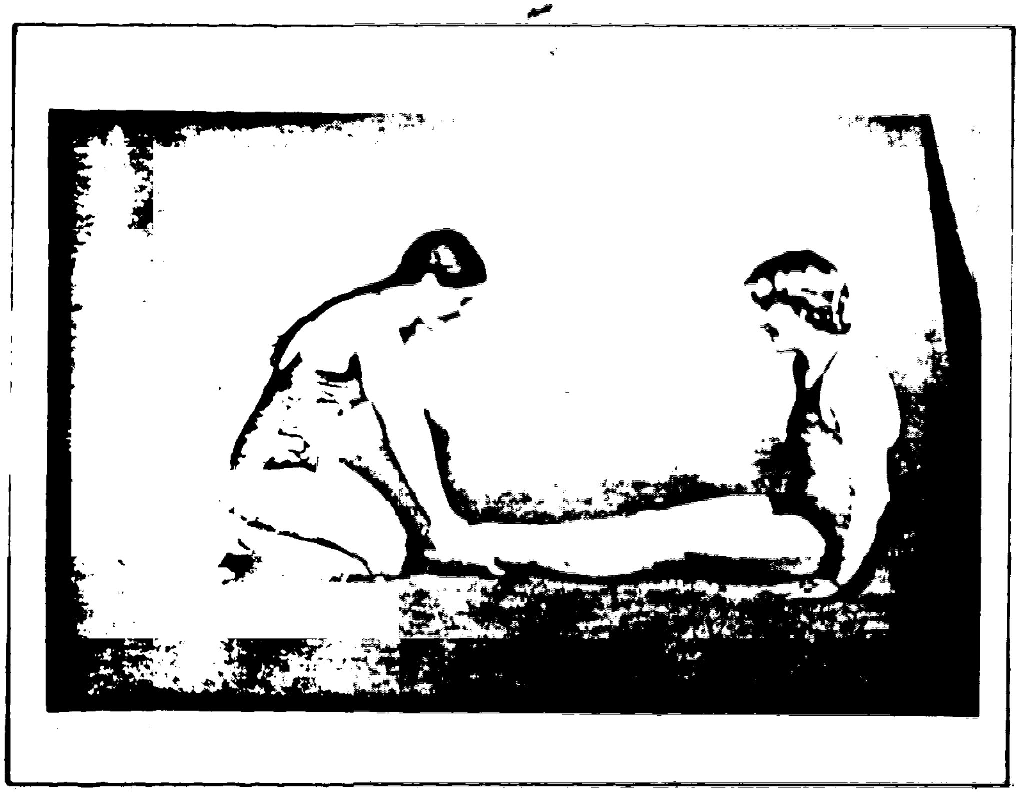
(ES)

Step 2. Partner (P) flexes at the hips, holding S's training feet distal to the ankles.



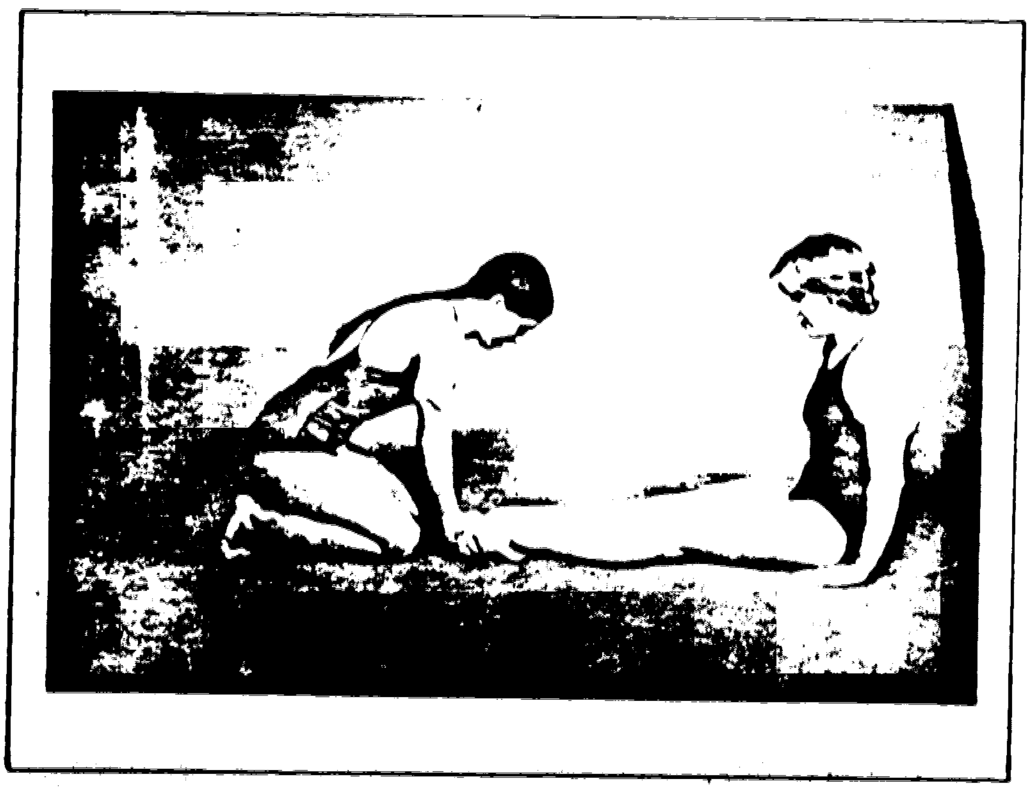
(ES)

Step 3. Subject (S) attempts to dorsi-flex the feet, while keeping the knees straight. P, with greater force, extends S's feet, in an arc, as far as possible, without severe pain for a vocal count of five (seconds).



(ES)

<u>Step 4.</u> Subject (S) relaxes, while P passively extends S's feet, as far as possible, keeping the knees straight, for a vocal count of five (seconds).



(ES)

Step 5. Subject (S) relaxes for a vocal count of fifteen (seconds) (step 1), then repeats steps two, three and four. The exercise is performed three consecutive times.

BALLISTIC STRETCH TRAINING

(BS)

Definition

This is a method of increasing flexibility whereby particular emphasis is placed on training each individual to make all movements in a relaxed rhythmic manner, but to put special effort toward carrying the movement to the limit of the subject's range of motion (McCue, 1953, p. 322).

Explanation

A maximal range of motion is attained by actively flexing or extending, in a relaxed rhythmic manner, a segment nearest to the joint being trained, in an arc, as far as possible. Repetitions of the exercise are performed, without severe pain. One repetition consists of one second concentric contractions. Subjects will perform 10 consecutive repetitions, then relax for fifteen seconds before repeating each exercise. The series of ten concentric contractions is performed in a rhythmic manner, explosive in effort.

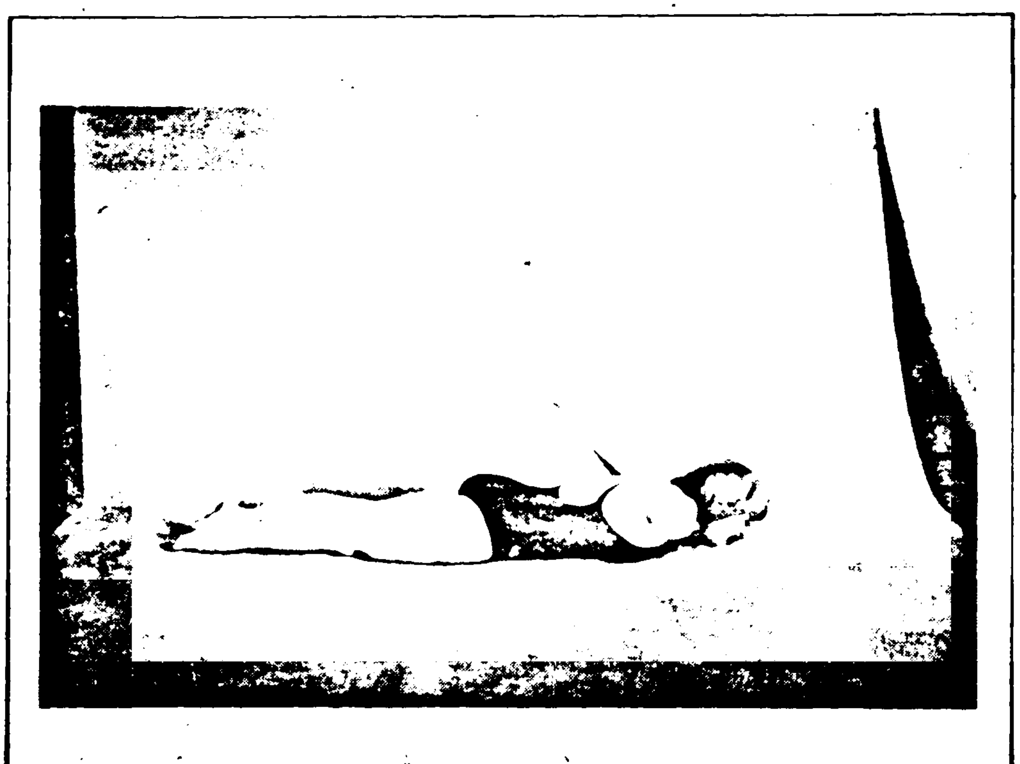
(BS)

Shoulder Extension Exercise (Stretching Shoulder Flexors)

Step 1. Subject (S) assumes a prone position on the floor, legs and back straight, arms at sides, with hands supinated.

(BS)

<u>Step 2.</u> In a relaxed rhythmic manner, the training arm is extended in an arc, at the shoulder joint, as far as possible, without holding the position, for ten consecutive repetitions. The subject's elbow is extended, with hand in a neutral position.



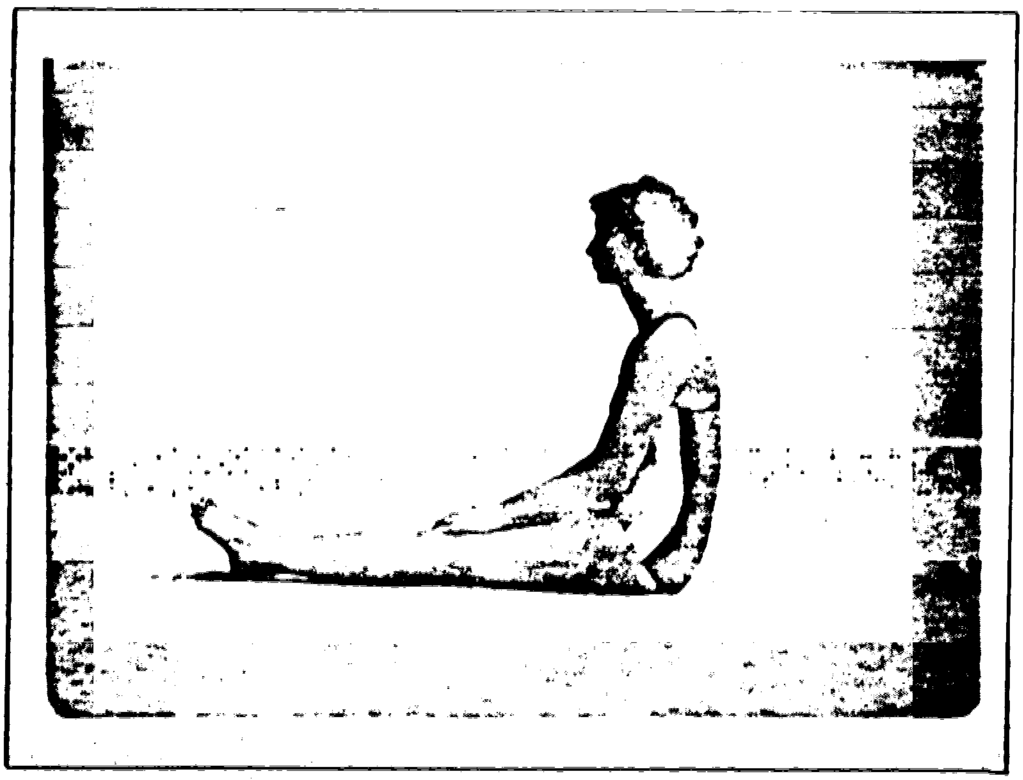
(BS)

<u>Step 3.</u> Subject (S) relaxes for a vocal count of fifteen (seconds) (step 1), then repeats step two. The exercise is performed three consecutive times.

(BS)

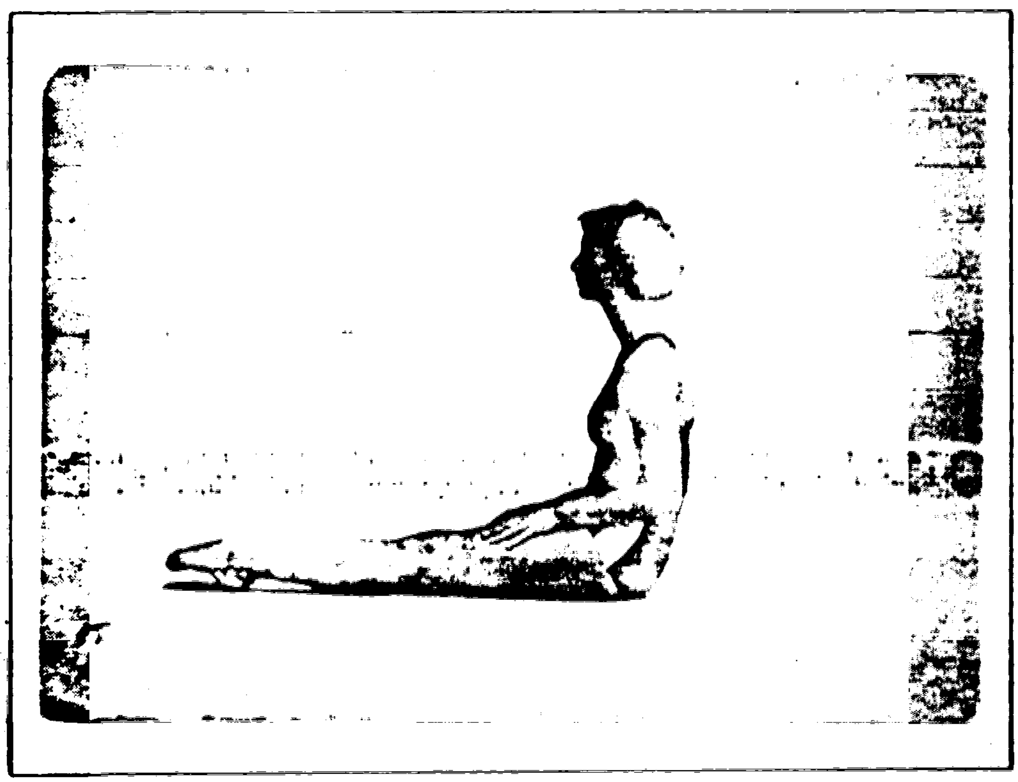
Shoulder Extension Exercise (Stretching Shoulder Flexors)

Step 1. Subject (S) assumes a sitting position on the floor, legs and back straight, arms at sides, with hands pronated.



(BS)

Step 2. In a relaxed rhythmic manner the training feet are plantar flexed in an arc, at the ankle joint, as far as possible, without holding the position, for ten consecutive repetitions.



(BS)

<u>Step 3.</u> Subject (S) relaxes for a vocal count of fifteen (seconds) (step 1), then repeats step two. The exercise is performed three consecutive times.

CONTRACT RELAX STRETCH TRAINING

(CS)

Definition

This is a method of increasing flexibility whereby an isometric contraction of the muscles to be stretched (muscles in a lengthened position to start) is followed by a concentric contraction of the opposite muscle group (Moore and Hutton, 1980, p. 323).

Explanation

A maximal range of motion is attained by actively flexing or extending a segment nearest to the joint being trained, in an arc, as far as possible. Repetitions of the exercise are performed, without severe pain. One repetition consists of:

a) two second concentric contraction,

b) six second isometric contraction, and

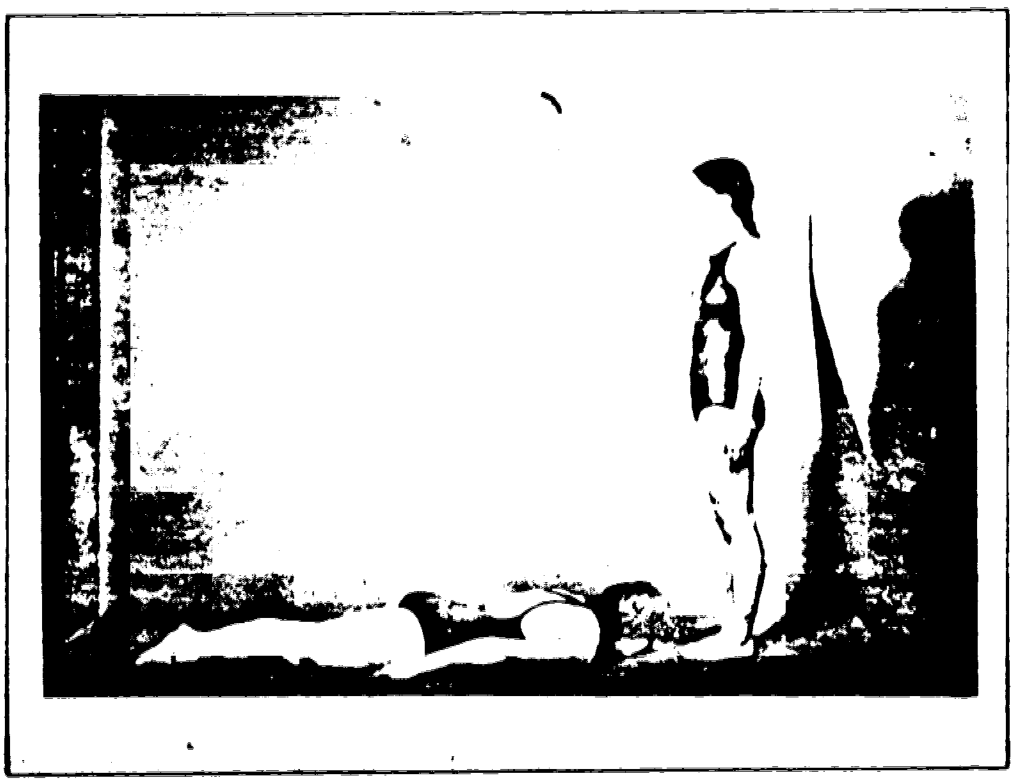
c) two second concentric contraction.

Subject immediately repeats the above exercise (rest optional). The isometric contraction performed by the exercise subject must be gradually, not explosively, increased in effort.

(CS)

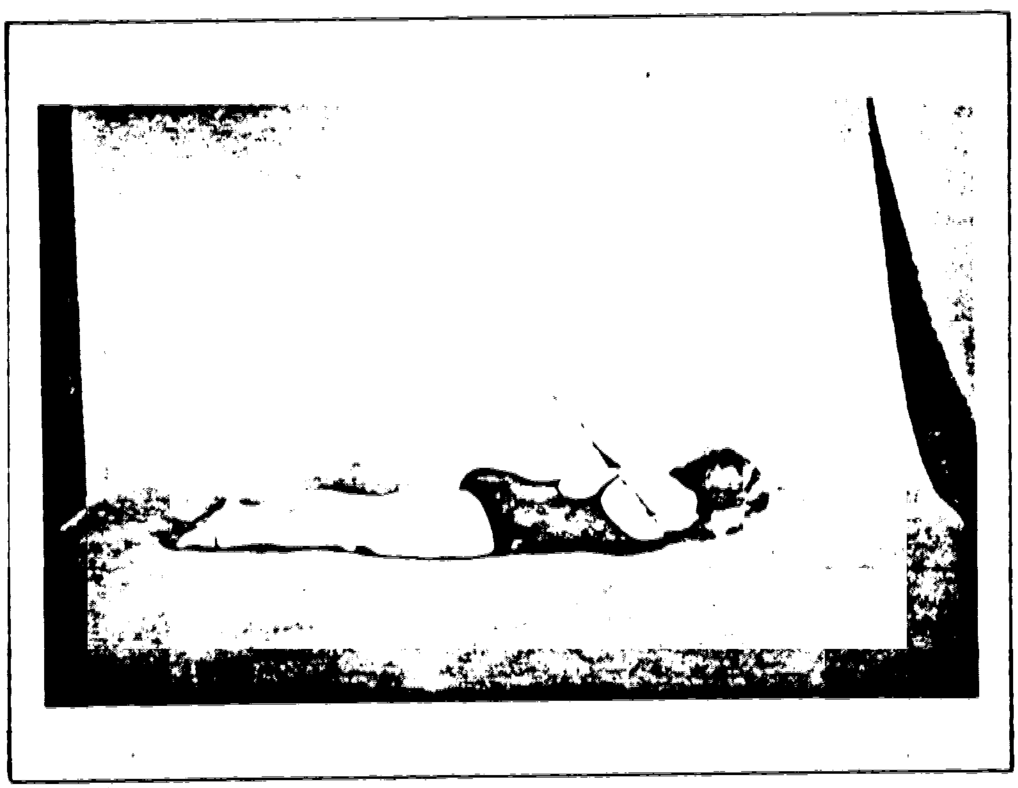
Shoulder Extension (Stretching Shoulder Flexors)

Step 1. Subject (S) assumes a prone position on the floor, legs and back straight, arms at sides, with hands supinated. Partner (P) stands in front of S, in an anatomical position.



(CS)

Step 2. Subject's (S's) training arm is extended, in an arc, at the shoulder joint as far as possible, with hand in a neutral position, for a vocal count of two (seconds).

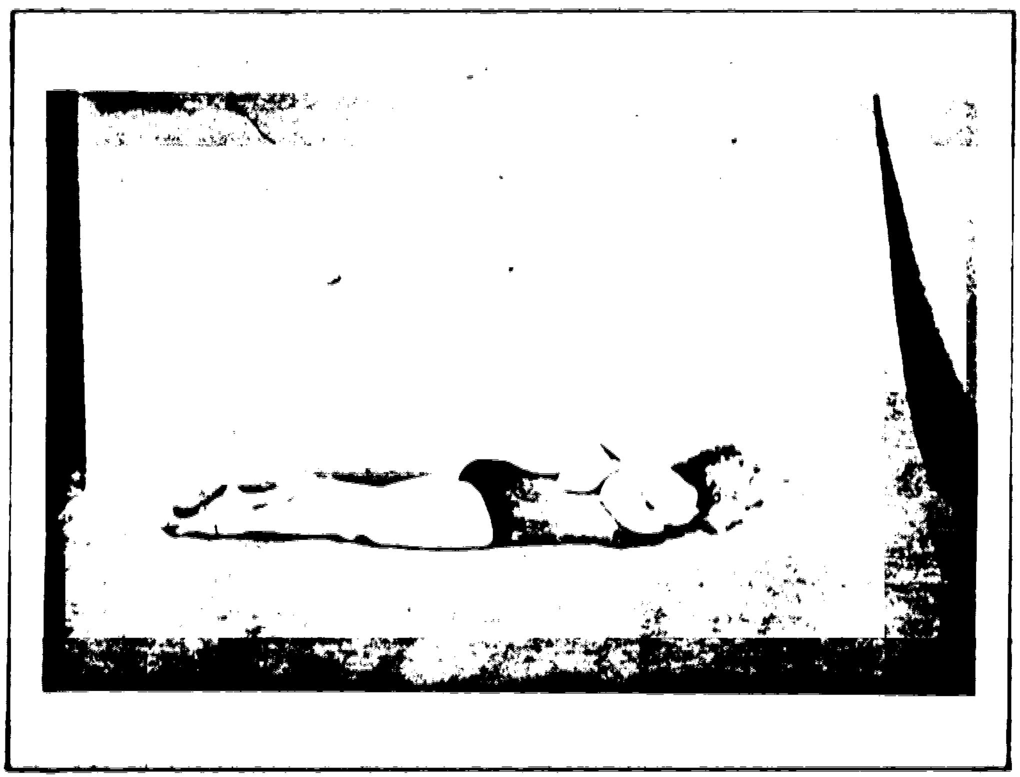


(CS)

Step 3. Partner (P) flexes at the hips, holding S's arm proximal to the wrist. S attempts to flex the arm, while keeping the elbows extended. P resists S's movement. P holds S's position for a vocal count of six (seconds) to produce an isometric contraction.

(CS)

Step 4. Subject (S) again fully extends the arm for a vocal count of two (seconds) keeping the elbow straight so that S attains the maximum extended range of motion in the shoulder joint, without severe pain.



(CS)

<u>Step 5.</u> Subject (S) relaxes for a vocal count of fifteen (seconds) (step 1), then repeats steps two, three and four.

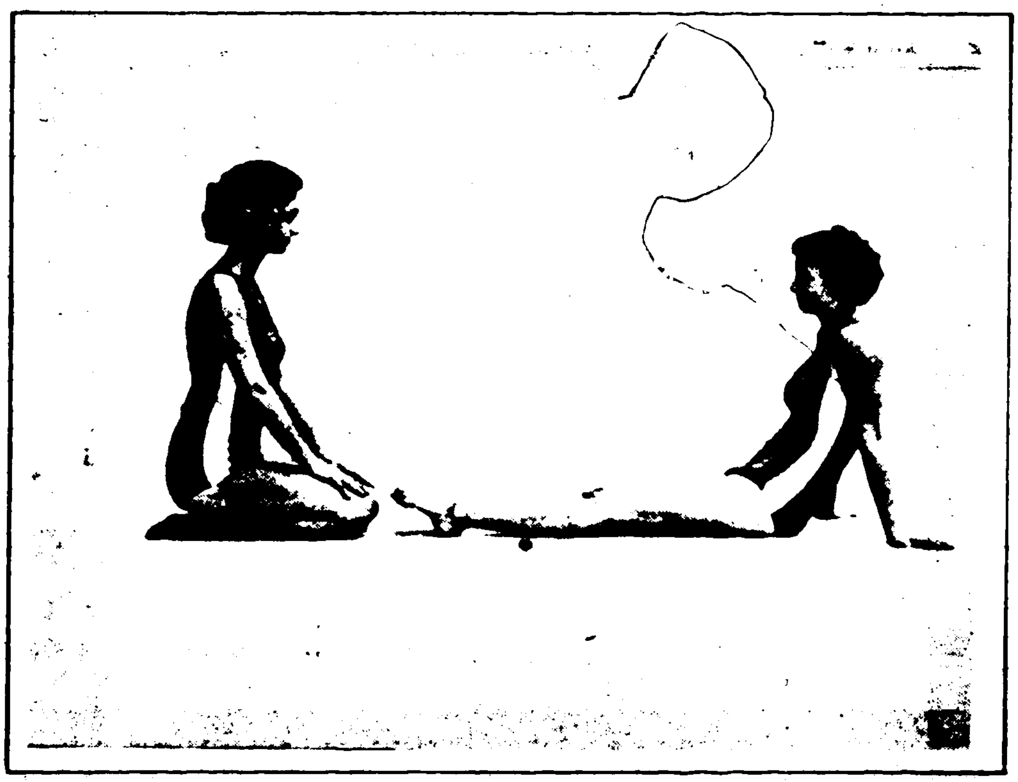
(CS)

Ankle Plantar Flexion Exercise (Stretching Dorsal Flexors)

Step 1. Subject (S) assumes a sitting position on the floor, legs and back straight, arms at sides, with hands pronated. Partner (P) kneels in front of S, in partial anatomical position.

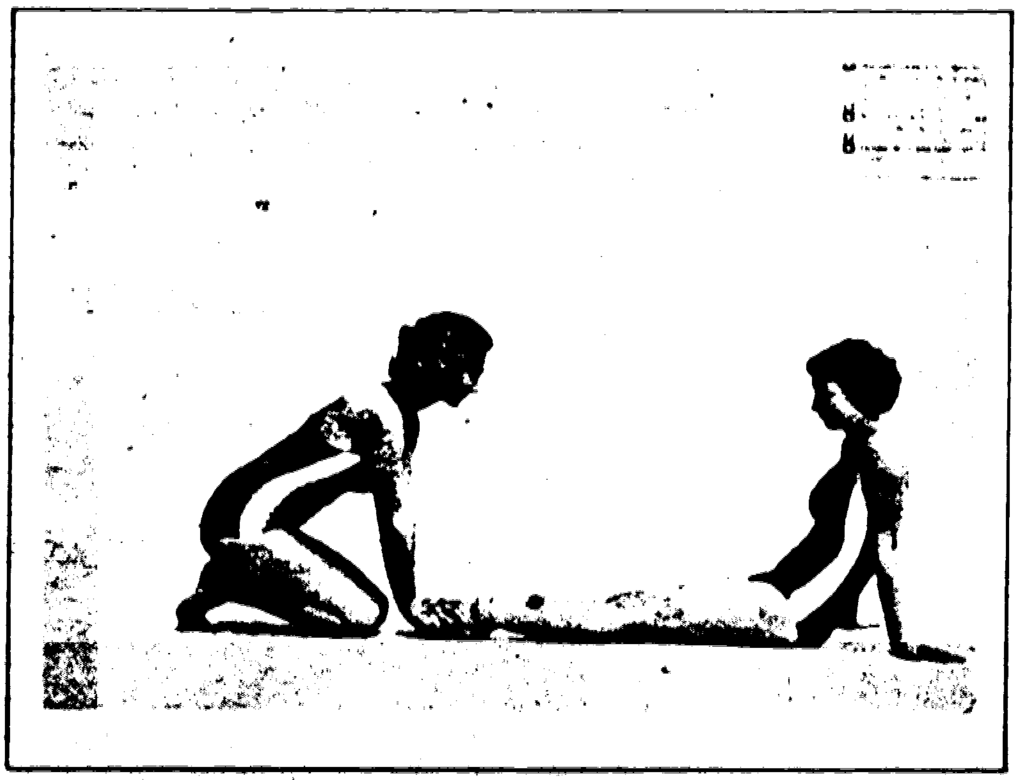
(CS)

Step 2. Subject's (S's) training feet are plantar flexed, in an arc, at the ankle joint, as far as possible, for a vocal count of two (seconds).



(CS)

Step 3. Partner (P) flexes at the hips, holding S's feet distal to the ankles. S attempts to dorsi-flex the feet, while keeping the knees extended. P resists S's movement. P holds S's position for a vocal count of six (seconds) to produce an isometric contraction.



(CS)

Step 4. Subject (S) again fully plantar flexes the feet for a vocal count of two (seconds) keeping the knees straight so that S attains the maximum flexed range of motion in the ankle joint, without severe pain.

(CS)

<u>Step 5.</u> Subject (S) relaxes for a vocal count of fifteen (seconds) (step 1), then repeats steps two, three and four. The exercise is performed three consecutive times.

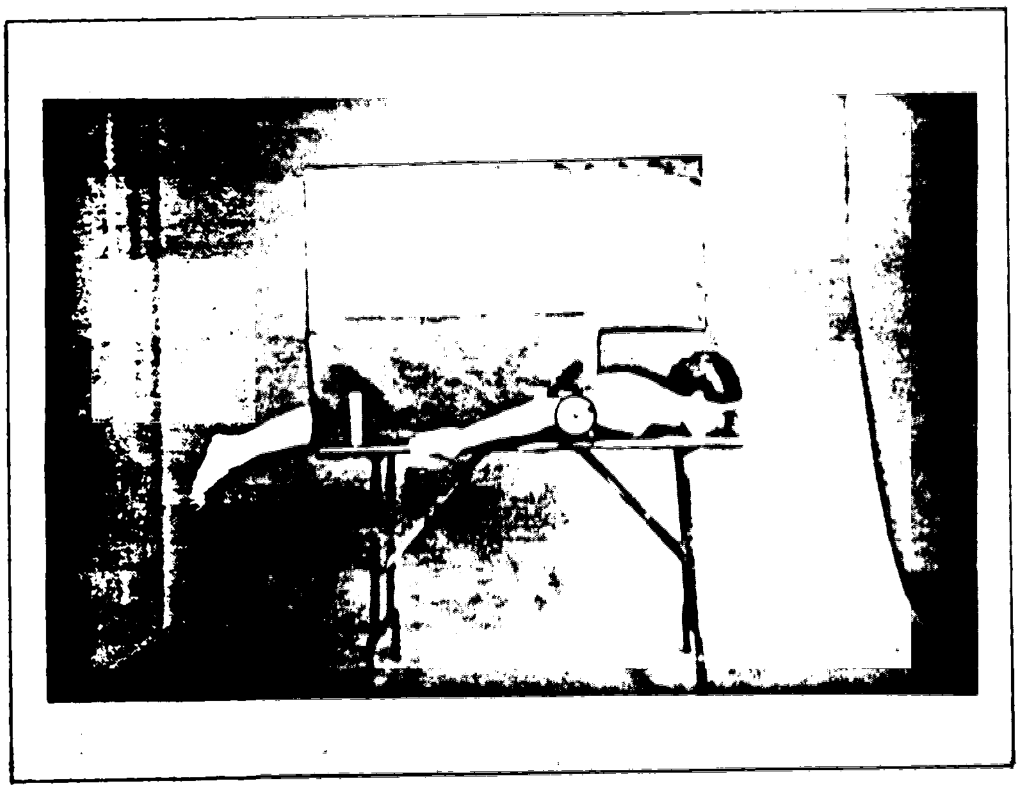
APPENDIX B

FLEXIBILITY TESTS AND APPARATUS

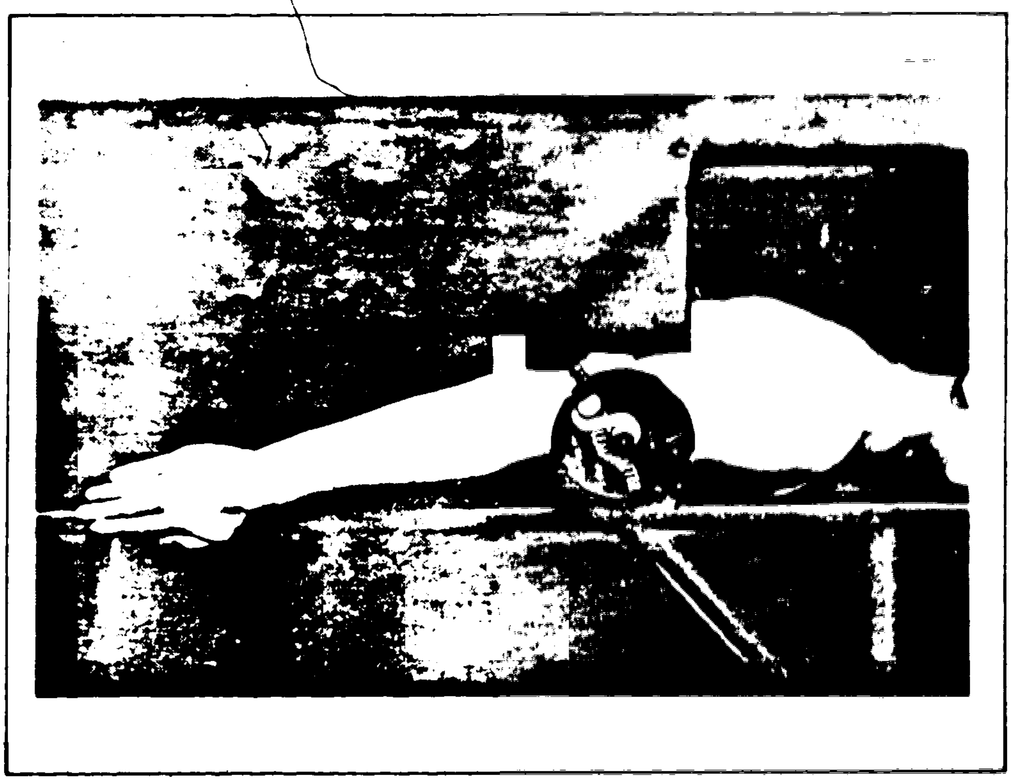
FLEXIBILITY TESTS

Shoulder Extension Test (Stretching Shoulder Flexors)

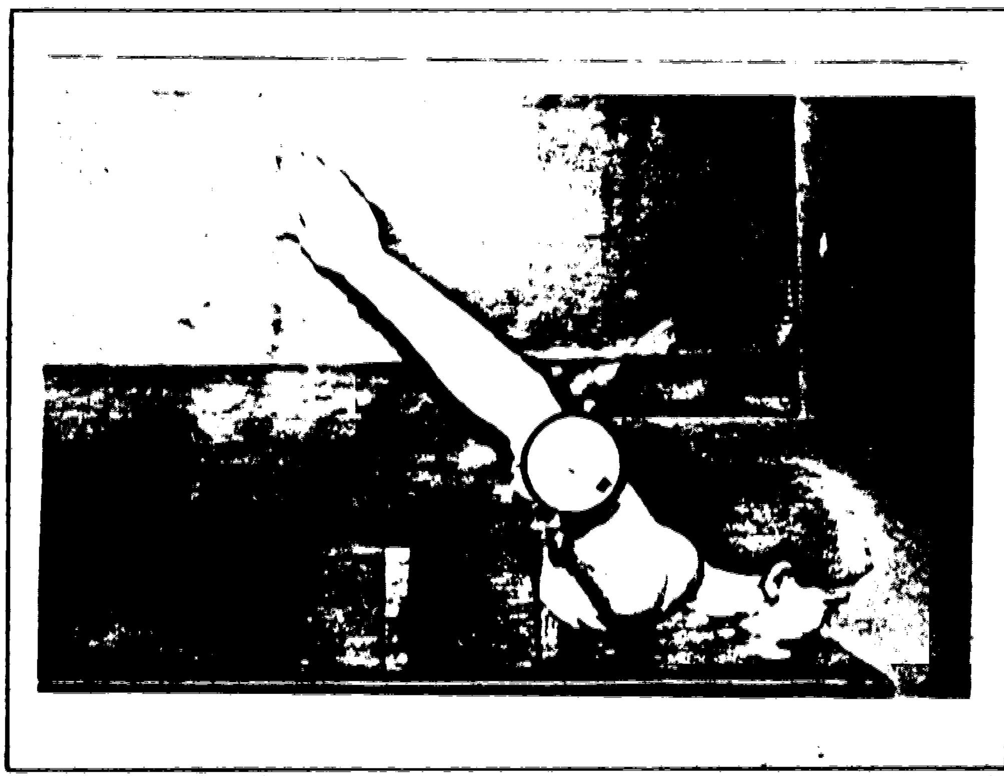
Step 1. Subject (S) assumes a prone position on the bench, legs and back straight, arms at sides, with hands in the neutral position.



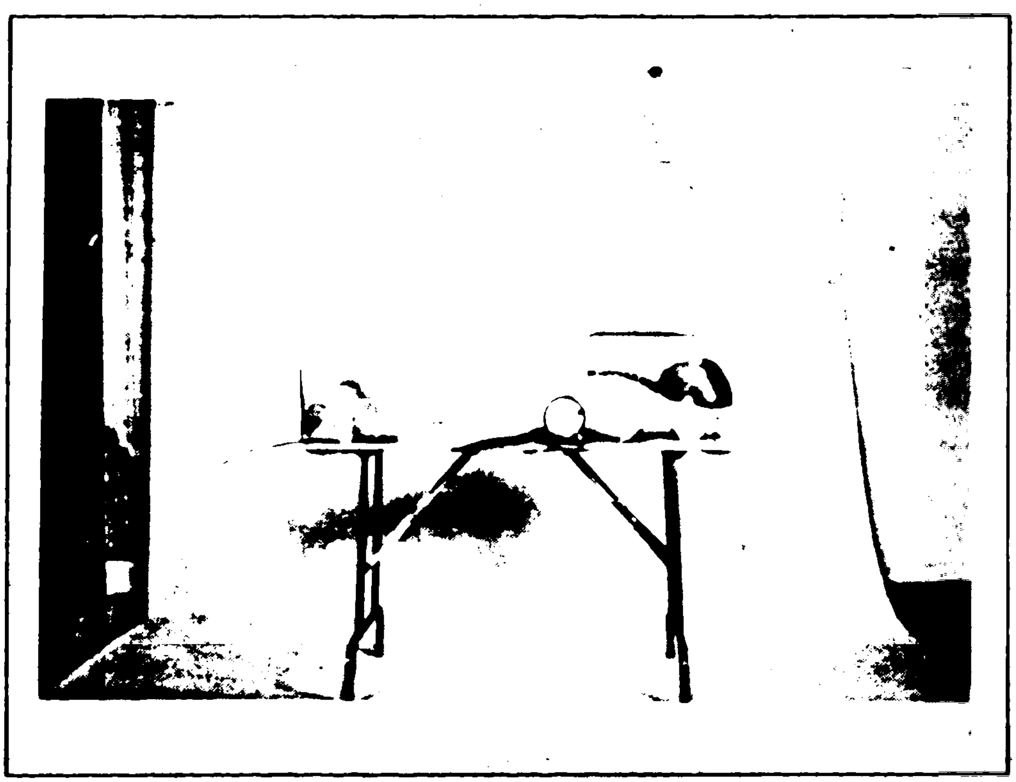
Step 2. The flexometer is strapped on the right dominant, lateral side of the arm, proximal to the elbow joint, with test shoulder beyond the bench. The portable wall is placed medial to the test arm.



<u>Step 3.</u> Subject's (S's) test arm is extended, in an arc, at the shoulder joint, with hand in a neutral position, for a vocal count of two (seconds). The palm of the hand slides lightly against the wall, as far as possible, and this position is held for a vocal count of three (seconds). The highest measurement is read and recorded.

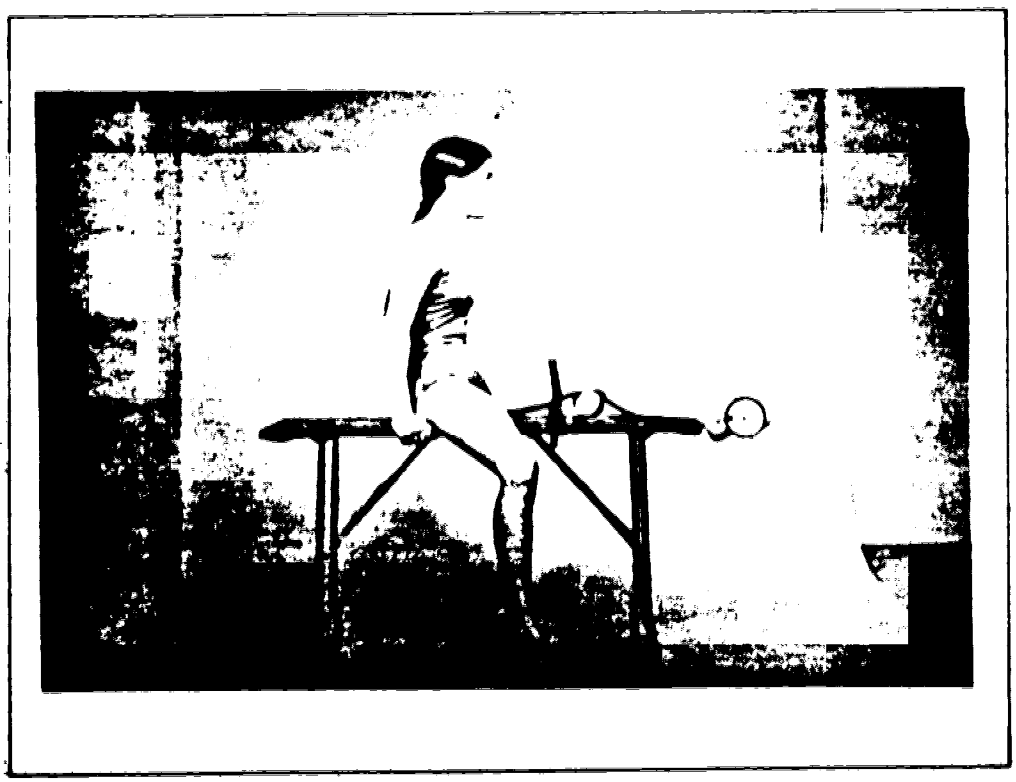


Step 4. Subject (S) relaxes for a vocal count of fifteen (seconds) (step 1), then repeats steps two and three. The test is performed three consecutive times.

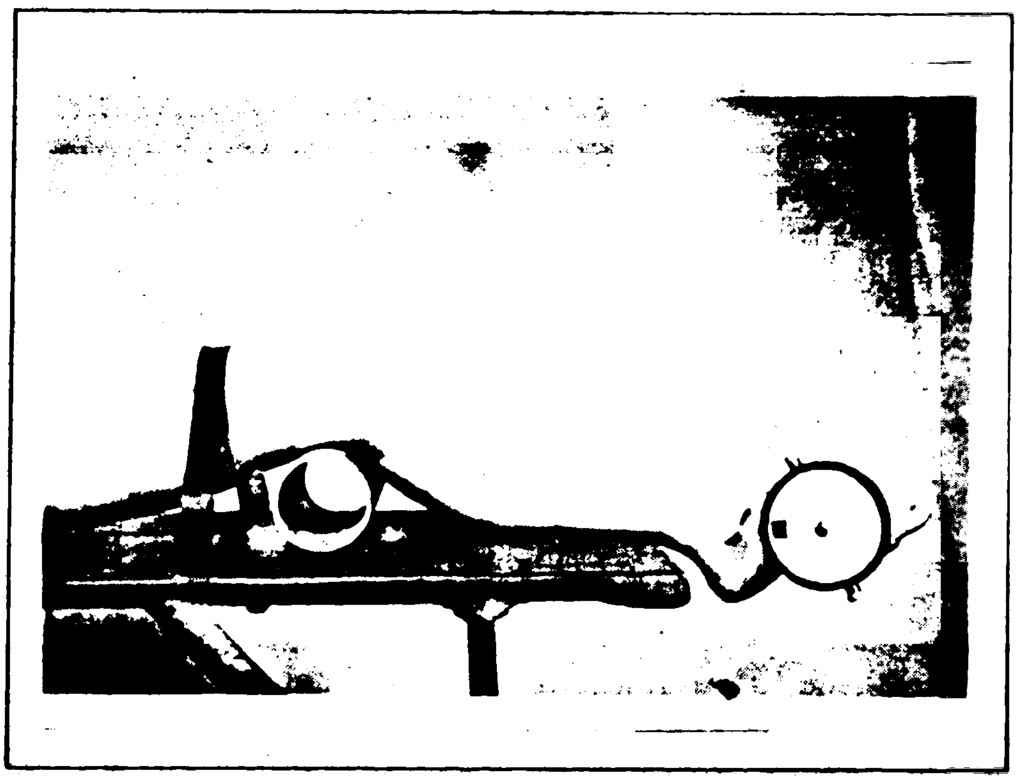


Ankle Plantar Flexion Test (Stretching Dorsal Flexors)

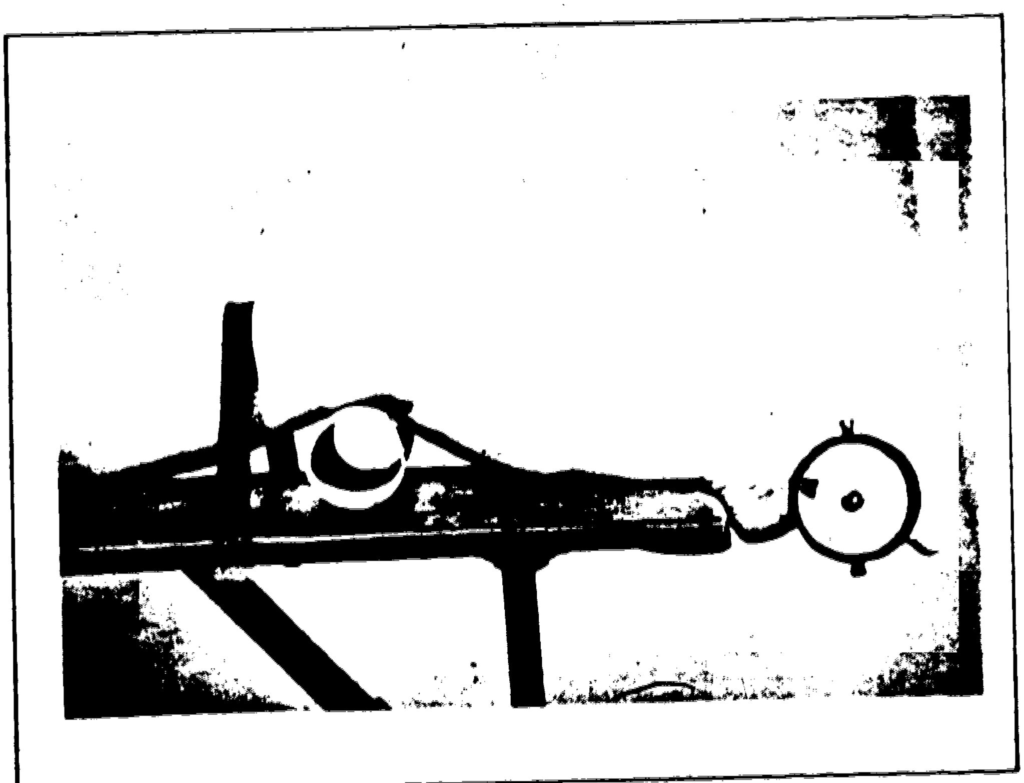
Step 1. Subject (S) assumes a sitting position on the bench, back straight, arms at sides. The test leg is flexed at the knee by placing a cylinder posterior to the knee joint, with the inactive foot at the side of the bench.



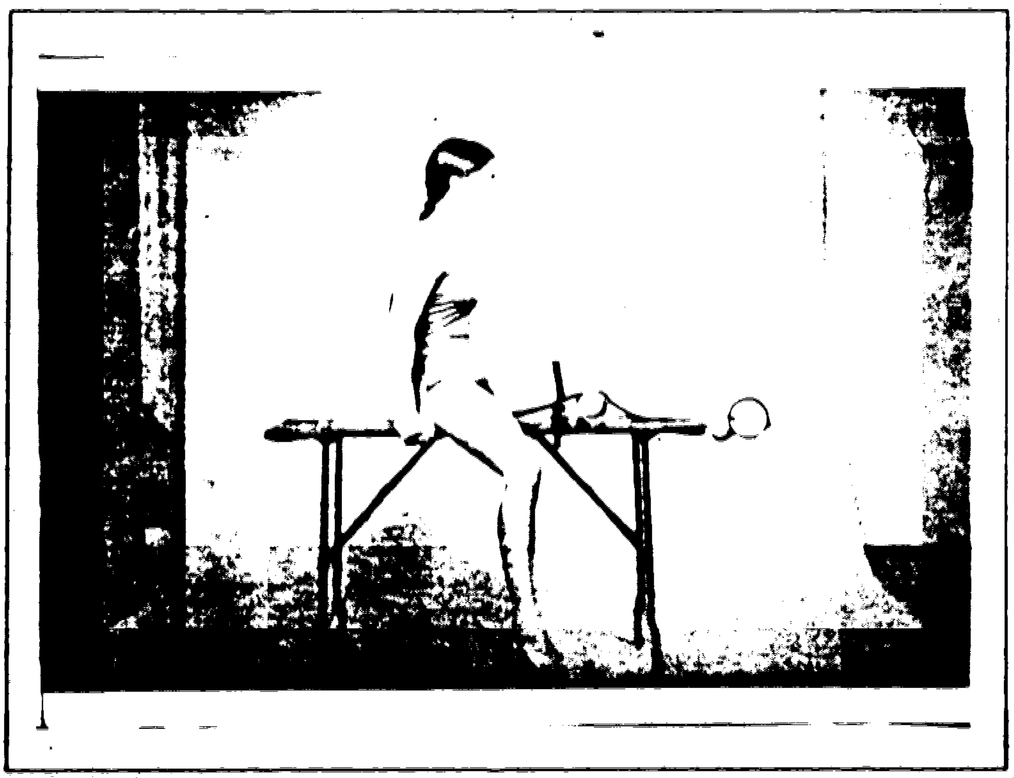
Step 2. Subject (S) is strapped to the bench, proximal to the knee joint. The flexometer is attached to the left dominant medial arch, with test ankle beyond the bench.



<u>Step 3.</u> Subject's (S's) test foot is plantar flexed, in an arc, at the ankle joint, for a vocal count of two (seconds). The ankle is plantar flexed, as far as possible, and this position is held for a vocal count of three (seconds). The highest measurement is read and recorded.



<u>Step 4.</u> Subject (S) relaxes for a vocal count of fifteen (seconds) (step 1), then repeats steps two and three. The test is performed three consecutive times.



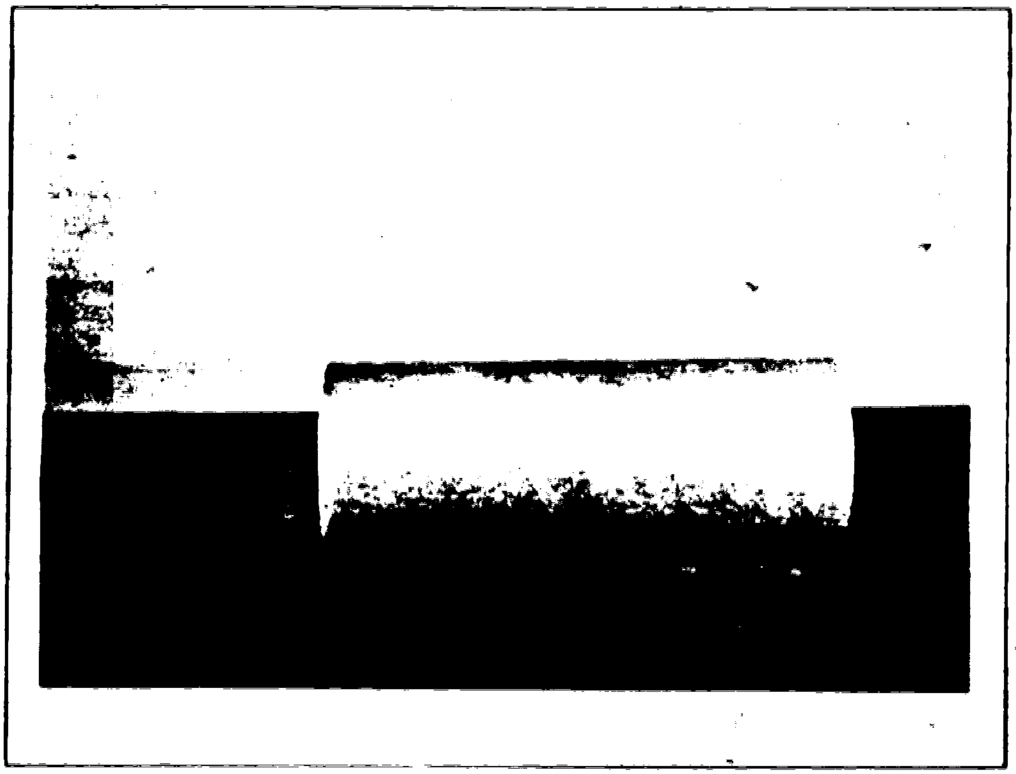


Figure A. Test cylinder for the ankle plantar flexion test.

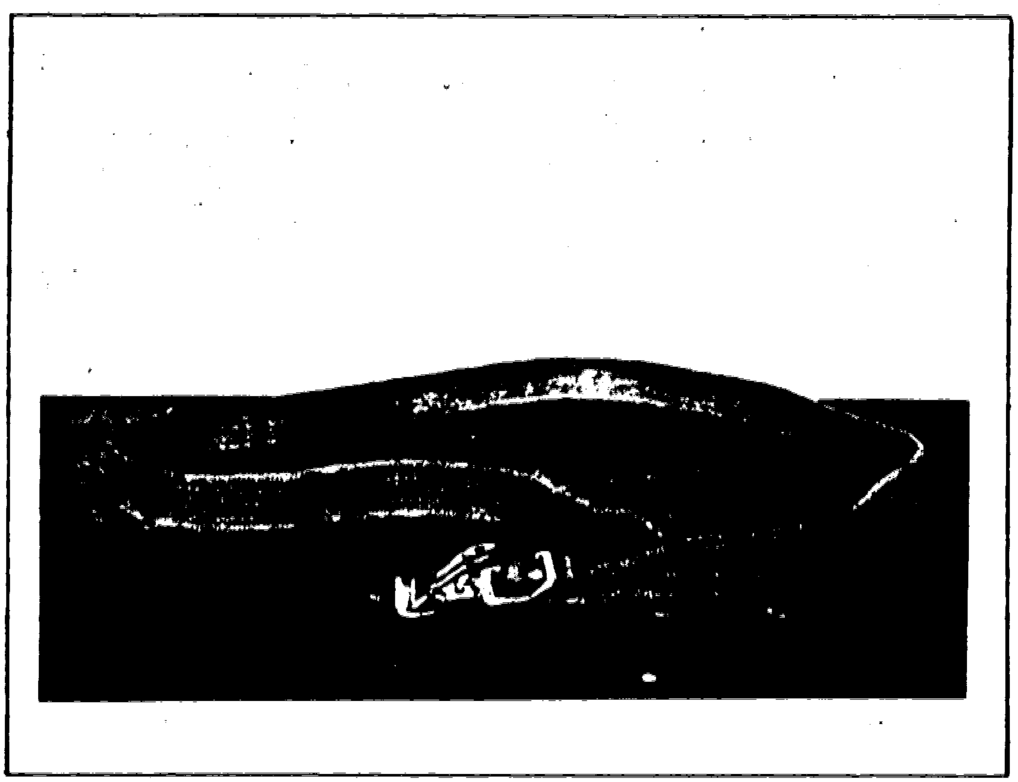


Figure B. Test strap for the shoulder extension test.

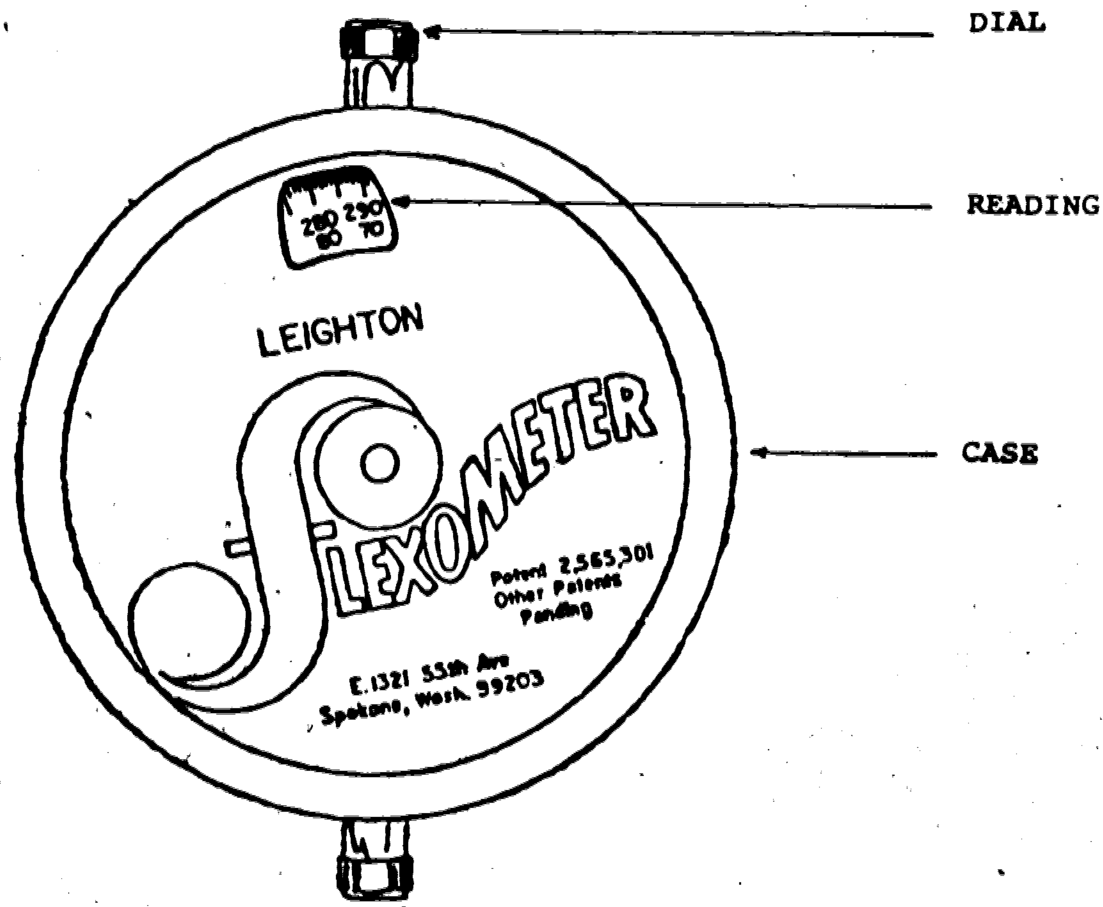


Figure C. The Leighton Flexometer.

APPENDIX C

CORRESPONDENCE

Lakewood Intermediate School
THIRD STREET N. · KENORA, ONTARIO P9N 3Y5 · PHONE 468 3131

November 6, 1981.

To Whom It May Conern,

Re: Flexibility Training Programme

Please be advised that Mr. Allan Turner has been conducting research on a Flexibility Training Programme for the months of September through December at Lakewood Intermediate School. Specifically, Allan has worked with two classes of girls physical education to compile the results which will form part of his Doctorate research.

We were pleased to have Allan in the school as he provided our students the opportunity to witness, first-hand, research being conducted; and, on several occasions, assisted us as a supply teacher. We are indeed grateful that Allan chose Lakewood for his research project and wish him every success in his future endeavours.

Sincerely,

R.C. Harvey,
Principal.

RCH/pb

112 - 8604 - 103 Street
Edmonton, Alberta
T6E 4B6

February 14, 1981

Mr. R. Harvey
Principal
Lakewood Intermediate School

Dear Mr. Harvey,

The purpose of this letter is to request permission to conduct a research study in Lakewood Intermediate School, from September to October, 1981.

The aim of this study will be to examine the effects of six different stretch training methods on active joint flexibility. Subjects will be 42 female junior high school students and the design will consist of six different groups with six students in each group. The students will be required to perform one exercise on the ankle and one on the shoulder joint at the beginning of each physical education class. The subjects will be tested before training, after two, four and six weeks of training, and two weeks following no flexibility training (retention test).

Since this program will be partial requirement for my doctoral thesis, I would sincerely appreciate your assistance regarding this request. Should further information be required, I will be pleased to provide it (1-403-433-0956).

Sincerely,

A. Allan Turner

Andrew Allan Turner
Prov. Ph.D. Candidate

INFORMATION SHEET

1) NAME: ______________________________

2) ADDRESS: ______________________________

____

3) PHONE: ______________________________

4) AGE: ______________________________

5) GRADE: ______________________________

6) HAND DOMINANCE: R L (circle one)

7) PREVIOUS INJURY/DISEASE TO ANKLE OR SHOULDER: YES NO

8) IF YES, EXPLAIN WHAT AND WHERE: ______________________________

____

____

____

9) SURGERY ON JOINTS: YES NO

10) LIST ACTIVITIES YOU WILL BE PARTICIPATING IN DURING THE NEXT EIGHT WEEKS.

1) ____________	6) ____________
2) ____________	7) ____________
3) ____________	8) ____________
4) ____________	9) ____________
5) ____________	10) ____________

APPENDIX D

RAW DATA

TABLE A

RAW SCORES (IN DEGREES) OF ANKLE JOINT FLEXIBILITY FOR EACH SUBJECT

#	S	A	B	C: C_1	C: C_2	#	S	A	B	C: C_1	C: C_2
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Symbols

- \# Number
- S Subject
- A Treatment
- B Week
- C Session

Treatment Conditions

- A_1 3S training (n = 6)
- A_2 2S training (n = 6)
- A_3 SS training (n = 6)
- A_4 ES training (n = 6)
- A_5 BS training (n = 6)
- A_6 CS training (n = 6)
- A_7 Control (n = 6)

Week in Experiment

- B_1 pre-training
- B_2 two-week training
- B_3 four-week training
- B_4 six-week training
- B_5 two-week retention

Session

- C_1 pre-session training
- C_2 post-session training

TABLE B

RAW SCORES (IN DEGREES) OF ANKLE JOINT FLEXIBILITY FOR EACH SUBJECT

#	S	A	B	C: C_1	C: C_2
121	1	5	1	107.00	108.50
122	1	5	2	111.50	110.50
123	1	5	3	107.50	107.00
124	1	5	4	114.50	114.50
125	1	5	5	108.50	110.50
126	2	5	1	094.50	095.00
127	2	5	2	095.00	094.00
128	2	5	3	093.50	093.50
129	2	5	4	101.50	098.50
130	2	5	5	094.50	095.50
131	3	5	1	098.00	103.50
132	3	5	2	104.50	103.50
133	3	5	3	107.00	107.00
134	3	5	4	113.50	113.50
135	3	5	5	108.50	108.50
136	4	5	1	112.50	113.00
137	4	5	2	112.00	111.50
138	4	5	3	112.00	115.00
139	4	5	4	112.00	111.50
140	4	5	5	108.50	108.50
141	5	5	1	101.50	102.50
142	5	5	2	102.00	103.00
143	5	5	3	102.50	102.00
144	5	5	4	105.00	107.50
145	5	5	5	100.50	101.50
146	6	5	1	113.50	115.00
147	6	5	2	115.00	115.50
148	6	5	3	118.00	120.00
149	6	5	4	117.00	121.00
150	6	5	5	110.50	110.00
151	1	6	1	110.50	110.50
152	1	6	2	110.00	111.50
153	1	6	3	107.50	108.50
154	1	6	4	114.50	115.50
155	1	6	5	108.50	110.50
156	2	6	1	113.50	113.50
157	2	6	2	111.50	113.00
158	2	6	3	114.50	118.50
159	2	6	4	120.00	121.50
160	2	6	5	111.00	114.00
161	3	6	1	091.50	093.50
162	3	6	2	093.00	098.00
163	3	6	3	094.50	097.50
164	3	6	4	101.50	103.50
165	3	6	5	095.00	098.00
166	4	6	1	104.00	105.50
167	4	6	2	105.50	106.00
168	4	6	3	101.50	104.50
169	4	6	4	107.00	108.50
170	4	6	5	104.00	107.00
171	5	6	1	101.50	103.00
172	5	6	2	100.50	101.50
173	5	6	3	103.50	104.50
174	5	6	4	104.00	105.00
175	5	6	5	102.50	102.50
176	6	6	1	105.50	105.50
177	6	6	2	104.50	105.50
178	6	6	3	105.50	108.00
179	6	6	4	107.50	104.50
180	6	6	5	102.50	107.00
181	1	7	1	098.50	098.50
182	1	7	2	095.50	095.00
183	1	7	3	091.50	093.00
184	1	7	4	097.50	097.50
185	1	7	5	095.00	095.00
186	2	7	1	104.50	105.00
187	2	7	2	104.50	105.50
188	2	7	3	104.50	103.50
189	2	7	4	107.00	108.50
190	2	7	5	104.50	104.50
191	3	7	1	118.50	118.50
192	3	7	2	114.00	113.00
193	3	7	3	113.50	114.00
194	3	7	4	120.50	123.50
195	3	7	5	115.50	115.00
196	4	7	1	104.50	104.50
197	4	7	2	105.50	107.00
198	4	7	3	105.50	108.50
199	4	7	4	108.00	107.50
200	4	7	5	108.50	107.00
201	5	7	1	104.00	104.50
202	5	7	2	110.50	110.00
203	5	7	3	103.50	103.50
204	5	7	4	107.50	108.50
205	5	7	5	110.00	110.50
206	6	7	1	105.00	108.00
207	6	7	2	104.00	104.00
208	6	7	3	103.50	103.00
209	6	7	4	104.50	104.00
210	6	7	5	104.00	105.50
211	SENDFILE				

END OF FILE

Symbols

- \# Number
- S Subject
- A Treatment
- B Week
- C Session

Week in Experiment

- B_1 pre-training
- B_2 two-week training
- B_3 four-week training
- B_4 six-week training
- B_5 two-week retention

Treatment Conditions

- A_1 3S training (n = 6)
- A_2 2S training (n = 6)
- A_3 SS training (n = 6)
- A_4 ES training (n = 6)
- A_5 BS training (n = 6)
- A_6 CS training (n = 6)
- A_7 Control (n = 6)

Session

- C_1 pre-session training
- C_2 post-session training

TABLE C

RAW SCORES (IN DEGREES) OF SHOULDER JOINT FLEXIBILITY FOR EACH SUBJECT

#	SAB	C: C_1	C: C_2	#	SAB	C: C_1	C: C_2
1	1 1 1	[illegible]	[illegible]	61	1 3 1	162.50	164.50
2	1 1 2	162.50	166.50	62	1 3 2	155.50	166.50
3	1 1 3	164.00	166.50	63	1 3 3	165.50	160.00
4	1 1 4	168.50	156.50	64	1 3 4	174.00	170.50
5	1 1 5	140.50	140.50	65	1 3 5	166.00	166.50
6	2 1 1	143.00	145.00	66	2 3 1	135.00	138.50
7	2 1 2	150.00	158.50	67	2 3 2	162.00	161.00
8	2 1 3	160.00	162.50	68	2 3 3	160.00	161.50
9	2 1 4	157.50	166.50	69	2 3 4	170.00	170.00
10	2 1 5	155.00	157.50	70	2 3 5	154.50	160.00
11	3 1 1	153.50	157.50	71	3 3 1	148.50	148.00
12	3 1 2	151.50	160.50	72	3 3 2	160.50	162.50
13	3 1 3	160.00	170.50	73	3 3 3	168.00	167.50
14	3 1 4	176.50	175.50	74	3 3 4	167.00	165.00
15	3 1 5	150.00	157.50	75	3 3 5	166.00	165.00
16	4 1 1	148.00	155.50	76	4 3 1	153.50	150.50
17	4 1 2	159.00	162.50	77	4 3 2	157.00	157.00
18	4 1 3	154.00	150.50	78	4 3 3	164.00	163.50
19	4 1 4	174.50	172.50	79	4 3 4	170.50	168.50
20	4 1 5	163.50	160.50	80	4 3 5	160.00	162.50
21	5 1 1	121.50	136.50	81	5 3 1	161.00	164.00
22	5 1 2	155.50	158.00	82	5 3 2	157.00	164.00
23	5 1 3	153.00	174.00	83	5 3 3	155.00	158.00
24	5 1 4	164.50	164.00	84	5 3 4	175.00	175.50
25	5 1 5	144.00	163.50	85	5 3 5	166.00	167.50
26	6 1 1	148.00	155.00	86	6 3 1	161.50	161.00
27	6 1 2	155.00	171.50	87	6 3 2	170.50	174.00
28	6 1 3	174.50	174.50	88	6 3 3	180.00	175.00
29	6 1 4	168.50	170.00	89	6 3 4	174.00	168.00
30	6 1 5	164.50	166.50	90	6 3 5	166.00	168.00
31	1 2 1	140.00	143.50	91	1 4 1	158.50	159.50
32	1 2 2	155.50	155.00	92	1 4 2	164.00	163.00
33	1 2 3	154.50	158.50	93	1 4 3	164.00	167.00
34	1 2 4	166.50	155.00	94	1 4 4	176.50	174.50
35	1 2 5	153.50	151.50	95	1 4 5	162.00	167.50
36	2 2 1	141.50	146.50	96	2 4 1	135.50	140.00
37	2 2 2	151.00	151.00	97	2 4 2	157.00	155.00
38	2 2 3	150.50	151.00	98	2 4 3	153.00	158.50
39	2 2 4	158.50	155.00	99	2 4 4	175.50	176.50
40	2 2 5	150.50	151.00	100	2 4 5	153.00	153.50
41	3 2 1	157.50	153.50	101	3 4 1	165.00	150.50
42	3 2 2	163.50	163.00	102	3 4 2	163.00	164.00
43	3 2 3	160.00	163.50	103	3 4 3	165.00	166.00
44	3 2 4	164.00	168.00	104	3 4 4	162.50	162.50
45	3 2 5	161.00	160.50	105	3 4 5	169.50	174.50
46	4 2 1	150.00	148.50	106	4 4 1	155.50	160.00
47	4 2 2	155.50	155.00	107	4 4 2	177.00	180.50
48	4 2 3	158.00	163.00	108	4 4 3	175.00	180.50
49	4 2 4	176.50	174.50	109	4 4 4	171.50	171.00
50	4 2 5	173.50	166.50	110	4 4 5	171.50	172.00
51	5 2 1	150.00	154.00	111	5 4 1	157.50	166.00
52	5 2 2	164.00	168.50	112	5 4 2	167.00	173.50
53	5 2 3	170.50	174.00	113	5 4 3	172.00	173.00
54	5 2 4	173.00	171.50	114	5 4 4	172.00	173.50
55	5 2 5	172.00	171.00	115	5 4 5	164.50	165.00
56	6 2 1	155.00	158.00	116	6 4 1	138.00	146.00
57	6 2 2	166.00	171.00	117	6 4 2	166.00	160.00
58	6 2 3	173.00	174.50	118	6 4 3	162.50	167.50
59	6 2 4	178.50	180.50	119	6 4 4	170.50	168.00
60	6 2 5	171.00	175.00	120	6 4 5	162.00	165.50

Symbols

- # Number
- S Subject
- A Treatment
- B Week
- C Session

Treatment Conditions

- A_1 3S training (n = 6)
- A_2 2S training (n = 6)
- A_3 SS training (n = 6)
- A_4 ES training (n = 6)
- A_5 BS training (n = 6)
- A_6 CS training (n = 6)
- A_7 Control (n = 6)

Week in Experiment

- B_1 pre-training
- B_2 two-week training
- B_3 four-week training
- B_4 six-week training
- B_5 two-week retention

Session

- C_1 pre-session training
- C_2 post-session training

TABLE D

RAW SCORES (IN DEGREES) OF SHOULDER JOINT FLEXIBILITY FOR EACH SUBJECT

#	S	A	B	C_1	C_2
121	1	5	1	[illegible]	[illegible]
122	1	5	2	[illegible]	[illegible]
123	1	5	3	[illegible]	[illegible]
124	1	5	4	[illegible]	[illegible]
125	1	5	5	[illegible]	[illegible]
126	2	5	1	[illegible]	[illegible]
127	2	5	2	[illegible]	[illegible]
128	2	5	3	[illegible]	[illegible]
129	2	5	4	[illegible]	[illegible]
130	2	5	5	[illegible]	[illegible]
131	3	5	1	[illegible]	[illegible]
132	3	5	2	[illegible]	[illegible]
133	3	5	3	[illegible]	[illegible]
134	3	5	4	[illegible]	[illegible]
135	3	5	5	[illegible]	[illegible]
136	4	5	1	[illegible]	[illegible]
137	4	5	2	[illegible]	[illegible]
138	4	5	3	[illegible]	[illegible]
139	4	5	4	[illegible]	[illegible]
140	4	5	5	[illegible]	[illegible]
141	5	5	1	[illegible]	[illegible]
142	5	5	2	[illegible]	[illegible]
143	5	5	3	[illegible]	[illegible]
144	5	5	4	[illegible]	[illegible]
145	5	5	5	[illegible]	[illegible]
146	6	5	1	[illegible]	[illegible]
147	6	5	2	[illegible]	[illegible]
148	6	5	3	[illegible]	[illegible]
149	6	5	4	[illegible]	[illegible]
150	6	5	5	[illegible]	[illegible]
151	1	6	1	[illegible]	[illegible]
152	1	6	2	[illegible]	[illegible]
153	1	6	3	[illegible]	[illegible]
154	1	6	4	[illegible]	[illegible]
155	1	6	5	[illegible]	[illegible]
156	2	6	1	[illegible]	[illegible]
157	2	6	2	[illegible]	[illegible]
158	2	6	3	[illegible]	[illegible]
159	2	6	4	[illegible]	[illegible]
160	2	6	5	[illegible]	[illegible]
161	3	6	1	[illegible]	[illegible]
162	3	6	2	[illegible]	[illegible]
163	3	6	3	[illegible]	[illegible]
164	3	6	4	[illegible]	[illegible]
165	3	6	5	[illegible]	[illegible]
166	4	6	1	[illegible]	[illegible]
167	4	6	2	[illegible]	[illegible]
168	4	6	3	[illegible]	[illegible]
169	4	6	4	[illegible]	[illegible]
170	4	6	5	[illegible]	[illegible]
171	5	6	1	[illegible]	[illegible]
172	5	6	2	[illegible]	[illegible]
173	5	6	3	[illegible]	[illegible]
174	5	6	4	[illegible]	[illegible]
175	5	6	5	[illegible]	[illegible]
176	6	6	1	[illegible]	[illegible]
177	6	6	2	[illegible]	[illegible]
178	6	6	3	[illegible]	[illegible]
179	6	6	4	[illegible]	[illegible]
180	6	6	5	[illegible]	[illegible]

#	S	A	B	C_1	C_2
181	1	7	1	[illegible]	[illegible]
182	1	7	2	[illegible]	[illegible]
183	1	7	3	[illegible]	[illegible]
184	1	7	4	[illegible]	[illegible]
185	1	7	5	[illegible]	[illegible]
186	2	7	1	[illegible]	[illegible]
187	2	7	2	[illegible]	[illegible]
188	2	7	3	[illegible]	[illegible]
189	2	7	4	[illegible]	[illegible]
190	2	7	5	[illegible]	[illegible]
191	3	7	1	[illegible]	[illegible]
192	3	7	2	[illegible]	[illegible]
193	3	7	3	[illegible]	[illegible]
194	3	7	4	[illegible]	[illegible]
195	3	7	5	[illegible]	[illegible]
196	4	7	1	[illegible]	[illegible]
197	4	7	2	[illegible]	[illegible]
198	4	7	3	[illegible]	[illegible]
199	4	7	4	[illegible]	[illegible]
200	4	7	5	[illegible]	[illegible]
201	5	7	1	[illegible]	[illegible]
202	5	7	2	[illegible]	[illegible]
203	5	7	3	[illegible]	[illegible]
204	5	7	4	[illegible]	[illegible]
205	5	7	5	[illegible]	[illegible]
206	6	7	1	[illegible]	[illegible]
207	6	7	2	[illegible]	[illegible]
208	6	7	3	[illegible]	[illegible]
209	6	7	4	[illegible]	[illegible]
210	6	7	5	[illegible]	[illegible]
211	$ENDFILE				

END OF FILE

Symbols

- \# Number
- S Subject
- A Treatment
- B Week
- C Session

Week in Experiment

- B_1 pre-training
- B_2 two-week training
- B_3 four-week training
- B_4 six-week training
- B_5 two-week retention

Treatment Conditions

- A_1 3S training (n = 6)
- A_2 2S-training (n = 6)
- A_3 SS training (n = 6)
- A_4 ES training (n = 6)
- A_5 BS training (n = 6)
- A_6 CS training (n = 6)
- A_7 Control (n = 6)

Session

- C_1 pre-session training
- C_2 post-session training

APPENDIX E

TABLES OF MEANS

TABLE E

TREATMENT(A) BY WEEK(B) BY SESSION(C) SUMMARY TABLE OF CELL MEANS FOR ANKLE DATA

	B_1		B_2		B_3		B_4		B_5	
	C_1	C_2	C_1	C_2	C_1	C_2	C_1	C_2	C_1	C_2
A_1	107.50	112.17	106.17	109.58	107.67	111.50	113.42	115.67	109.00	113.25
A_2	104.58	107.50	104.33	107.75	105.00	107.58	110.67	113.67	105.92	108.92
A_3	105.33	104.92	104.83	104.58	105.42	104.50	108.92	108.75	106.83	105.92
A_4	104.75	106.42	104.08	107.25	105.00	107.42	107.92	111.25	105.25	108.83
A_5	104.67	106.42	106.67	106.33	107.08	107.42	110.67	111.25	105.00	105.58
A_6	104.42	105.08	104.17	106.42	104.50	105.92	109.08	110.42	104.08	106.83
A_7	104.92	105.08	105.67	105.75	103.67	103.58	107.17	107.75	106.08	106.08
Average Means	105.17	106.79	105.13	106.81	105.48	106.85	109.69	111.25	106.02	107.92

TABLE F

TREATMENT (A) BY WEEK (B) SUMMARY TABLE OF CELL MEANS FOR ANKLE DATA

	B_1	B_2	B_3	B_4	B_5	Average Means
A_1	109.83	107.88	109.58	114.54	111.13	110.59
A_2	106.04	106.04	106.29	112.17	107.42	107.59
A_3	105.13	104.71	104.96	108.83	106.38	106.00
A_4	105.58	105.67	106.21	109.58	107.04	106.82
A_5	105.54	106.50	107.25	110.96	105.29	107.11
A_6	104.75	105.29	105.21	109.75	105.46	106.09
A_7	105.00	105.71	103.63	107.46	106.08	105.58
Average Means	105.98	105.97	106.16	110.47	106.97	107.11

TABLE G

TREATMENT(A) BY SESSION(C) SUMMARY TABLE OF CELL MEANS FOR ANKLE DATA

	C_1	C_2	Average Means
A_1	108.75	112.43	110.59
A_2	106.10	109.08	107.59
A_3	106.27	105.73	106.00
A_4	105.40	108.23	106.82
A_5	106.82	107.40	107.11
A_6	105.25	106.93	106.09
A_7	105.50	105.65	105.58
Average Means	106.29	107.92	107.11

TABLE H

WEEK(B) BY SESSION(C) SUMMARY TABLE OF CELL MEANS FOR ANKLE DATA

	C_1	C_2	Average Means
B_1	105.17	106.79	105.98
B_2	105.13	106.81	105.97
B_3	105.48	106.85	106.16
B_4	109.69	111.25	110.47
B_5	106.02	107.92	106.97
Average Means	106.29	107.92	107.11

TABLE I

TREATMENT (A) BY WEEK (B) BY SESSION (C) SUMMARY TABLE OF CELL MEANS FOR SHOULDER DATA

	B_1		B_2		B_3		B_4		B_5	
	C_1	C_2	C_1	C_2	C_1	C_2	C_1	C_2	C_1	C_2
A_1	144.08	151.00	160.58	163.08	164.08	166.75	172.17	175.17	164.25	167.33
A_2	150.50	152.67	164.75	165.75	169.08	170.92	175.50	175.42	168.58	167.58
A_3	150.33	150.58	162.42	161.17	163.92	162.92	171.92	169.92	162.75	161.75
A_4	150.67	153.50	164.00	165.50	165.92	168.83	175.25	174.67	160.58	163.17
A_5	148.83	149.25	161.25	161.58	166.00	166.00	173.00	171.25	163.67	163.33
A_6	152.25	152.25	161.75	163.00	162.50	164.58	174.67	174.50	163.17	163.50
A_7	143.58	143.33	154.33	155.58	153.83	154.17	161.58	161.58	155.08	155.17
Average Means	148.61	150.37	161.29	162.24	163.62	164.88	172.01	171.79	162.58	163.12

TABLE J

TREATMENT(A) BY WEEK(B) SUMMARY TABLE
OF CELL MEANS FOR SHOULDER DATA

	B_1	B_2	B_3	B_4	B_5	Average Means
A_1	147.54	161.83	165.42	173.67	165.79	162.85
A_2	151.58	165.25	170.00	175.46	168.08	166.08
A_3	150.46	161.79	163.42	170.92	162.25	161.77
A_4	152.08	164.75	167.38	174.96	161.88	164.21
A_5	149.04	161.42	166.00	172.13	163.50	162.42
A_6	152.25	162.38	163.54	174.58	163.33	163.22
A_7	143.46	154.96	154.00	161.58	155.13	153.83
Average Means	149.49	161.77	164.25	171.89	162.85	162.05

TABLE K

TREATMENT(A) BY SESSION(C) SUMMARY TABLE OF CELL MEANS FOR SHOULDER DATA

	C_1	C_2	Average Means
A_1	161.03	164.67	162.85
A_2	165.68	166.47	166.08
A_3	162.27	161.27	161.77
A_4	163.28	165.13	164.21
A_5	162.55	162.28	162.42
A_6	162.87	163.57	163.22
A_7	153.68	153.97	153.83
Average Means	161.62	162.48	162.05

TABLE L

WEEK(B) BY SESSION(C) SUMMARY TABLE
OF CELL MEANS FOR SHOULDER DATA

	C_1	C_2	Average Means
B_1	148.61	150.37	149.49
B_2	161.29	162.24	161.77
B_3	163.62	164.88	164.25
B_4	172.01	171.79	171.89
B_5	162.58	163.12	162.85
Average Means	161.62	162.48	162.05