EFFECTS OF STATIC, BALLISTIC AND MODIFIED PROPRIOCEPTIVE NEUROMUSCULAR FACILITATION STRETCHING EXERCISES ON THE FLEXIBILITY AND RETENTION OF FLEXIBILITY IN SELECTED JOINTS

by

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DEDICATION

This study is dedicated to my parents, Louis F. and Isabel M. Rivera for the ever-existing faith and encouragement they have given to me throughout the course of my life, studies and accomplishments.

Their traditions have enveloped in me, a cultural awareness and aspiration to be proud and not to dream but to work hard in order to attain the otherwise unattainable goals.

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CHAPTER I

INTRODUCTION

Introduction

The beneficial effects to the individual in the improvement of physical appearance, body function and performance of skills, provides an immediate justification for optimal levels of regular physical fitness and activity in this modern "push-button" society. Each individual has the capacity or potential to improve his/her figure, body function and skill level, unless prevented by medical conditions beyond control. Based on this assumption, strength, endurance and flexibility (plasticity) of the muscles has an important role that exceeds the mere functions required for daily living. Muscular activity provides stimulation necessary for organic function and tone, affects bone structure and body shape, and even provides an outlet for stress and tension.

There is no single activity to develop or maintain one's physical potential. Training for strength, flexibility, endurance, and coordination in exercise or sports tends to have a highly specific quality in attaining an optimum level in physical fitness. Training in these areas, using the overload (intensity) or specificity (specialization)

of exercise principles, have been found to produce high levels of physical performance and muscular improvement. It is necessary to repeat exercises regularly in order to maintain high levels of physical performance obtained through training. A properly formulated training program designed to enhance strength, flexibility and coordination could produce desired effects in the attainment of an athlete's maximum potential.

Individuals unaccustomed to physical activity, or athletes beginning a training program sometimes experience muscular discomfort with the sudden onset of exercises. When muscular tissue is overloaded by unaccustomed activity, waste products produced by exercise collect across the cell membrane into tissue fluid which gains access to pain nerve endings, this potassium is produced more rapidly than the blood can remove it, as a result muscular soreness may persist. This is one probable factor causing pain in muscles during the initial training period. Muscular pain may also be attributed to microscopic ruptures of muscle fibers. More recently, DeVries (12) proposed a spasm theory which postulates that the ischemia produced by unaccustomed activity includes the theories stated above but further speculates that pain is also caused by localized muscle spasm or cramp.

From the stand point of the physical educator or coach, this spasm theory becomes an obstacle that must be overcome in order to proceed in training. For many years, coaches have known that prompt

stretching of cramped muscles generally relieves a muscle spasm or cramp. Research studies have concluded that simple stretching techniques are effective in providing prevention and relief of cramped or sore muscles. (2, 12) The need for flexibility whether it be for reduction of cramped muscles, exercise, or training is an extremely important variable to an athletic coach.

In competitive gymnastics, shoulder, trunk and ankle flexibility can be a decisive factor in the achievement of an outstanding athletic performance. Flexibility is important to each individual and athlete because graceful, efficient movement is unlikely without it. Flexibility is the range of possible movement in a joint or series of joints involved in a specific movement. This degree of movement commensurate with other parameters of fitness such as strength, endurance and coordination are important factors for the attainment of maximal athletic performance.

Other important attributes of flexibility are: (1) long flexible muscles are less likely to be injured than are short weak muscles; (2) muscle stretching is effective in relieving muscle soreness; and (3) flexibility retention lasts longer than other aspects of fitness such as strength and endurance.

The success of athletic and physical fitness programs is dependent upon the knowledge of the teacher, coach or supervisor in charge of training. These instructors should know, in detail, specifics

concerning physiological and kinesiological factors that tend to enhance athletic performance. Physical educators should expand their knowledge in order to explore the relationship of flexibility to performance variables. It has been found that sex, age, body build, muscular temperature and prevention of injury through the use of flexibility exercises are specific factors of extreme importance to an athlete who is attempting to attain maximal performance.

In past years, four types of flexibility training methods have been devised and used by physical educators, coaches and physical therapists in order to obtain increments of improved flexibility within the muscles of the body. They are ballistic exercise, static exercise, yoga and modified proprioceptive neuromuscular facilitation (PNF) techniques of stretching.

The ballistic technique is initiated in a bobbing manner in an attempt to increase the stretched distance with each bouncing motion. The static stretching method is another technique currently used, and is generally in opposition to the ballistic method. This stretch method is a sustained action in which the athlete reaches the full limits of his/her range of flexibility and then applies slow force to attain deeper stretch. This ultimate position is generally held for a specified amount of time.

Yoga is a system of exercise in which the participant utilizes slow movements and held positions for the improvement of muscular

flexibility. This technique projects similar characteristics as that of static stretch. Another method designed by Kabat, and advocated by Knott and Voss (31) to increase range of motion is proprioceptive neuromuscular facilitation. It is now acknowledged in both kinesiology and treatment as a therapeutic exercise.

The body is an efficient mechanism capable of many motor activities. When there is a deficiency of the neuromuscular mechanism an individual is unable to respond adequately to the demand made on the body. Techniques of PNF involve placing a demand where a response is required. Several research studies have involved modified approaches to this PNF method in order to apply them to an individual with normal ranges of motion. The PNF method technique requires the use of concentric (muscle shortening) stretch, then an isometric contraction against some type of resistance, and finally an eccentric (lengthening the muscle gradually from its shortened state) stretch.

More recent research has suggested much controversey concerning the ballistic, static, and PNF stretch techniques currently being used in training programs. (31, 51)

In past years many physical educators and medical specialists have questioned the conventional "ballistic" way of improving flexibility. Although this method has been found effective for developing flexibility, muscular soreness has resulted from use of this method.

The static stretching technique is another method currently being investigated in opposition to the ballistic method. The static method has also proven to be important in the development of flexibility. There is some evidence that muscular soreness may be reduced or relieved with static stretching. The static and ballistic styles are probably most representive of the types of flexibility exercises currently existing in physical education and athletic programs today.

The PNF stretching technique has been modified to facilitate the normal subject. Instead of diagonal patterns used in the actual PNF method, exercises adapted to a normal subject were performed in the transverse (horizontal) plane. Very few studies have actually investigated this method in a comparative study to the ballistic or static methods. Modifications of the PNF technique have noted significant improvements in flexibility with the use of this method.

Holland (24) cited many studies that adequately tested all the various flexibility techniques which were inclusive of static, ballistic, yoga and PNF. However these investigations failed to study flexibility retention. In his implications, Holland contends this type of testing to be highly valuable to the study of flexibility.

With flexibility having been researched and found to be significant for training and physical performance improvement, it is important for a coach to understand and properly administer adequate training exercises to meet the flexibility needs of his/her athletes.

At the same time, it is important to know which flexibility technique is the better method in the attainment and retention of flexibility.

Purpose of the Study

The purpose of this study was to compare ballistic, static, and PNF exercises designed to improve the range of motion in the neck, shoulder, trunk, hip and ankle joints of the body of high school males and females. A subproblem was to investigate the range of motion retention capabilities of each type of exercise.

Scope of the Study

The study was delimited to seventy-nine high school boys and girls between the ages of fifteen and seventeen who were enrolled in a required program of coeducational physical education at Topeka High School in Topeka, Kansas. The subjects were classified as sophomores, juniors or seniors during the school year 1977-78.

This study attempted to further increase the present scope of knowledge concerning the development of flexibility of the neck, shoulder, trunk, hip and ankle, as measured by the Leighton flexometer, on three methods of exercise: (1) ballistic stretching, (2) static stretching, and (3) a modified PNF stretch technique.

Each exercise group was an intact group and randomly assigned to an exercise technique. Each exercise group participated

in a six week training program for a total of thirty sessions.

The exercise routines for the static and ballistic group consisted of nine exercises, lasting approximately ten minutes each day, five days a week. The PNF group performed seven exercises which required approximately twelve minutes due to the use of partners during exercise.

The scope included only non-varsity athletes. Any subject who was absent from five or more class periods was excluded from further analysis. When severe illness was a resulting factor of the subject not giving maximal effort in all exercising sessions, subjects were excluded from further testing.

Assumptions and Limitations

It was assumed that the subjects were representative of the normal population distribution of high school students between the ages of fifteen and seventeen, and maximal effort was given by each subject during the exercise sessions. It was further assumed that the subjects tested did not practice the exercises outside the classroom. It was assumed that subjects were free from injury or muscular limitation in or around the joint. Those with known injuries were omitted from the study.

Limitations observed by the investigator were that all subjects were not tested on the same days and were from intact classes.

The exercises used for the PNF group were devised slightly different than those used for the ballistic and static groups and were also considered limiting factors. Another limitation beyond the control of the investigator was concerning the isometric stage involved in the PNF exercises. The stronger subjects sometimes performed isotonic-type contractions rather than isometric.

This investigation did not measure all factors involved in the action of flexibility. The study was restricted to joint range of the ankles, hip, trunk, shoulders, and neck. It did not consider the flexibility of other body segments or joints. The components of strength, coordination, endurance, power, and control were not within the scope of this study. It has been found that these factors commensurate with stretching are influential in the attainment of higher degrees of flexibility. (8, 29, 46, 49, 50)

Significance of the Study

Since the polio era of the 1950's, flexibility has been researched extensively and has brought about a vast amount of studies. (25) The research findings concerning flexibility were at one time primarily revealed by research specialists in the medical profession. (31, 39) Recent advancements in physical medicine and rehabilitation have indicated the importance of flexibility as it is related to general fitness. (39) However, other research studies have concluded that

flexibility was considered to be a specific rather than general component of fitness. (10, 26, 36) These studies also reported normal ranges of joint mobility to be vitally important in the mere performance of simple daily activities. (25)

Literature supports the fact that participation in certain activities results in the development of a rather specific pattern of increased joint flexibility. (13, 26) With flexibility having been researched and found to be significant to performance improvement, a coach should understand and properly administer flexibility training exercises to his athletes. The need for flexibility training programs varies with the athletic endeavor. Some coaches may not desire an extreme amount of flexibility for his athlete. However in some activities flexibility is vitally important in order to prevent possible injury. A swimmer requires shoulder and ankle flexiblity in order to attain greater success. The outstanding gymnast specifically requires shoulder and upper back flexibility. A coach should use specific flexibility training and conditioning for the development of specific attributes which are essential in the execution of a successful athletic performance. This specificity of training would also lessen the amount of time spent for developing components which may be irrelevant to the performance of the athlete. The flexibility training exercise program would not be the same for a gymnast as it would be for a wrestler. For these reasons it is imperative for coaches to know specifics about

flexibility factors which may enhance athletic performance.

While coaching gymnastics and track for five years, the investigator experienced the necessity for knowing flexibility exercises which would adequately meet the needs of the athletes. It was vitally important to set up a good flexibility training program since these sports require extreme upper and lower back flexibility. After taking a semester course in yoga, the investigator became interested and incorporated yoga into her high school physical education classes. Flexibility came easily to the students. Improvements were quickly noticed by a week-to-week testing program. In an attempt to develop other flexibility programs, the author researched literature to seek more advanced techniques in muscular stretching. There seemed to be some controversy and lack of consistency in literature concerning the theory of stretch techniques that the author chose to undertake this investigation. As a physical educator and coach, the investigator believed that the results of this study could expand the knowledge of research in the study of the effects of flexiblity in relation to the specific static, ballistic, and PNF exercises and the feasibility of their use. This study will further add to the literature the effect of each of these stretching exercise methods on joint mobility of the human subject. This research investigation also attempted to yield results that would aid in future studies to determine which technique produces longevity in the retention of flexibility. (8)

The question of which method is most advantageous has only drawn comparisons of the ballistic and static stretch in most studies. In very few studies is the PNF method observed in physical education or sports related studies. The result of this study hopefully will enhance the use of stretch techniques currently being employed by physical educators and coaches in the field of sports and athletics.

Definitions

An understanding of the following definitions is important in the reading of this research investigation. These definitions will appear and apply throughout this study:

1. Articulation - A joint in the body.
2. Ballistic - A muscular stretching exercise which is initiated in a bobbing manner in an attempt to increase the stretched distance with each bouncing motion. (51) "Body momentum is utilized to force the muscle groups extensively as can be tolerated." (32:67)
3. Dynamic - Same connotation as ballistic.
4. Extension - Joint extension involves returning from flexion to the anatomical position. (14:45)

5. Flexibility - The range of movement about a joint. The range of motion of the areas investigated in this study will consider the movement being about a transverse axis for measurement.

6. Flexion - A coronal axis lies in the coronal plane and extends horizontally from side to side. The movements of flexion and extension take place about this axis in a sagittal plane.

7. PNF - Abbreviation for "proprioceptive neuromuscular facilitation". A stretching technique involving maximal contraction of the stretched muscle (agonist) followed immediately by a concentric contraction of the shortened (antagonist) muscle. (25:611) In this study this method will involve concentric (shortening), with an isometric contraction, followed by eccentric lengthening of the flexor muscle gradually from its shortened state. The latter stage will involve the use of the static effect.

8. Static - An extent or sustained action in which the muscle reaches its full limits of stretch and then slow force is applied to attain a

deeper stretch, which is held for a specified amount of time. (51)

CHAPTER II

REVIEW OF RELATED LITERATURE

Introduction

The review of related literature is divided into four parts. Part One is concerned with related studies on flexibility and its relationship to other physiological factors such as sex, age, body build, muscular temperature, and prevention of injury in the attainment of maximal athletic performance. Part Two deals with research of flexibility in regard to training and exercise. Part Three reviews several related studies concerning flexibility research in the areas of ballistic stretching, static stretching, proprioceptive neuromuscular facilitation (PNF) methods of stretching, and other techniques of stretching. Studies investigating retention of flexibility were also covered. Part Four reviews several sources which test and measure flexibility already utilized in research.

Physiological Factors that Effect Athletic Performance

Research investigators are now treating flexibility as a specific factor in physical performance rather than a general

component. (10, 12, 22, 26, 35) Studies have indicated that sex (44, 54, 57), age (7, 10, 28, 32), body build (5, 10, 32, 50), muscular temperature (8, 10, 16, 32), and prevention of injury (2,3, 32, 43, 44) through the use of flexibility exercises are specific variables of extreme importance to an athlete who is attempting to attain maximal performance.

Investigation by Cureton (10) supported the fact that a good athlete is most likely to have greater flexibility in the trunk, ankles, and shoulder. He reported four Japanese athletes who broke the world 880 yard relay record averaged 31.3 percent better trunk flexion than the American athletes. Twenty-one Olympic swimmers as compared to one hundred average swimmers were 11.4 percent more flexible in the ankles and 7.7 percent more flexible in the trunk.

Cureton (10), in his investigation of flexibility exercises, stated that there are many flexibility factors that "have never been studied intensively since some of the necessary aspects are not measurable in the living human subject". (10:381) Such aspects as anatomical relations in the joints, physical characteristics of the tissues, muscular tensions over any joint area, and the influence of injuries are areas of significant importance as probable variables in the effects of flexibility in relation to maximal athletic skill and performance. (10, 32, 40)

Specificity of Flexibility

Flexibility has long been termed as a characteristic or component of fitness. (10, 13, 16, 32, 39) Recent advancements in physical medicine and rehabilitation have indicated the importance of flexibility as it is related to general fitness. (39) Although flexibility has been a concern of therapists and medical personnel relative to rehabilitation, (25) knowledge of exactly how much flexibility an individual should possess has not as yet, been scientifically demonstrated. (10, 13, 36, 39) At one time flexibility was considered a general quality and the ability to touch the toes was considered an adequate evaluation. (33)

Several studies (10, 13, 26, 28) have given evidence that flexibility is specific to the different joints of the body. Leighton (36) also projected the theory that flexibility is not a general but a specific factor with each joint. He concluded that no one test item could determine whether an individual was flexible, and that flexibility could only be specific to a particular joint or joints involved in a specific movement.

Sex Variables

Vinogradov (54) stated that "because of their lower muscular strength, women have adapted themselves to the distribution of stress

over a greater number of muscle groups, resulting in the formation of a characteristically feminine type of motor coordination. Women have a smooth transition from contraction to relaxation of the muscle groups and visa versa". (54:82) He further noted that women compensate for their lack of strength, speed, and endurance by becoming more adept to exercises requiring flexibility, rhythm, coordination and plasticity.

In his investigation, Zaharieva (57) concluded that a women's physical capacity fluctuates under influences of menstruation, pregnancy and childbirth. He also reported that women would come closer to the results achieved by men in physical activities requiring speed, rhythmic performance, coordination, plasticity and endurance over a shorter time. However, they would "lag behind in sports and events requiring more general endurance, speed, stamina, muscular strength, and power stress". (57:82)

Related literature (19, 26) revealed that relative to flexibility, boys and girls do not vary greatly in the flexibility of principle joints. Forbes (19) found that girls were more flexible in more joints than boys at the age of twelve, and that boys in reverse were more flexible in more joints than girls at age eighteen.

Age Variables

Reviewed studies (1, 10, 28, 32) have shown a gradual

impairment of movement and flexibility with the advancement of age. Hupprich and Sigerseth (26), in their study of the specificity of flexibility in girls, reported that flexibility of girls increased between age six and twelve, and then declined. At the age of eighteen girls were more flexible in certain joints than girls at age six.

The influence of age on the flexibility of various aged women was studied by Jervey. (28) She investigated the flexibility of selected joints in nine specific age groups and concluded that flexibility declines with age in inactive women between the ages of eighteen and seventy-four, and that flexibility in women is highest in most joints at ages twenty-five through twenty-nine.

Other studies cited the fact that with an increase in age there is a gradual loss of flexibility in the joints and their surrounding tissues. Cureton (10) added that aging of the body shows up in a progressive loss of flexibility due to the deposition of solid elements in the joints.

Amar (1), as cited by Cureton (10:387), summarized Young's module to show that resistance to bending is 31 percent greater in a seventy-four year old man than a thirty year old man. Amar further concluded that these figures suggest caution for older men taking exercise in which maximum joint action is required.

The amount of time necessary to achieve satisfactory warm-up of the muscles has also been found to increase with age. (32)

Wertheim (10, 28), using Young's module also, in an investigation of the muscle of fresh corpses indicated that muscle is more elastic in a one year old than in an older person. The difference was eighty percent. He further concluded, muscle is more resistant to breakage at a younger age, approximately sixty-three percent greater at one year than thirty years, and fifty-three percent greater at thirty years than at seventy-four.

Hupprich and Sigerseth (26) studied three hundred girls who ranged from six to eighteen years of age. Twelve measurements of flexibility were obtained on each girl. Analysis of data found that in nine of the twelve measurements, girls increased in flexibility from ages six to twelve and then decreased gradually in the shoulder, knee, and hip flexibilities from ages six to eighteen. It was concluded that flexibility became more progressive from childhood to adolescence and then became less flexible after adolescence.

Body Build

Body size is generally determined by measurement of such characteristics as height, weight, muscular development, adipose tissue, and skeletal structure. Research has provided many studies which have investigated the relationship of body size as it compares to flexibility. It was found by Broer and Galles (7), Harvey and Scott (23), and Fieldman (17), in their studies of forward flexibility tested

by the toe-touch test, that the relationship of trunk-plus-arm length to leg length was not an important factor in the performance of the test for persons with an "average" build. However, for persons with extreme body types, the trunk-plus-arm length to leg length was a significant factor in flexibility performance of the test.

Further investigations revealed that somatotypes create a variance on the anatomical difference in range of motion at the joints. Tyrance (53), in his study on relationships of extreme body types to ranges of flexibility, attempted to determine predictions that could be made about flexibility in regard to a known body size. His evidence indicated that as one's neck size increases, one's range of hip flexion decreases significantly and his general flexibility decreases gradually.

Many studies have implicated body build as a definite factor of flexibility. (5, 50) Siders (50) investigated hip strength and flexibility and assessment of somatotypes as one of his areas of study. He found a high positive correlation between strength and mesomorphy. Evidence by Siders (50) in a study of gymnasts during a season of training found that strength was negatively related with performance, flexibility, endomorphy and ectomorphy. He concluded that no relationship existed between somatotype and performance or between flexibility and performance, endomorphy and mesomorphy.

Bosco (5) in a study of champion gymnasts as they compared to comparably aged, normal college men found the gymnasts to be

significantly smaller, stronger and more flexible in the ankles, trunk and shoulders.

Muscular Temperature

In regard to muscle temperature, several studies have found that the flexibility and temperature of a muscle can be enhanced through warm-up exercises. (4, 8, 16) Warm-up is believed to aid in performance. With temperature of muscle at an adequate degree, the muscle allows chemical reactions that occur during contraction to take place more readily. (16) Flexibility exercises elevate the muscle temperature and can be conducive to performance. (2)

Biesterfeldt (2), through many cases of research, tested the use of heat and found that even chronically tight muscled athletes could stretch effectively after twenty minutes in a wet 105 degree steam room. Another study found that ice massage followed by ice and stretching can be helpful in getting around the pain of an old injury. It was also noted that good circulation and deep muscles limit the chilling effect and therefore may alter the effectiveness of the method.

Many studies significantly impress the importance of flexibility prior to competition in order to warm the muscles and allow for greater joint mobility. (29, 32) Cureton (10) further suggested that flexibility exercises, if increased gradually may condition muscles, tendons, ligaments, and bones to allow for greater

strength as well as flexibility. These factors are basic to successful performance in skills as well as fundamental to the prevention of injuries.

Prevention of Injury

Factors of injury or its prevention were gleaned in the literature available. (2, 3, 32, 43, 44) In many sources of literature several generalizations were said to be contributing factors to injuries or their prevention. (2, 32, 44) Some of the generalizations were leading to the fact that the more flexible athlete is less prone to injury. (3) If an athlete is to develop full power in the muscle and prevent reoccurring injuries it is important to continuously lengthen the muscles to attain greater movement range. (43)

Millar (43) recommended that rehabilitation upon recovery of an injury should include exercise, stretching before activity and strength exercises. A general property of all muscles is that the force developed at contraction is greater if the muscle is under stretch at the time of contraction. Flexibility is of importance to the muscle for this reason. (44)

More shoulder, elbow and wrist injuries are reported in gymnastics and wrestling than in any other sport. (32) In tennis, ankle. knee and wrist injuries are more common. Klafs stated (32:46) "since the source of all bodily motion is in the joints, an understanding of

the structure, strengths, and weaknesses of these articulations is necessary if proper conditioning to prevent injury or to recondition following injury" is to occur.

Characteristics of the joint action of the shoulder, ankle, and hip were reviewed. In regard to possible injury of these areas, Klafs (32) summarized the articulation and their most common occurrances of injury:

> Ankle - Range of motion is 75 degrees to 8 degrees moving from plantar flexion to dorsiflexion, and 50 degrees to 70 degrees, from inversion to eversion. Since body weight transmitted through both fibula and tibia to the talus, this joint is very susciptible to stress injuries and breaks.
>
> Hip - Permitting a degree of freedom second only to the shoulder is usually injured because of an occurrance of the joint being forced beyond the limits of its range of motion.
>
> Shoulder - This joint, the most freely moveable joint of the body, is extremely susceptible to injury due to its lack of protection and strength due to surrounding tissue and its insecure joint position.

Research studies have indicated the most dangerous period in any sport or conditioning program to be the first three to four weeks, because the athlete lacks flexibility and sufficient strength. (32) Klafs (32) further suggested that the increase of flexibility and range of joint motion, coupled with strengthening of the supporting muscles enables an athlete to withstand more severe strain, impact, and twisting than he could have previously. Flexibility may be altered by such factors as joint pathology, hereditary joint structural differences,

elasticity of body connective tissue, reciprocal muscle coordination and muscle viscosity. Therefore many factors may inhibit or facilitate flexibility. Studies have concluded that the hip and shoulder articulation possess the widest range of motion, and these joints are most susceptible to injury.

In a study comparing ballistic and static techniques, DeVries (12), Twietmeyer (52), and Holt, Travis and Okita (25), found no significant difference in flexibility with one method over the other. Twietmeyer (52) and DeVries (12) found that only complaints of muscle soreness following training sessions came from members of the ballistic group. In another study, DeVries (12) subjected seventeen students to exercises devised to intentionally induce soreness. Immediately he used static stretch on the nondominant arm and nothing to the dominant one. He found the students not treated with static stretch produced higher levels of soreness. This method, DeVries suggested could be used in the care of injuries, or as a possible prevention to soreness after exercise. Klafs (32) further theorized the use of static stretch until the athlete is aware of his muscular limitations and then a possible change to ballistic stretch.

Flexibility in Relation to Training and Exercise

Literature has revealed that specificity and overload in flexibility training has a significant effect on increase of joint

mobility. (2, 12, 18, 19, 28, 32, 41, 43)

Millar (43) studied four hundred patients with calf strains and found that prevention of disability was aided by early treatment and static dorsiflexion stretching during training sessions before workout in an activity. Other investigations demonstrated the effects of training for flexibility to positively enhance performance of the range of motion and that the success was due to the use of exercises specific to stretching. (19, 26)

In several studies reviewed, the increase of flexibility was specific only to the area being tested. (10, 26, 36) Felshin (16) strengthened the specificity theory when submitting that attempts to improve flexibility in one area will not improve flexibility elsewhere unless exercise is applied to that second area.

Training geared for flexibility should include some strength components. (16, 29, 32) Related literature has revealed that during movement, an increase in flexibility must accompany an increase of strength, or the range of motion may be altered considerably. (29, 32) Studies have also shown that exercises of flexibility can achieve their goal without decreasing strength (3, 30, 32, 50), and exercises to enhance strength must have an increase of range of motion or "muscle-boundness" could occur. (10, 29, 32)

In a study to determine the relationship between range of movement at the elbow joint and success in gymnastic skills,

Johnson (29) ascertained that the principle of dynamic resistance using selected exercises, one of stretch, one involving support and one weighted exercise, did in fact develop a greater range of motion and a greater degree of skill was attained. He further concluded that strength combined with flexibility exercises is an important factor in the attainment of a high degree of skill in an athlete.

Klafs (32) emphasized the increase of flexibility and range of joint motion, coupled with the strengthening of the supporting muscles enables an athlete to withstand more severe strain, impact, and twisting than he could prior to conditioning for both strength and flexibility.

Studies on the effects of extensive flexibility training of athletes have found improvement in the joint range of motion of the athlete. (3, 18, 49) Pre-season training has been found to produce greater increases in strength and flexibility while plateaus developed during the regular season. Sayed (49) in comparing the effectiveness of three conditioning programs (circuit training, weight training and Swedish exercise) on ninth-grade boys found the Swedish exercise group to have attained greater flexibility than the other two groups and that their level of strength was not decreased.

Other variables important to training that were emphasized in related studies were the principles of use and disuse (16, 32) overload, progression, specificity, retrogression, warm-up and

warm-down. Klafs and Fleshin (16, 32) concluded these areas are important factors in improving conditioning for any of the parameters of fitness. Since movement was found to be achieved at an efficiency level of less than twenty-five percent, an athlete, in order to attain greater range of motion must go slightly beyond the point of pain.

Boling (3) studied the development of plantar flexion strength, flexibility and reaction time using isometric and isotonic exercises, running stadium stairs and heavy resistance running on the Penny Power Pull. He found intensity and repetition of training to be highly significant variables in the improvement of flexibility.

Review of Related Studies on Stretch Techniques

Static and Ballistic Studies

Many studies (6, 12, 21, 34, 38, 47, 48, 52) have investigated the effects of static stretch as it compared to ballistic stretch in the attainment of increased flexibility. In a kinesiology review of literature in regard to the physiology of flexibility, Holland suggested (12:59):

> "There is insufficient data comparing the efficacy of ballistic and static stretching in improving joint mobility, but it seems there is less danger of connective tissue trauma with the latter technique. It may well be that there are two different kinds of flexibility: one that is functionally dynamic in nature and one that can only be measured in inactive positions of the joint."

Fleishman (18), as cited by Holland (12:50) completed a factor analysis of flexibility and indicated that dynamic and static stretch were both significant components of flexibility.

Riddle (48) compared the effects of three exercise training methods on 252 college freshman women. The exercise methods were: static stretch, ballistic stretch, and a combination of the two. Measurement was by means of the Leighton flexometer. The subjects met three times per week for the entire fall term. The training session consisted of seven exercises geared to increase flexibility in the trunk and hips. Riddle found the subjects in all three groups had increased in flexibility, however the ballistic stretch seemed more effective for increasing trunk-hip flexibility over that of the static stretch technique.

Bridell (6) compared the effects of static and dynamic exercises on the hip flexibility of 92 college men. His training session ran nine weeks with a total of sixteen sessions. The results reflected a gain in flexibility of both methods, with no difference of one over the other.

Biesterfeldt (2) stated "We suppress the stretch reflex to gain recoil through a full range of motion." (2:22) In stretching, an athlete must by some means insure against the reflexive contraction of the stretched muscles while stretching. An athlete must attempt to overcome resistance from the muscles, ligaments and tendons

that surround the joints by the use of various methods of stretching. Biesterfeldt referred to ballistic stretch as an "old way" and presented the fact that there was no improvement beyond a minor point when using this method. This type of exercise early in season has shown that ten percent or more performers suffered some degree of muscle pull. (2, 32, 55)

The first experimental attempt to support the spasm-static technique theory was DeVries. (12) The subjects, seventeen college males, were exercised to intentionally induce soreness of the arms. Immediately following exercise the nondominant arm was stretched by static methods. DeVries found that the dominant arm, not subjected to static stretch produced higher levels of soreness. In another study, DeVries (12) compared the effect on flexibility of static and ballistic stretch exercises. Fifty-seven college males were tested. He found no significant differences in flexibility with on method over the other.

DeVries (12) found no difference when comparing the two methods of static and ballistic stretch. He concluded that static stretching is just as effective as the ballistic method, but the later offered three disadvantages: (1) the possibility of over-extensibility of the tissues involved, (2) lower energy requirements, (3) and that ballistic stretching may cause muscular soreness, while static will not.

Similar Stretch Technique Studies

Several related studies investigated other stretch techniques that were more effective than either the ballistic or static stretch methods. (2, 12, 45, 51) The high tension static stretching technique is one of those methods and has become popular. (12, 51) It involves maximum contraction of the muscle group to be stretched, then a period of hold for five to ten seconds, then a continuation into a static stretch of the specified muscle group. This procedure is believed to allow the golgi tendon to relax the muscle group and at the same time contributes to the increase of strength through isometric contraction. Yoga uses much the same principle as the high tension static stretch technique.

In a study of twenty-seven male college students, Moses (45) determined that groups who practiced yoga improved in range of motion at the hip, hip and trunk, and neck at the .01 level. DeVries (12) and Twietmeyer (52) also compared the effectiveness of the stretching methods used in Hatha Yoga as opposed to the conventional ballistic method. Training was conducted for seven weeks. Both investigators found a definite improvement in flexibility, but no significant difference was found between the groups at the .05 level.

Proprioceptive Neuromuscular Facilitation Studies (PNF)

Knott and Voss (31) illustrated the use of a highly effective stretch technique (PNF) as a treatment by physical therapists and cited this technique as being used in attempts to achieve relaxation when muscle spasms and pain persists. In the treatment of most therapeutic cases, isometric contraction and relaxation are the main techniques of stretch used in the PNF method. Di Gennara (14) added that muscle training should include eccentric as well as concentric movement to attain neuromuscular improvement.

Holt, Travis, and Okita (25) compared the effects of fast stretch, slow stretch and a modification of PNF on the hip and trunk. These author's method was an isometric contraction of the agonist muscle followed by a concentric contraction of the antagonist muscle. The study involved twenty-four male college students. The six groups of four subjects reported for training three days a week for three weeks. The investigators rotated the methods so that each group exercised with all three methods for one week of each method. Measurement was taken by a sit and reach test before and after each session. The authors found the mean improvement for the PNF method twice as significant in mean gains over the other methods.

With success in the testing of modified PNF methods, concentric and eccentric movement has further been investigated. (14,

25, 50) Di Gennara (14) noted that muscle tension exerted through the use of concentric (muscle shortening) and eccentric (lengthening the muscle gradually from its shortened state) movement is important to attain maximum neuromuscular benefits.

In a similar study, Tipton (51) found that with "high tension" input, the static system tends to activate the Golgi tendon which ultimately triggers "relaxation." When the static force is applied the muscle, greater flexibility will result. This further strengthens the high tension approach which has been found to be of more significant value than either the ballistic or static stretch.

Flexibility Retention Studies

Twietmeyer (52) compared the effects of seven weeks of participation in static and ballistic exercises on increasing and retaining flexibility. The retention test was taken four weeks after the post-test. His subjects were sixty-one college males. The training sessions were scheduled two days a week. Three groups were used. They were: static group, ballistic group, and a control group. Five Hatha Yoga exercises were used. The Leighton flexometer was the measuring instrument used along with a gravity goniometer. Twietmeyer reported that the static and ballistic stretch group showed a gain during training, and a loss during the retention interval. However the final flexibility level was still higher than the initial

flexibility level. The control group showed little change throughout the duration of the experiment.

In a kinesiology review of current literature in the study of the physiology of flexibility, Holland (24) found few studies that determined whether any one stretching technique would result in better flexibility for longer periods of time. Holland supported the fact that flexibility methods which could be found to retain flexibility for longer durations would be more beneficial to an athletes training program.

Review of Tests and Measurement of Flexibility

At one time, Leighton (36) researched and found little record of studies related to varied exercise upon the flexibility of different segments. Now, many studies have noted significant improvement in range of motion in regard to body segments and flexibility exercises developed to increase flexibility. (6, 17, 39) Several studies measured the effect of different types and amounts of exercise upon the range of various segmental movements. (25, 28, 29, 50) The joint areas in relation to body segments and flexibility that were most studied were the ankle (3, 13, 26, 30, 34, 36); knee (26, 34, 36, 42); hip-trunk (6, 7, 17, 25, 39, 49, 50, 56); and shoulder (10, 26, 28, 49)

Harris (22) in a study of flexibility through factor analysis reported that results from her investigation indicated that flexibility

characteristics were even more specific than she hypothesized.

> "The major conclusion is that there is no evidence that flexibility exists as a single general characteristic of the human body. Thus, no one composite test or no one joint action measure can give a satisfactory index of the flexibility characteristic of an individual." (22:69)

In 1936, Cureton (10) devised a battery of tests of flexibility which measured trunk flexion, trunk extension, shoulder elevation and ankle flexibility. The measurement device was a sliding caliper for the first three tests. A device measuring the distance between two marks made on a piece of paper representing the flexed and extended positions of the feet measured the fourth test. The trunk test did not correlate highly to the other three tests, nor did trunk extension and shoulder elevation correlate highly with the others except on self tests. He concluded that flexibility was definitely a function more structural in nature than general.

Current modifications of the Cureton test scoring system occurred to allow for the subjects size, a factor omitted from consideration in Cureton's scoring of the test. (40) Although the tests are only approximately accurate the reliability was about .85 if subjects were warmed up.

Wells and Dillon (56) devised a test to measure back and leg flexibility. Two other tests measuring leg and back flexibility were the Scott and French "standing, bobbing test" and the "sitting, bobbing test." Wells felt that although the tests were highly reliable,

they contained some undesirable features. Wells noted the Scott and French test gave many students a feeling of insecurity or apprehension when being measured from a leaning pose involved in the standing position. This prevented maximal effort. The "sitting, bobbing" test was rejected because when a maximal forward reach was attempted, the subjects would slide. This provided for inaccurate measurement. Wells and Dillon considered these undesirable features and devised a test to facilitate the weaknesses. The validity of the test was determined by correlating the sum of four trials with four trials of the Scott and French test and the standing bobbing test. The reliability for the Wells test was 98, the Scott and French test .96, and sitting, bobbing 90. Wells concluded that the sit and reach test was valid in measuring back and leg flexibility, and that it measured consistently higher than scores for the standing, bobbing test.

Reviewed literature has brought mention to the Wells test and many studies have used this testing method. (7, 9, 23, 25, 39, 40) Many studies using this test have obtained high reliability. (7, 39) Broer and Galles (7) in their study obtained .97 reliability in the objectivity coefficient for the toe touch test. Mathews, Shaw and Bohnen (39) obtained a reliability of 98 in the same test.

Leighton (36) studied the available measurement devices. He then devised an instrument that could be applied quite readily at twenty-one different points chosen on a moving segment. In later

literature the number increased to twenty-two. (40) This device was found to be much easier to use, was more accurate, and saved time over the other instruments tested. To test the reliability of his instrument to measure flexibility. Leighton used thirteen flexibility tests and administered them to fifty-six students at the University of Oregon. Leighton found that the instrument and method devised for the purpose of measuring range of motion was reliable (.98) and therefore considered valid. Since then, many studies (7, 26, 28, 30, 34, 39, 40, 42, 49, 50, 53) have applied this instrument to their investigations of segmental movement in relation to range of motion to determine flexibility increases.

Exactly how much flexibility an individual should possess has not been scientifically proven. In the Kraus-Weber floor touch, a passing grade was the ability to touch the floor. (39) The only reported validity for this test was evidence gained when Hirshland (33) reported a follow-up study of these tests on patients who had once been tested on posture at the Columbian Presbyterian Medical Center. In 1945, Kraus and Weber devised tests for muscular fitness. The tests were not designed to determine optimal levels of muscular fitness, but rather to determine if an individual had sufficient strength and flexibility of the body parts to meet normal daily demands placed on the body. (33) The test measured back and hamstring flexibility. The subject stands erect, on command he leans down slowly to

attempt to touch the floor and hold for three counts. According to Kraus and Hirshland, the ability to hold the three counts signified adequate flexibility. (10)

Several studies (7, 33, 39) of related literature have used this method of testing in measuring joint range of motion or increase of flexibility. Reliability correlation cited in the related literature found Mathews, Shaw and Bohnen to have reported a .98 reliability coefficient in their study. (39)

Harvey and Scott, (23) in a study to determine the reliability of the bend and reach test, found that the Wells and Dillon test not only eliminated a feeling of apprehension from the subjects tested but also claimed the higher scores in this particular method of testing. This refuted Scott and Frenchs' theory that (12:29) "standing scores will always run a little higher because of the effective use of gravity and because the hips are shifted back of the heels when standing, thus shortening the distance to the feet." McCloy (40) noted that the Scott-French bobbing test and the Wells-Dillon sit and reach test do not account for the length of the extremities in their scoring. He contended that "a person with short legs and long arms has an advantage in such tests." (40:34)

Broer and Galles (7) investigated the relationship of trunk-plus-arm length (reach) to leg length in the ability to perform the toe touch test. Results indicated that the relationship to reach length to

leg length was not an important factor in performing the toe-touch test. The persons tested were of average body build. However, when extremes were measured, they further found that a longer trunk-plus-arm in relation to shorter legs did give an advantage in performing the test.

Summary

Successful studies have demonstrated flexibility to be a specific rather than general component of fitness. (10, 12, 22, 26, 35) It has been found that flexibility in certain sports contributed to the attainment of success and decreased the probability of injury. (32) Many studies noted significant improvement of flexibility following a duration of stretch exercise training. (6, 12, 25, 52)

Literature indicated flexibility to be a highly significant factor in the attainment and efficiency of performance of an athlete. (2, 3, 5, 10, 28, 32, 44, 50, 54, 57) It was further advocated that in order for an athlete to develop full power in the muscle, it is important for that muscle to be stretched regularly. (12, 32)

Results of studies reviewed have significantly proven training and exercise to be effective in gaining increments of improvement in joint range of motion. (29, 32)

The findings of the studies reviewed in this chapter revealed that there were a variety of methods used by other investigators to

compare exercise stretching methods and their effects upon flexibility. (6, 12, 25, 38, 48, 52) Very few investigations made any attempt to study flexibility retention. (48, 52)

The literature indicated that several methods are available for improving flexibility. (6, 12, 25, 38, 45, 48) Studies reported that static (2, 6, 12, 18, 24), dynamic (2, 6, 12, 18, 24), combinations of the two (12, 38, 48), Yoga (12, 45, 52), and PNF modifications (14, 25, 31) all improved flexibility at a significant level.

The flexibility measures in the related literature centered around the Leighton flexometer, due to the high reliability percentages substantiated in previous studies. (22, 23, 36, 37, 52) The techniques of evaluating the flexibility of an individual varied considerably from the effectiveness of the flexometer. (23,39)

CHAPTER III

PROCEDURE

Research Design

The purpose of this study was to compare three types of exercises designed to improve the range of motion in selected joints of the body of high school males and females. A subproblem was to investigate the range of motion retention capabilities of each type of exercise.

This study was designed to investigate the development of flexibility of the ankle, hip, trunk, shoulder, and neck after six weeks of training. The three methods of training used were ballistic exercises, static exercises, and a modified version of the proprioceptive neuromuscular facilitation (PNF) exercise technique. A fourth group was used as a control (no exercises) group. Tests devised by Leighton (37) for the measurement of the selected joints range of motion were used and the measurement instrument was the Leighton flexometer. (36, 37)

This study was conducted at Topeka High School in Topeka, Kansas, between the fall and spring semester of 1978. A total of

seventy-nine students from four separate coeducation physical education classes were randomly assigned to perform a particular flexibility exercise technique. Each of three groups followed a specific stretching exercise program over a six week training period. The fourth group served as a control group. This group performed no stretching exercises. Because of the intensity of contractions and the difference in the method, the PNF exercises were designed slightly different than the ballistic and static exercises. However, the exercises facilitated the same joint areas and muscle groups as that of the other two groups. The PNF exercises also resembled those exercises performed by the ballistic and static groups. The Leighton flexometer was the instrumentation used to measure the degree of motion around the ankle, hip, trunk, shoulder and neck joints.

Data were compiled and computed for statistical comparisons of the group means. Analysis of Variance and Co-variance with Repeated Measures were computed by the BMDP2V program at the University of Kansas Computation Center. A Newman-Keuls multiple comparison method was used to determine where the differences occurred between and within the groups.

Selection of Sample

Seventy-nine students between the ages of fifteen and seventeen were tested for the study. Subjects were used from four

coeducation physical education classes. The classes were active in three weeks of fencing and three weeks of recreational sports at the time of exercise training.

Each class was randomly assigned to one of the following four exercise groups: PNF stretching group, static stretching group, ballistic stretching group, and control group. The PNF group contained eighteen subjects, twelve boys and six girls; the static group - nineteen subjects, four boys and fifteen girls; the ballistic group - nineteen subjects, nine boys and ten girls; and the control group - twenty-three subjects, twelve boys and eleven girls. The control group did not engage in any flexibility exercises during the training period.

Those students competing in any type activity in or outside of the school or those students who had physical disabilities were eliminated from this study.

Organization of Treatment Procedures

Training Procedure

The training period for all three exercise methods was six weeks in length. The training sessions were held five days each week for approximately ten minutes at the very beginning of each class period, following roll call. The session for the PNF group was

approximately twelve minutes due to the fact that partners were required in order to complete each exercise.

In the ballistic and static group, the exercises were increased gradually in the lengths of time allowed for completion of each exercise. The repetition of each exercise performed was:

Week No.	Exercise Performed
1	once
2	once
3	twice
4	twice
5	three
6	three

The investigator allowed rest periods of approximately fifteen seconds between exercises. Since the last two weeks placed a lengthy demand on the muscles, the investigator allowed longer rest periods between exercises (approximately thirty seconds to one minute.

"The time schedule for each exercise performance was as follows:

first week	20 seconds;
second week -	20 seconds;
third week	20 seconds;
fourth week	25 seconds;
fifth week	25 seconds;
sixth week	30 seconds." (52:37)

This procedure was also used by Bridell (6) and Tweitmeyer (52). Because of the static held positions required in the static and PNF groups, the shorter time period at the beginning of the training session was required. (6, 25, 52) Puhl (47) found that time periods

of over thirty seconds were excessive. For this reason this time increment was acceptable to the investigator.

The procedure used during the performance of exercises for the PNF group required three phases: (1) Phase One - total flexion of intended muscle group; (2) Phase Two consisted of a six second isometric contraction to contract the flexor, and; (3) Phase Three consisted of concentric contraction of the flexors to increase range of motion. The later phase was done slowly, similar in magnitude as that of the static exercise. The subject was allowed to assist in gaining further stretch as long as the part was stretched slowly and in the totally flexed position (eg. grabbing the leg to add stretch to the hamstring and gastrocnemius). Holt, Travis and Okita (25) used a similar method, however, these investigators did not allow the subject to assist.

All subjects were instructed not to participate in these or similar stretching exercises at any time other than the regular training sessions. The investigator administered the exercises to each group as well as controlled the environment in an attempt to retain a similar atmosphere (noise, temperature of room) for each exercising session throughout the six weeks.

Exercise Routines

The description of exercises maybe more easily understood

with an interpretation of the words in context as the investigator defined and used them. This interpretation follows:

Concentric contraction - is synonymous with isotonic contraction meaning the shortening contraction of the muscle in which one level of tension throughout the contraction occurs.

Isometric contraction - is one muscle length throughout the contraction.

Eccentric contraction refers to expenditure of energy of the muscle to produce force that is less than the opposing side, although the muscle tries to shorten, it is actually lengthened during its contraction phase.

Flexors refers to the muscles involved in putting the body into a "flexed position."

Extensors refers to the muscle groups used in "extension" of the body.

Anterior muscle groups muscle groups which are the principle muscles causing "flexion."

Posterior muscle groups - muscle groups which opposes the act of flexion.

Antagonist - the muscle opposing the act of flexion.

Movers - refers to the muscle that contracts against a resistance; aide in flexion of the body parts.

Prime mover is the principle muscle in the act of flexion. (eg. in the analysis of the action of flexing the arm at the elbow joint, the antagonist is the triceps brachii, the biceps brachii is the mover and the prime mover is the brachialis)

There were nine different exercises used in the static and ballistic group and seven exercises for the PNF group. These exercises were all designed to increase joint range of motion of the

ankles, hip, trunk, shoulders, and neck. The exercise routine performed by the PNF group was designed differently than that of the ballistic and static groups, although the exercises resembled one another. The hip and trunk PNF exercises were developed by Holt, Okita and Travis (25). The other PNF exercises were developed by the investigator. The PNF exercises were also named by the investigator in order to properly describe the figures photographed (Appendix C).

The ten exercise positions used for the ballistic and static group were similar to those used in Hatha Yoga. The investigator selected two stretch exercises for each of the five areas studied. The exercises were designed to stretch the anterior muscles with one exercise and posterior muscle groups on the second exercise. The exercises selected to enhance flexibility of the anterior muscle groups were:

Ankles	"The Kneeling Position" (11:27)
Hip	"Half - Locust" (52:27)
Trunk	"The Snake" (11:24)
Shoulder and Neck	"The Folded Leaf" with arm and head variations. (11:43)

The exercises used on the posterior muscles were:

Ankles	"Gastrocnemius Stretch" (32:80)
Hip	"Swan" (52:34)

Trunk - "The Plough" (11:85)

Shoulder - "Shoulder Stretch" (32:79)

Neck "The Candle" (11:84)

In this study these positions will be representative of static and ballistic stretch positions with variations on the descriptive performance of each exercise. Twietmeyer (52) used similar yoga techniques in his exercise work sessions and found them to increase flexibility in the areas he tested.

The static group performed each exercise moving into the flexed position slowly until a stable position was maintained "near" the maximum range of motion, then complete range was obtained slowly and held for the specified amount of time. (51) This would depend on the week, due to the increase in length of time and repetition for each exercise per week. The "near" maximum position was determined solely by the subject.

The ballistic group did not assume a held position. Instead the subjects performed a bobbing motion in an attempt to increase the stretched distance with each bouncing motion. (32, 51) Specified time and repetition of exercise was described in the training procedure.

The following is a description of the nine exercises with modification for each group used in the order they were performed in the sessions: (Refer to Appendix C for illustrations)

1. "The Kneeling Position" (11:27) (Appendix C - Fig. 1):

With legs together, the beginning position was a forward kneeling position. Subject sat back on his heels. The static group remained in the seated position with concentration on extending the ankles and holding this position for the required length of time. For greater stretch subjects were instructed to lean further back. The ballistic group bounced on the ankles only to the point of moderate stretch and then was instructed to proceed cautiously to increase the stretch on each bounce for the required time. Bending and extending the elbows was allowed for the bouncing rhythm in this exercise. The ultimate limits of this exercise position are pictured in Appendix C - Figure 2.

2. "Gastrocnemius Stretch" (32:80) (Appendix C - Fig. 3): The subject stood approximately three to four feet from the wall, varying from subject to subject due to leg length and body size. The feet were flat on the floor, making sure the heel was down throughout the exercise. The body was inclined forward to an angle of approximately 65 degrees. The body support was with an extended arm, palms against the wall. The static group was allowed to lean the body toward the wall by flexing the arms adding greater stretch slowly to maximum range, then holding for required time. This was not pictured in Figure 3. The ballistic group also leaned into wall, then extended arms again in a bouncing action toward the wall leaning in closer with each bounce to attain maximum stretch. This was not illustrated in Figure 3. In the third week, a second phase was added

to this exercise. The beginning and exercise position was the same. The difference was in a pedaling-type motion (Fig. 3) which allowed the weight to alternate from left to right as the heels were driven into the floor. The arms remained straight in this phase of the exercise. The time and repetition allowed to hold the position was the same as that used in the other exercises.

3. "Half Locust" (52:27) (Appendix C Fig. 4): The subject began in a prone lying position with chin resting on the floor. The arms were extended at sides, palms down. The leg was extended at the hip joint by lifting it as far as possible above the floor and keeping it completely straight. Throughout the exercise the chin and opposite hip to the leg being exercised remained on the floor. This prevented the back from twisting while trying to stretch backward. The exercise was performed on each leg. The static group slowly lifted to maximum extension and held this position for the specified time. The ballistic group used a pumping action as they attempted maximum stretch with each lift.

4. "Swan" (52:34) (Appendix C Fig. 5): The subject began in a sitting position with the legs extended. Subject left one leg straight forward while externally rotating the leg as the hip and knee flexed to allow the sole of the foot to rest against the inside of the thigh of the extended leg. The subject dropped his head and leaned forward reaching as far down the extended leg as possible.

The exercise was performed on each leg.

The remaining descriptions are concerned with the exercise only and not the modifications for each group. The action for the static group was a slow movement into the stretched position until nearing maximum stretching and then slowly adding stretch to an extreme point and holding for the required time. The ballistic group bounced reaching maximum stretch on the first bounce, then attempted to increase range of motion with each bounce.

5. "The Snake" (11:24) (Appendix C - Fig. 6): The beginning position was prone lying, palms on floor at shoulder level, elbows bent. The subject initiated action by beginning the sequence of movements throwing the head as far back as possible, then pushing into the floor and extending the arms to completely curve the back as far backwards as possible.

6. "The Plough" (11:85) (Appendix C- Fig. 7): Subject began in a supine lying position with arms at the sides, palms down. The subject raised the legs over head until the toes touched the floor behind the head. The arms were then raised over head, palms up with hands placed under the feet, which were flexed at the ankles (Fig. 7). The weight was distributed at the shoulder area and not the lower neck. The shoulders were flat to the floor for greater control.

7. "The Folding Leaf" (11:43) with arm and head raising variations (Appendix C Fig. 8): This position began on the knees. Subject sat back on extended ankles with torso straight up. The next movement required the subject to lean forward so that the nose rested between the knees, arms remained at sides, palms up, completely relaxed. This position resembles the body being folded into three layers or a pose similar to that of a sleeping baby. The arm variation consisted of subject interlocking the fingers of both hands behind the back and raising the extended arms up and toward the head to attain maximum stretch for the specified time. At the same time the head was raised up and as far back as possible. The chest remained down on the knees with the head only lifting slightly.

8. "Shoulder Stretch" (32:79) (Appendix C - Fig. 9 and 10): The subject assumed an approximate shoulder width stance. The arms were extended forward so that fingers interlaced and palms faced away from the body throughout the exercise. Arms were raised overhead with the elbows extended during the exercise and stretched backwards as far as possible (Fig. 9).

The second phase of this exercise (Appendix C Fig. 10) was to begin with fingers interlaced behind the back so that the palms faced the back of the subject. The exercise position was reached as the subject bent forward at the hips, at the same time the arms (straight) were stretched backwards. The head stayed down with the

chin tucked in. This position was held for the required time (Fig. 10). The ballistic group stretched the arms in a bouncing motion.

9. "The Candle" (11:84) (Appendix C Fig. 11): The subject bent the legs so that knees were above the chest from a supine lying position, at the same time raising and straightening legs to the vertical position. The body formed a right angle with head. The chin was tucked in to rest on the chest above the sternum. The weight was the lower neck to avoid blocking the air passage.

The exercises for the PNF group were structured so that emphasis was placed on the three important phases occurring throughout the duration of each exercise. For all exercises the procedure was similar to that used by Holt, Travis and Okita (25). Instead of diagonal patterns used in the actual PNF method, exercises were performed in the transverse plane. The actual procedure required three phases:

1. Phase One This phase of the exercise required flexing at one or possibly more joints of a body segment. The range of movement continued until the subject could feel the extensor muscles stretch. This phase was held ten seconds. The movement required slowly stretching into a near maximum position.

2. Phase Two - This phase required the assistance of a partner who participated as the resistance to the isometric contraction of the muscles to be stretched (extensors). The contractions all

lasted six seconds. Partner did not allow the segment being exercised to move more than four inches past the point in which subject first began the contraction. During the last three weeks, contractions lasted ten seconds.

3. Phase Three - Immediately following phase two, the subject was instructed to contract muscle flexors concentrically in order to increase range of motion in the extensors being used. This was held for ten seconds in all exercises.

Prior to the beginning of the exercise sessions subjects were properly informed of terms and muscle actions relating to each of the three phases. The following is a description of the PNF exercises with each exercise described according to the phase: (For illustrations of the exercises refer to Appendix C.)

1. "Ankle Stretch" (Appendix C Fig. 12): The subject sat on the floor, legs extended, the bottom of the feet were placed flat against the wall so that the feet were in a line perpendicular to the floor. The subject kept the legs straight, knees were extended and right ankle was dorsi-flexed until he felt the stretch on the gastrocnemius muscle. An isometric contraction was then performed in an attempt to extend the ankle. The wall was the resistance. A partner was not used in this exercise. The subject leaned on his arms with palms on the floor to impede backward sliding. Subject was then instructed to immediately contract the ankle flexors

concentrically, as in Part One. The same exercise was performed by the subject, except the exercise was on the left ankle.

2. "The Kneeling Position" (Appendix C - Fig. 13 and 14): Subject sat back on the heels, leaning backward until stretch was felt on the anterior muscles of the leg (Fig. 13). The subjects were instructed to push the top of the feet (or toes) into the ground causing the isometric contraction of the flexors. During this phase the subjects leaned forward to assume a more upright position (Fig. 14). Subjects were instructed to lean backwards to feel the stretch of the flexors once again (Fig. 14).

3. "Hip Stretch" (Appendix C Fig. 15 and 16): The subject, in a supine lying position, was instructed to lift the right leg, flexing the ankle so that it was at a right angle to the leg. The knee was kept straight and the ankle flexed throughout this exercise. The leg was lifted until the extensor (hamstring) was stretched. Resistance by a partner at this point was applied above the ankle and in the center of the thigh. Subject began the isometric contraction when the leg was perpendicular to the floor. The extensors were now in a concentric contraction. This later phase required concentric contraction of the flexors. In this phase the subject was allowed to grasp the leg and pull slowly to attain greater and deeper stretch. This exercise progression in Figures 15 and 16 were used on both legs and constituted one complete exercise repetition.

4. "Trunk Stretch" (Appendix C Fig. 17 and 18): This exercise was performed in a standing position. Subject was instructed to maintain knee extension throughout the duration of the exercise. Beginning from a standing position, the trunk was flexed forward as far as possible. A partner positioned over the back and to the side of the subject placed his hands on the lower and upper back. The subject was stopped in an attempt to extend the trunk to an upright position. Trunk flexors were again contracted in order to increase range of motion in the trunk extensors. This exercise progression pictured in Figures 17 and 18 constituted one exercise repetition.

5. "Shoulder Stretch" (Appendix C Fig. 19): This exercise was performed in the same manner as the ballistic and static "Shoulder Stretch" shown in Figure 9. The subject assumed a sitting position, rather than standing. The arms were extended forward so that the fingers were interlaced, palms faced away, and arms were extended overhead until the extensors were on stretch. Resistance was added to both arms at the elbows. An assistant stood at subject's back in order to hold the arms. The subject attempted to contract the extensors. The subject then stretched back overhead as far as possible, putting the extensors on stretch.

7. "Neck Stretch" of the anterior muscles (Appendix C-Fig. 20); The subject was in a prone lying position palms down, shin on the floor. The subject lifted his head up and stretched back as far

as possible and held this position. Resistance was applied to the forehead to restrain the forward contraction. The subject lifted his head again for anterior neck muscle stretch. Resistance was once again applied. In the next stage the subject stretched up and back to a fully extended position. This latter phase was performed exactly like the snake (refer to Fig. 6).

7. "Neck Stretch" of posterior muscles (Appendix C - Fig. 21): The subject was in a supine lying position. The subject placed overlapping hands on the back of his head. The chin was tucked and the head was stretched forward as far as possible. This position was held for the specified time. Resistance was added to the back of the head to restrain any backward movement of the head. This contraction was held. The head was dorsi-flexed once again for the required time.

At the conclusion of these seven exercises the subjects exchanged places and the partner was then exercised and the subject became the assistant.

Throughout each exercise, the investigator instructed all three exercise groups that on completion of the exercise, the subjects should come out of all positions by reversing the movement in a slow controlled manner. It was further stressed to all subjects to try and relax all muscles that were being stretched in order to attain greater flexibility in the working muscle groups. The repetition of these

exercises followed the same increments as performed by the ballistic and static groups.

Measurement Procedures

Selection of the Testing Instrument

The investigator used the following criteria in the selection of a testing instrument for this study:

1. The instrument had been found in other studies to be highly reliable and valid. (36, 52)
2. Because of the administrative feasibility and educational application of the instrument, this instrument has proven useful in many investigations.

The instrument used in this study to measure flexibility was the Leighton flexometer. This instrument makes use of the force of gravity to move the dial of the flexometer. The amount of movement, in degrees of angular rotation, was read directly from the dial. The instrument was diverse in that it could essentially be applied at any point chosen on a moving segment. This device has been found to be easy to use, very accurate, and saves time over other instruments tested. (36) After performing several tests the investigator found the flexometer to be reliable and valid.

Testing Design

A total of four testing sessions were used in this research investigation:

1. The first, or pre-test was given the Thursday and Friday preceding the beginning day of the exercise training period.

2. The second test was given to the subjects six weeks later beginning the Monday following the last exercise training session.

3. The first retention test was given exactly two weeks following the post-test date.

4. The second retention test was given two weeks after the first retention test. The last two measurement sessions were devised to note the retention of flexibility in the four groups.

Measurement Technique

The subjects were measured by the investigator in alphabetical order, individually, in the athletic training room. All subjects were reminded the day before testing that they were not to participate in any type of activity prior to actual testing. A class period was used the day before the pre-test for a thorough explanation of the study and its importance that each subject participate and perform to their maximum potential. At this time subjects were given an explanation and demonstration of the testing procedure.

During the actual testing session each subject was given a practice trial without measurement to reacquaint him with the measuring procedure. (17) All measurements were taken from the subject's nondominant side.

Any errors performed by subjects were verbally corrected by the investigator during the preliminary and second trials and the third trial was recorded. The first and second trials were not recorded, these trials were used for practice. Fieldman (17) and Harvey and Scott (23) found that the reliability of flexibility scores were higher on trials three and four.

All subjects were tested in gym suits and measured according to the directions presented by Leighton. (37) A score was the most distant point reached and held (angular displacement) in relation to the zero mark, scores were recorded in degrees. When the subject reached either maximum flexion or extension the dial on the flexometer was locked in.

Measurements of flexibility were taken by means of ten tests devised by Leighton to measure flexion and extension of the neck, trunk, hip, shoulder, and ankle joints. (37)

Neck Measurement Technique

The starting position for both flexion and extension measurements was a supine lying on a wooden table. The head and

neck projected over the end, shoulders were square and even with the edge, arms were at the sides. The flexometer was fastened to the left side of the head, positioned directly over the ear. The zero mark was set.

The movement count was as follows:

1. Flexion - The head was raised and moved to an extreme position as near the chest as possible, the dial was locked.

Shoulder Measurement Technique

In the beginning position for this test, the subject stood against a projecting corner of a wall. The arm extended just beyond the projected corner. The heels, buttocks and shoulder touched the wall. Arms were at sides. The instrument was fastened to the side of the upper arm.

The movement procedure was:

1. Flexion - arm was moved forward and upward in an arc, when subject had moved as far as possible the dial was locked. The hand during this movement should allow the palm to slide against the wall.

2. Extension - The direction of the subject's palm toward the wall was the same. The subject's arm moved down and backward in a rotating motion until an extreme point was reached, where the dial was then locked.

Trunk Measurement Technique

The subject began in a standing position, feet together, knees straight with arms extended overhead. The hands were clasped with palms up. The instrument was fastened to the right side of the chest just below the armpit. For boys, the meter was fastened at nipple level, for the girls, the device was positioned approximately four inches lower.

The movement count was:

1. Flexion - The subject bent forward to maximum reach distance and the dial was locked. The arms and trunk remained in a straight line with head between the arms during the movement.

2. Extension - The upper trunk and arm action remained in line as the subject bent backward as far as possible. The dial was locked. The feet remained in contact with the floor throughout the performance of both these movements.

Hip Measurement Technique

The starting position was exactly the same as that used in the trunk measurement. The flexometer was fastened on the right side of the hip at the height of the umbilicus. The measurement of movement was exactly the same as that used in trunk measurement. Both flexion and extension were tested.

Ankle Measurement Technique

The subject began this measurement in a sitting position on a wooden table with the leg being tested, supported by the table and the ankle of this leg projecting over the end of the table. The other leg extended downward with the feet resting on the floor. This varied with the difference in leg length in relation to the height of the table. The instrument was attached to the inside of the feet.

The movement measurement was as follows:

1. Flexion - The subject turned the feet upward and toward the knee until extreme range was attained, the dial was locked.

2. Extension - The foot was dropped downward to a maximum point, the dial was locked.

On this measurement the natural position of the foot was oblique and it was in this position in which the zero mark was set.

Personnel Used

The investigator used a student teach and senior student assistants to record information during testing. These assistants were instructed prior to the testing on their responsibilities for properly recording the data. Training was not required since the task was only recording. The investigator administered all measurement. This was the extent to which assistance was used throughout

the duration of the study.

Equipment Used

Ensolite wrestling mats and a stop watch were used for all exercise training sessions. A wooden training table, three feet high and approximately six feet long, was used for testing. No other equipment was necessary for completion of the study.

Collection of Data

Data were collected during the four flexibility testing sessions to determine the extent of flexibility possessed by the subjects. The ankle, hip, trunk, shoulder and neck flexibility of each subject was measured four times: Pre-test, post-test and two retention tests. The third trial of each test was considered the subject's flexibility score for each of the testing sessions.

A form was developed to provide quick access to the five measurements taken of each subject from each of the testing sessions (see Appendix A). Each measurement was recorded in degrees by noting the angular displacement from a point at rest to a point of maximum flexion or extension, of the segment or joint being tested. On the form two scores were recorded; one score for the amount of flexion and the other for the degrees of extension for each of the five areas being measured. The data from these sheets were gathered

and used for statistical analysis.

Flexion and extension measurements of each subject were taken at the ankle, hip, trunk, shoulder and neck joint areas. The total range was considered to be the subjects flexibility score for each testing session. There were a total of four testing sessions: pre-test, post-test and two retention tests. Group means were used for all statistical computations, with the exception of the reliability correlations. All numbers statistically evaluated were rounded to the nearest hundredth. The raw data analyzed for all subjects may be found in Appendix A (Tables 2-17).

Analysis of Data

Data were compiled and computed for statistical comparisons of the group means. Analysis of Variance and Co-Variance including Repeated Measures were computed by the BMDP2V program at the University of Kansas Computation Center. The level of significance of .05 was selected as the level for acceptance.

A one way analysis of variance and co-variance with repeated measures was used for two purposes: (1) to find the differences in flexibility means between and within the four groups and (2) to compare changes in flexibility between the pre-test and post-test means, the pre-test and first retention test means, the pre-test and second retention test means, the post-test and first

retention test means, the post-test and the second retention test means, and the first retention and second retention test means.

Comparisons of flexibility changes among groups were statistically evaluated by an analysis of variance. Upon comparing the means, if the analysis of variance led to a significant F test, the Newman-Keuls method was used to determine where the significant differences were. In this investigation the .05 level of significance was chosen and the groups have unequal n's. The Newman-Keuls method uses a significance level of .05. This method also uses the studentized range applied to unequal n's. Bases on these two important facts, the Newman-Keuls method for making multiple comparisons was chosen by the investigator, in order to determine where the significant differences between and within the groups were.

Reliability

Five subjects (students) were randomly chosen and measured with the Leighton flexometer at the ankle, hip, trunk, shoulder and neck. Both flexion and extension readings were taken of these joint areas. Two measurements of the specified areas were taken on two separate days.

In a preliminary test for consistency of measurement, the following reliability scores, using sum of the squates, test-retest method were correlated by the investigator; ankle - .927; hip - .999;

trunk - .995; shoulder 989; and neck - 928; (see Appendix A for the pilot study raw scores).

In a study by Leighton (36) the following reliability scores were found: ankle 99; hip - 97; trunk - 997; shoulder - 98; and neck - 98.

CHAPTER IV

ANALYSIS OF DATA

Introduction

The purpose of this study was to compare three types of exercise designed to improve the range of motion in selected joints of the body of seventy-nine high school males and females. Retention capabilities of each type of exercise was also observed in this investigation.

This study was designed to investigate the development of flexibility of the ankle, hip, trunk, shoulder, and neck after six weeks of training. The three methods of training used were ballistic exercises, static exercises, and a modified version of a proprioceptive neuromuscular facilitation (PNF) exercise technique. A fourth group was used as a control (no exercises) group. Tests devised by Leighton (37) for the measurement of the selected joints range of motion were used and the measurement instrument was the Leighton flexometer. (36)

A total of four testing sessions were used. The first, or pre-test was given preceding the exercise training period. The

second test was given the day after the last training session, six weeks after the exercise program began. The first retention test was given exactly two weeks after the post-test. The second retention test was given two weeks after the first retention test. The total retention interval was four weeks.

The ankle, hip, trunk, shoulder, and neck flexibility of each subject was measured in each of the four testing sessions. The third trial of each test, using the non-dominant side of the subject was considered the subjects flexibility score for each of the tests.

Data were compiled and computed for statistical comparisons of the group means. The raw data for all tests may be found in Appendix B - Tables 2-17. Analysis of variance with repeated measures and co-variance were computed by the BMDP 2V program at the University of Kansas Computation Center. The design used was one grouping factor and one trial factor. The ANOVA table design was taken from Winer (64), and has also been used for interpretation of the BMDP program. A Newman-Keuls multiple comparison method was used to determine where the differences between and with in the groups were. The 05 level of significance was accepted by the investigator for all data statistically analyzed. For further statistical investigations in this study, and to further distinguish between and within groups, it was tentatively accepted that no one exercise method was different over the other.

Findings

Comparisons of Ankle Flexibility

Raw data for the ankle measurements may be found in Appendix B - Tables 2 - 17. Figure 22 charts the ankle mean changes that occurred between the groups over the entire ten week testing period.

The results of the analysis of variance on ankle flexibility measures (Table 18) revealed significant F ratios for between the group and within the group effects, at the .05 level.

Table 18

Analysis of Variance on Ankle Flexibility Measures

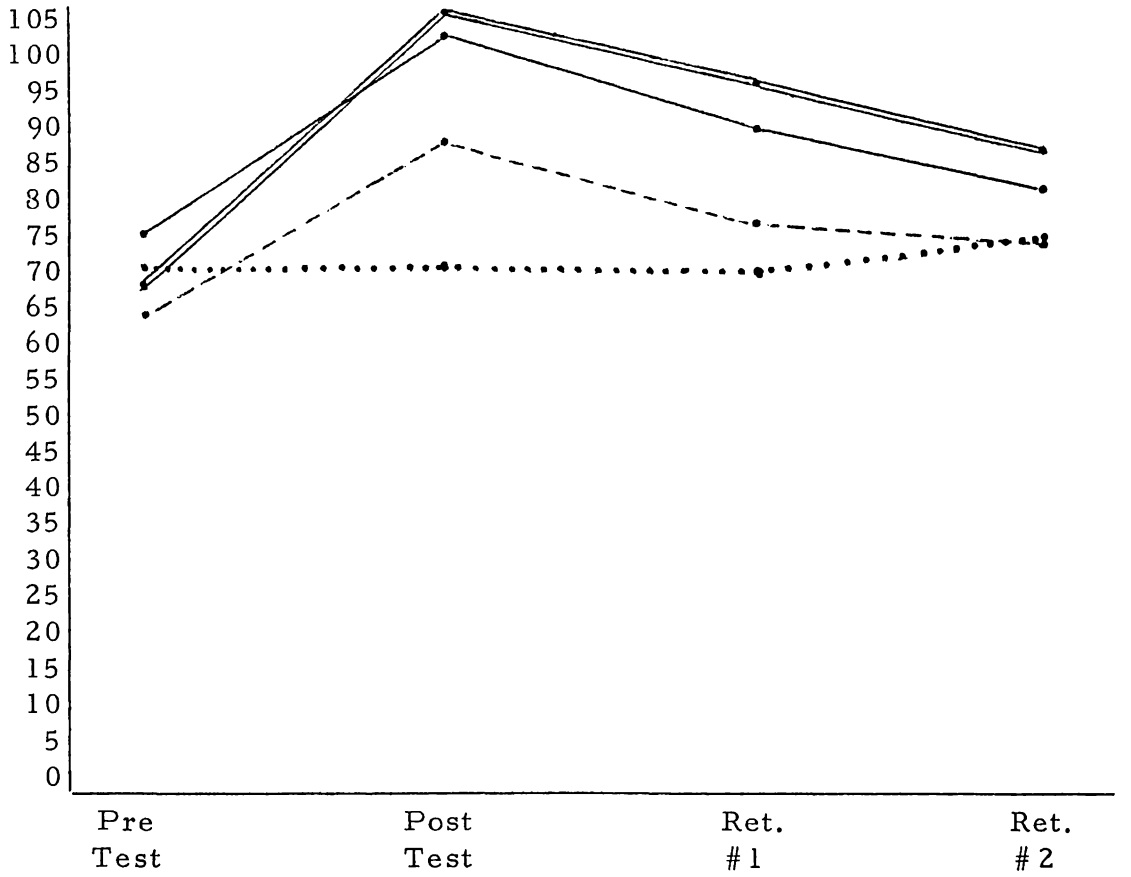
Source	SS	df	MS	F
Between groups	44708.86	78		
Between	14950.20	3	4983.4	12.56
Within	29758.66	75	396.78	
Within Tests	25420.02	234		
Between	8452.98	9	939.22	12.46
Within	16967.04	225	75.41	

*2.48 and 1.92, respectively, are needed for significance beyond .05.

The Newman-Keuls mehtod was used to find the differences between (Table 19) and within (Table 20) the group means.

Figure 22

Ankle Flexibility Mean Changes



---Ballistic
—— Static
═══ PNF
• • • Control

Table 19

Ankle Flexibility Differences between the Groups
(Newman - Keuls)

		Q Value / S.R.	Q Value / S.R.	Q Value / S.R.	
Group-Mean-	B 63.16	P 67.94	C 70.35	S 74.27	
B	-	2.46 / 2.95	3.71 / 3.58	5.7 / 3.96*	PRE-TEST
P	-	-	1.24 / 2.95	3.23 / 3.58	
C	-	-	-	.62 / 2.95	
S	-	-	-	-	
	C - 70.39	B - 88.26	S - 101.11	P - 103.28	
C	-	9.23 / 2.95*	15.84 - 3.58*	16.95 / 3.96*	POST-TEST
B	-	-	6.64 - 2.95*	7.74 / 3.58*	
S	-	-	-	1.12 / 2.95*	
P	-	-	-	-	
	C - 71.42	B - 77.79	S - 89.37	P - 92.33	
C	-	3.21 / 2.95*	9.23 / 3.58*	10.75 / 3.96*	RET. #1
B	-	-	5.97 / 2.95*	7.49 / 3.58*	
S	-	-	-	1.52 / 2.95	
P	-	-	-	-	
	B - 74.79	C - 75.26	S - 82.69	P - 86.61	
B	-	.24 / 2.95	4.07 / 3.58*	7.46 / 3.96*	RET. #2
C	-	-	3.83 / 2.95*	5.85 / 3.58*	
S	-	-	-	2.02 / 2.95	
P	-	-	-	-	

S.R. = Critical Value of Studentized Range
*Denotes significance at .05 level.

Application of the Newman-Keuls (Table 19) to determine differences between the groups ranked the PNF and static methods significantly superior to both the ballistic and control groups in the post test results. There was no statistically significant difference between the PNF group as compared to the static group in the post, or two retention tests. The only instance in which the control group showed no differences to the three exercise groups was during the pre-test. The ballistic and static groups did exhibit a significant difference in the pre-testing session. These differences were discussed later on in the chapter.

Table 20 summarizes the differences between test means for all the groups, using the Newman-Keuls method. All three exercise groups revealed significant flexibility gains between the pre- and post-tests. Although these three groups displayed significant flexibility losses during the four week retention interval, they did not show a significant flexibility loss when comparing the pre- to the final retention test. The control group did not lose or gain significantly in ankle flexibility measures over the course of the study.

Table 20

Ankle Flexibility Differences between the Tests
(Newman - Keuls)

		Q Value / S.R.	Q Value / S.R.	Q Value / S.R.	
Group-Mean-	Pre 63.16	R2 74.79	R1 77.79	Post 88.26	
Pre	-	5.99 / 2.95*	7.54 / 3.58*	12.94 / 3.96*	Ballistic
R2	-	-	1.55 / 2.95	6.94 / 3.58*	
R1	-	-	-	5.40 / 2.95*	
Post	-	-			
	Pre-74.21	R2 - 82.68	R1 - 89.37	Post - 101.11	
Pre	-	4.37 / 2.95*	7.81 / 3.58*	13.87 / 3.96*	Static
R2	-	-	3.45 / 2.95*	9.5 / 3.58*	
R1	-	-	-	6.05 / 2.95*	
Post	-	-	-	-	
	Pre-67.94	R2 - 86.61	R1 - 92.33	Post - 103.28	
Pre	-	9.62 / 2.95*	12.57 / 3.58*	13.22 / 3.96*	PNF
R2	-	-	2.95 / 2.95*	8.59 / 3.58*	
R1	-	-	-	5.64 / 2.95*	
Post	-	-	-	-	
	Pre-70.35	Post - 70.39	R1 - 71.48	R2 - 75.26	
Pre	-	.02 / 2.95	.58 / 3.58	2.53 / 3.96	Control
Post	-	-	56 / 2.95	2.51 / 3.58	
R1	-	-	-	1.91 / 2.95	
R2	-	-	-	-	

S.R. = Critical Value of Studentized Range
*Denotes significance at .05 level.

Comparisons of Hip Flexibility

Raw data for the hip measurements may be found in Appendix B Tables 2 17. The analysis of variance on hip measures is summarized in Table 21. The differential sesitivity for tests between and within ghe groups obtained a significant F ratio.

Table 21

Analysis of Variance on Hip Flexibility Measures

Source	SS	df	MS	F
Between groups	195341.76	78		
Between	37105.69	3	12368.56	5.86
Within	158236.07	75	2109.81	
Within Tests	81735.28	234		
Between	15284.81	9	1698.31	5.75
Within	66450.47	225	295.34	

*2.48 and 1.92, respectively, are needed for significance beyond .05.

The group comparisons, using the Newman-Keuls (Table 22) revealed no significant differences between the groups in the pre-test measures.

All three exercise groups reflected significant hip flexibility mean gains between the pre- and post-tests. Between the post- and first retention test the hip flexibility loss shown by the ballistic group was significantly different from the losses shown by

Table 22

Hip Flexibility Differences between the Groups
(Newman Keuls)

		Q Value / S.R.	Q Value / S.R.	Q Value / S.R.	
Group-Mean-	P 126.94	C 132.49	B 136	S 141.79	
P	-	.27 / 2.95	2.36 / 3.58	3.87 / 3.96	PRE-TEST
C	-	-	.91 / 2.95	.28 / 3.58	
B	-	-	-	1.51 / 2.95	
S	-		-	-	
	C-143.48	B - 164.89	P - 172.44	S - 185.05	
C		5.57 / 2.95*	7.54 / 3.58*	10.82 / 3.96*	POST-TEST
B	-	-	1.97 / 2.95	5.25 / 3.58*	
P	-	-	-	3.28 / 2.95*	
S	-	-	-	-	
	C-143.57	B - 154.05	S - 174.21	P - 174.94	
C	-	2.73 / 2.95	7.98 / 3.58*	8.17 / 3.96*	RET. #1
B	-	-	5.25 / 2.95*	5.44 / 3.58*	
S	-		-	.19 / 2.95	
P	-	-	-	-	
	B-146.79	C - 151.48	P - 173.17	S - 181.26	
B		1.22 / 2.95	6.87 / 3.58*	8.98 / 3.96*	RET. #2
C	-	-	5.65 / 2.95*	7.75 / 3.58*	
P	-	-	-	2.11 / 2.95	
S	-	-	-		

S.R. = Critical Value of Studentized Range
*Denotes significance at .05 level.

the PNF and static groups. In the first retention test no significant difference was found between the PNF and static groups.

Over the course of the ten week study, the PNF ans static groups showed no significant loss in hip flexibility. In this final retention test the ballistic and control groups showed no significant differences between each other, and the PNF and static groups also displayed no significant difference from one another.

The control group was found to be statistically different from the PNF or static groups in all of the tests, except the pre-test.

The PNF and static groups were significantly greater in hip flexibility gains and retention as compared to the ballistic and control groups.

It is important to note, that although the static group was ranked highest in the post-test measure, the PNF groups pre-test mean was 15 degrees lower than the static group mean. The degrees difference reflected in these two groups post-test mean was only 13 degreees. This would indicate the PNF group as having gained 2 degrees over the static group mean in the post-test measurement.

In Table 23 and Figure 23 the hip flexibility means on each of the four tests are presented. The three exercise groups displayed a significant increase in hip flexibility gains between the pre- and post-tests. During the first retention interval, none of the exercise groups differed significantly. Between the first and second retention

Figure 23

Hip Flexibility Mean Changes

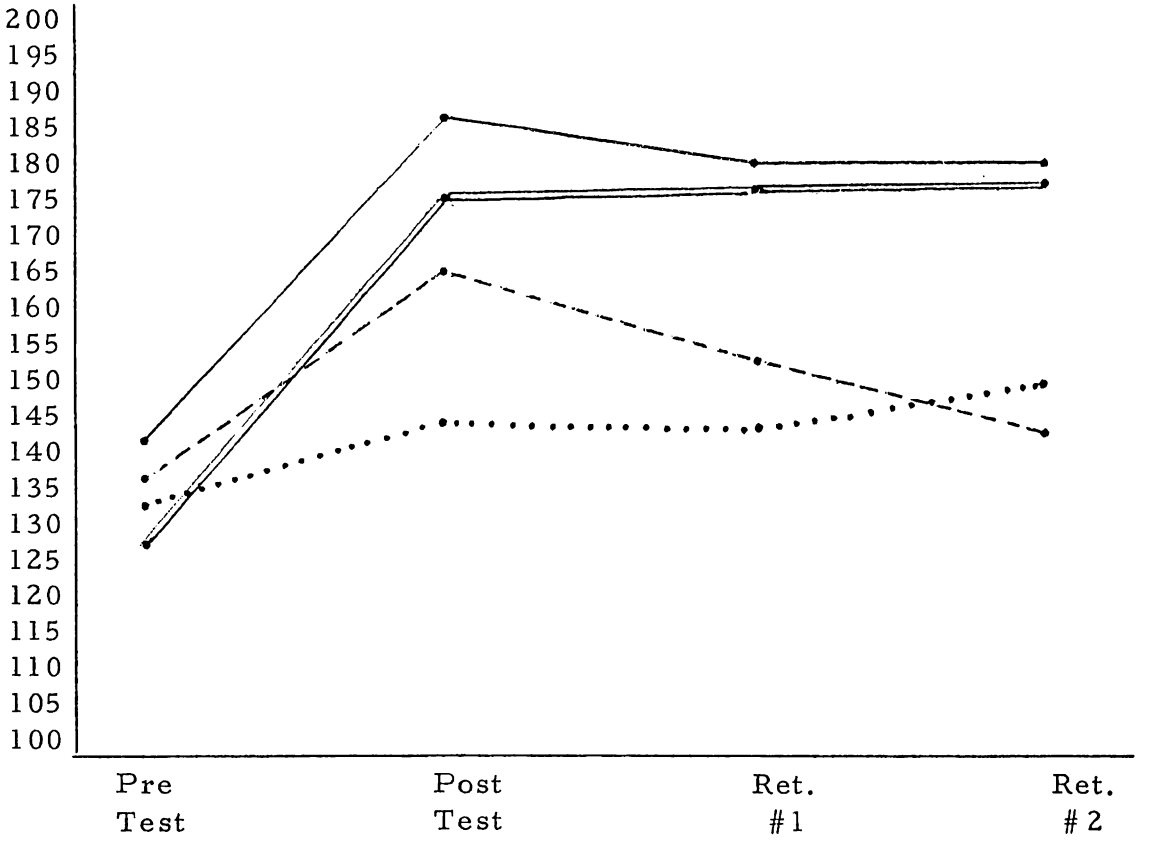


Table 23

Hip Flexibility Differences between the Tests
(Newman - Keuls)

		Q Value / S.R.	Q Value / S.R.	Q Value / S.R.	
Group-Mean-	Pre 136	R2 146.79	R1 154.05	Post 164.89	
Pre	-	2.81 / 2.95	4.70 / 3.58*	7.52 / 3.96*	BALLISTIC
R2	-	-	1.89 / 2.95	4.71 / 3.58*	
R1	-	-	-	2.82 / 2.95	
Post	-	-	-		
	Pre -141.79	R1 - 181.26	R2 - 181.26	Post - 185.05	
Pre	-	8.44 / 2.95*	10.28 / 3.58*	11.27 / 3.96*	STATIC
R1		-	1.84 / 2.95	2.83 / 3.58	
R2		-	-	99 / 2.95	
Post		-	-	-	
	Pre-126.94	Post - 172.44	R2 - 173.17	R1 - 174.94	
Pre		11.85 / 2.95*	12.04 / 3.58*	12.5 / 3.96*	PNF
Post	-	-	.19 / 2.95	.65 / 3.58	
R2	-	-		.46 / 2.95	
R1	-	-	-	-	
	Pre-132.48	Post - 143.48	R1 - 143.57	R2 - 151.48	
Pre	-	2.86 / 2.95	2.89 / 3.58	4.95 / 3.96*	CONTROL
Post	-	-	.02 / 2.95	2.08 / 3.58	
R1	-	-	-	2.06 / 2.95	
R2	-	-	-	-	

S.R. = Critical Value of Studentized Range
*Denotes significance at .05 level.

tests, the ballistic group continued to decrease. However, the PNF and static groups crossed one another, with one group decreasing as the other increased. Between this final retention interval the static and PNF groups displayed no significant loss in hip flexibility. The measurements between these directional gains or losses between this final retention interval were not statistically significant.

Throughout the duration of the four week retention interval there was not a significant loss in hip flexibility in either the PNF or static groups. The ballistic group did record a statistically significant decrease during this same retention interval.

The static and PNF groups were significantly higher in total hip flexibility gains and retention as compared to the ballistic exercise group. The ballistic group revealed a significant hip flexibility loss between the pre- and final retention tests, the static and PNF groups flexibility losses were not statistically recognized.

The control group only exhibited a significant flexibility decrease between the pre- and second retention test.

Comparisons of Trunk Flexibility

Raw data for the hip measurements may be found in Appendix B Tables 2 17. Analysis of variance (Table 24) for the trunk flexibility mean scores revealed a significant F probability between and within the groups.

Table 24

Analysis of Variance on Trunk Flexibility Measures

Source	SS	df	MS	F
Between groups	196740.72	78		
Between	26801.35	3	8933.78	3.94
Within	169939.37	75	2265.86	
Within Tests	60458.45	234		
Between	10130.99	9	1125.67	5.03
Within	50327.46	225	223.68	

*2.48 and 1.92, respectively, are needed for significance beyond .05.

Figure 24 is illustrative of the direction in which the group means were plotted. These patterns resembled the comparisons made on the hip flexibility means.

No differences were found between the groups in the pre-test measures (Table 25). The direction of all three exercise groups were in the direction of flexibility gains as recorded in the post-test measurement and the increase in trunk flexibility was

Figure 24

Trunk Flexibility Mean Changes

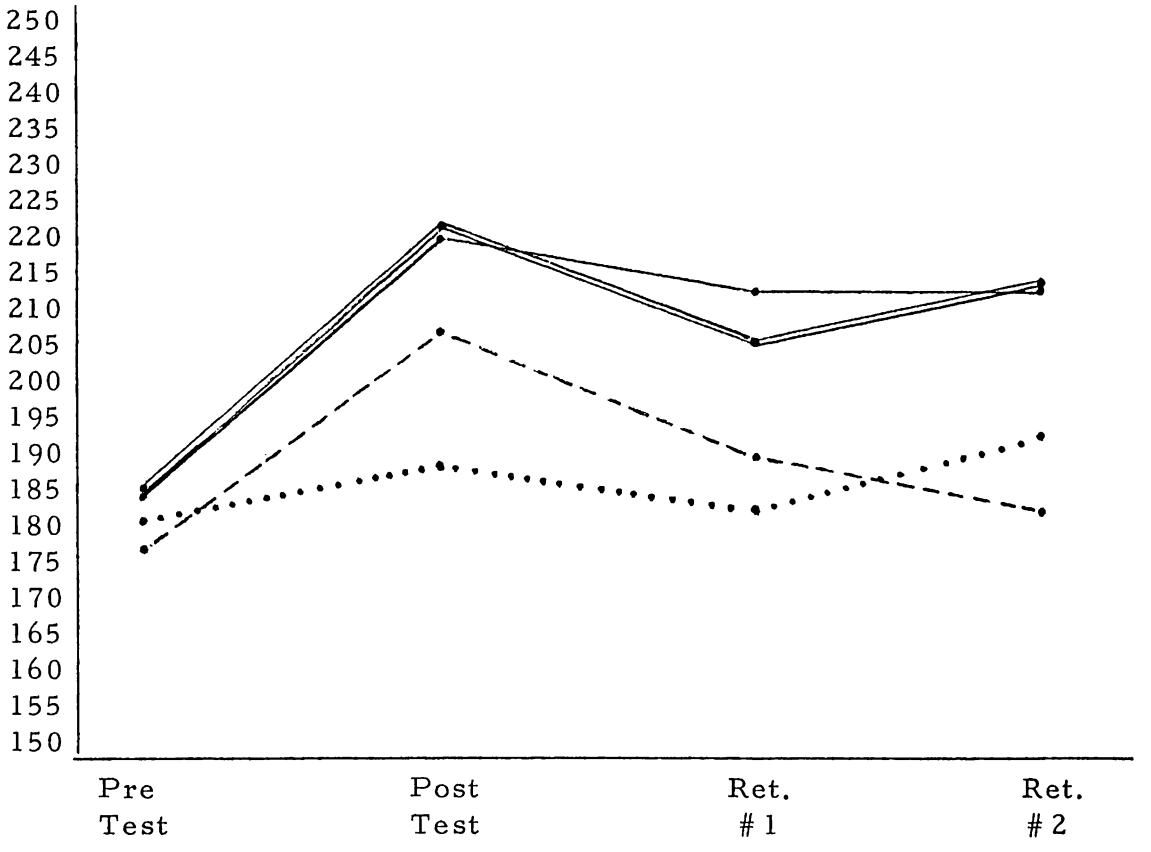


Table 25

Trunk Flexibility Differences between the Groups
(Newman - Keuls)

		Q Value / S.R.	Q Value / S.R.	Q Value / S.R.	
Group-	B	C	S	P	
Mean-	175.84	180.87	184.05	184.61	
B	-	1.5 / 2.95	2.46 / 3.58	2.62 / 3.96	PRE-TEST
C	-	-	.95 / 2.95	1.12 / 3.58	
S	-	-	-	.17 / 2.95	
P	-	-	-	-	
	C-188.78	B - 206.47	S - 218.05	P - 220.33	
C	-	5.3 / 2.95*	8.76 / 3.58*	9.45 / 3.96*	POST-TEST
B	-	-	3.47 / 2.95*	4.15 / 3.58*	
S	-	-	-	.68 / 2.95	
P	-	-	-	-	
	C-183.57	B - 190.42	P - 208.22	S - 212.58	
C	-	2.05 / 2.95	7.38 / 3.58*	8.68 / 3.96*	RET. #1
B	-	-	5.46 / 2.95*	6.63 / 3.58*	
P	-	-	-	1.30 / 2.95	
S	-	-	-	-	
	B-184.21	C - 197.13	S - 212.58	P - 213.56	
B	-	3.87 / 2.95*	8.49 / 3.58*	8.79 / 3.96*	RET. #2
C	-	-	4.62 / 2.95*	4.92 / 3.58*	
S	-	-	-	.29 / 2.95	
P	-	-	-	-	

S.R. = Critical Value of Studentized Range
*Denotes significance at .05 level.

statistically significant.

The PNF and static group significantly exceeded the level of the ballistic and control groups over the four week retention interval. Overall the PNF and static groups significantly exceeded the level of trunk flexibility gains and retention as compared to the ballistic group. The PNF and static groups showed no significant differences in the retention tests. In the retention tests the ballistic group was significantly different than the PNF and static groups in trunk flexibility gains.

There were significant differences between the mean scores of the control group as compared to the static and PNF groups in the last three trunk flexibility measures. There were no significant differences existing between the ballistic and control group in either of the retention test means.

The Newman-Keuls (Table 26) was applied to the data on trunk flexibility tests. Figure 24 presents a graphic interpretation of the trunk flexibility changes. This illustration can be used to better understand the variances between the trunk flexibility tests.

Between the pre- and post-training tests, all three exercise groups displayed significant trunk flexibility increments.

In comparing the post- and first retention test between the groups, the ballistic and PNF test means significantly dropped,

Table 26

Trunk Flexibility Differences between the Tests
(Newman - Keuls)

		Q Value / S.R.	Q Value / S.R.	Q Value / S.R.	
Group-Mean-	Pre 175.84	R2 184.21	R1 190.42	Post 206.47	
Pre	-	2.51 / 2.95	4.37 / 3.58*	9.17 / 3.96*	BALLISTIC
R2	-	-	1.86 / 2.95	6.66 / 3.58*	
R1	-	-	-	4.81 / 2.95*	
Post	-	-	-	-	
	Pre-184.05	R1 - 212.58	R2 - 212.58	Post - 218.05	
Pre	-	8.54 / 2.95*	8.54 / 3.58*	10.18 / 3.96*	STATIC
R1	-	-	0 / 2.95	1.64 / 3.58	
R2	-	-	-	1.64 / 2.95	
Post	-	-	-	-	
	Pre-184.61	R1 - 208.22	R2 - 213.56	Post - 220.33	
Pre	-	7.07 / 2.95*	8.67 / 3.58*	10.69 / 3.96*	PNF
R1	-		1.6 / 2.95	3.63 / 3.58*	
R2	-	-	-	2.03 / 2.95	
Post	-	-	-	-	
	Pre-180.87	R1 - 183.57	Post - 188.78	R2 - 197.13	
Pre	-	.81 / 2.95	2.37 / 3.58	4.87 / 3.96*	CONTROL
R1	-	-	1.56 / 2.95	4.06 / 3.58*	
Post	-		-	2.5 / 2.95	
R2	-	-	-	-	

S.R. = Critical Value of Studentized Range
*Denotes significance at .05 level.

the static group did not. However, observing the entire four week retention interval, the ballistic group exhibited a significant trunk flexibility loss. The PNF and static groups did not decrease significantly between this same retention interval tests.

Overall, the PNF and static group showed significant group mean gains and retention in trunk flexibility over the course of the ten week study, as compared to the ballistic group. The ballistic group did not display any significant flexibility mean gains between the pre- and final retention test.

The control group showed a gradual, but not significant increase in trunk flexibility during the first two measurements, then exhibited a significant trunk flexibility increase between the first and second retention test.

Comparisons of Shoulder Flexibility

Raw data for the shoulder measurements may be found in Appendix B Tables 2 - 17. Comparisons of the shoulder flexibility changes between and within the groups once again showed a significant F probability from the analysis of variance test (Table 27).

Table 27

Analysis of Variance on Shoulder Flexibility Measures

Source	SS	df	MS	F
Between groups	207387.01	78		
Between	95117.63	3	31705.88	21.18
Within	112269.38	75	1496.93	
Within Tests	226165.13	234		
Between	61405.74	9	6822.86	9.32
Within	164759.39	225	732.26	

*2.48 and 1.92, respectively, are needed for significance beyond .05.

A graphic illustration of the shoulder flexibility mean changes may be found in Figure 25.

The Newman-Keuls method provided an interesting comparison between the groups (Table 28). None of the groups differed significantly in the pre-test measurement.

In the post-test measurement all three exercise groups

Figure 25

Shoulder Flexibility Mean Changes

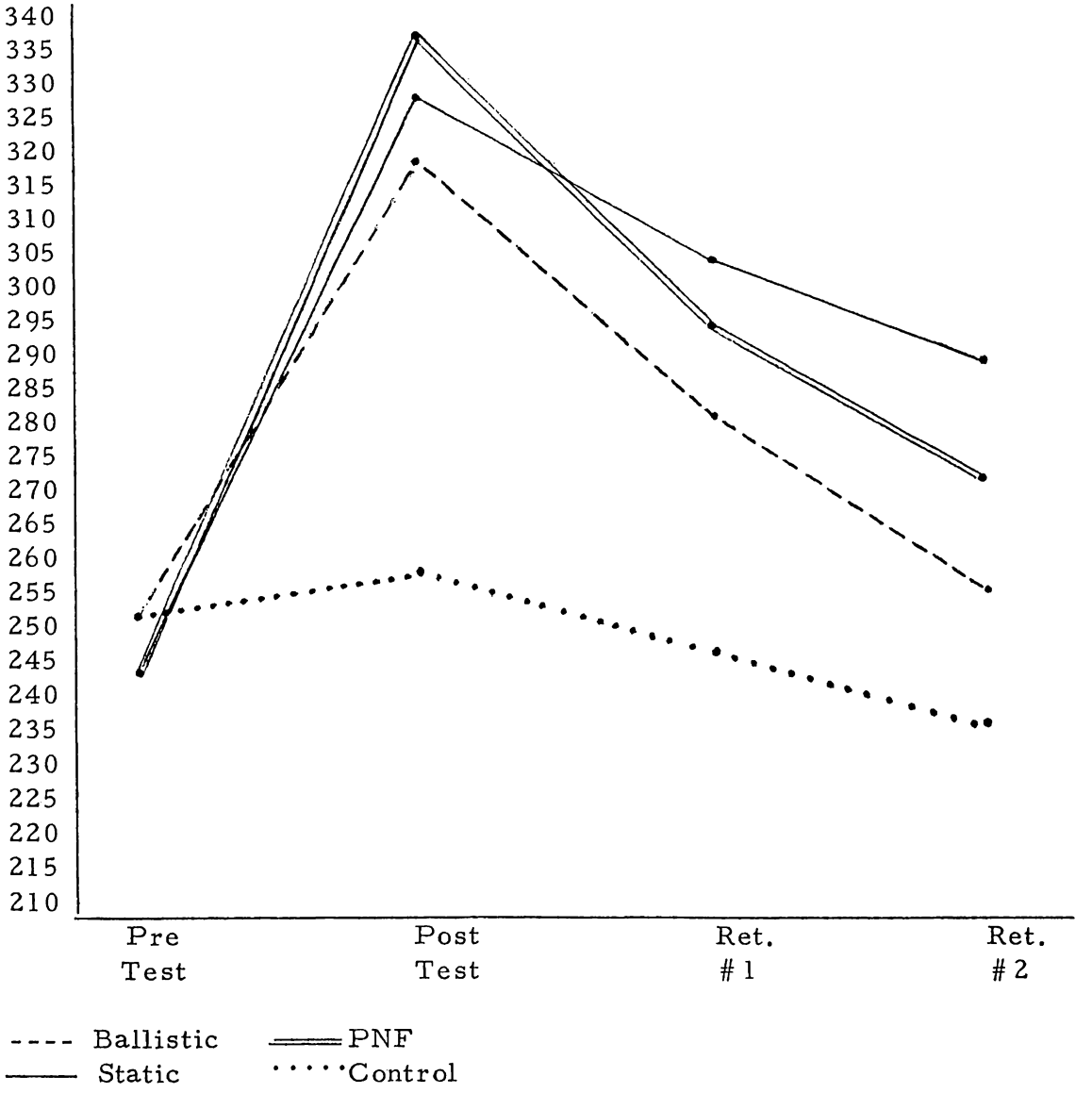


Table 28

Shoulder Flexibility Differences between the Groups
(Newman - Keuls)

		Q Value / S.R.	Q Value / S.R.	Q Value / S.R.	
Group-Mean-	S 243	P 243	B 251.11	C 251.17	
S	-	0 / 2.95	1.34 / 3.58	1.35 / 3.96	PRE-TEST
P	-	-	1.34 / 2.95	1.35 / 3.58	
B	-	-	-	.01 / 2.95	
C	-	-	-	-	
	C-256.13	B - 318.26	S - 327.53	P - 336.56	
C	-	10.27 / 2.95*	11.8 / 3.58*	13.29 / 3.96*	POST-TEST
B	-	-	1.53 / 2.95	3.02 / 3.58	
S	-	-	-	1.49 / 2.95	
P	-	-	-	-	
	C-246.96	B - 282.95	P - 294.17	S - 304.53	
C	-	5.95 / 2.95*	7.90 / 3.58*	9.51 / 3.96*	RET. #1
B	-		1.85 / 2.95	3.57 / 3.58	
P	-		-	1.71 / 2.95	
S	-	-	-	-	
	C-239	B - 256.05	P - 272.33	S - 289.68	
C	-	2.82 / 2.95	5.51 / 3.58*	8.38 / 3.96*	RET. #2
B	-	-	2.69 / 2.95	5.56 / 3.58*	
P	-	-	-	2.87 / 2.95	
S	-	-	-	-	

S.R. = Critical Value of Studentized Range
*Denotes significance at .05 level.

increased significantly in shoulder flexibility, with no differences between the exercise groups. The control group differed from all the groups in this test. Between the post- and first retention test, the direction was a flexibility decrease, this mean decrease although found to be significant did not show differences between any of the exercise groups, with the exception of the control. The final retention measure recorded, indicated a shoulder flexibility loss in all the groups. However, the ballistic group was found to be significantly different than the PNF and static groups in flexibility gains. In the final retention measure the PNF and static groups did not differ significantly, nor was there any difference between the ballistic and control groups. The PNF and ballistic group also showed significant differences between each other in this final measurement.

A significant difference of the control group as compared to the three exercise groups was obtained in all the tests of shoulder flexibility except the pre-test.

The shoulder flexibility differences between the tests were obtained, using the Newman-Keuls comparison method and are presented in Table 29 and Figure 25. In comparisons of the group means between the pre- and post-training tests, all three exercise groups showed significant gains in shoulder flexibility,

Table 29

Shoulder Flexibility Differences between the Tests
(Newman - Keuls)

		Q Value / S.R.	Q Value / S.R.	Q Value / S.R.	
Group-Mean-	Pre 251.11	R2 256.05	R1 282.95	Post 318.26	
Pre	-	.82 / 2.95	5.26 / 3.58*	11.10 / 3.96*	BALLISTIC
R2	-	-	4.45 / 2.95*	10.28 / 3.58*	
R1	-	-	-	5.84 / 2.95*	
Post		-	-	-	
	Pre-243	R2 - 289.69	R1 - 304.53	Post - 327.53	
Pre		7.72 / 2.95*	10.17 / 3.58*	13.97 / 3.96*	STATIC
R2	-	-	2.45 / 2.95	6.25 / 3.58*	
R1	-	-	-	3.8 / 2.95*	
Post	-	-	-	-	
	Pre-243	R2 - 272.33	R1 - 294.17	Post - 336.56	
Pre	-	4.85 / 2.95*	8.46 / 3.58*	15.46 / 3.96*	PNF
R2	-	-	3.61 / 2.95*	10.62 / 3.58*	
R1	-	-	-	7.01 / 2.95*	
Post	-	-	-	-	
	R2-239	R1 - 246.96	Pre- 251.17	Post - 256.13	
R2	-	1.32 / 2.95	2.01 / 3.53	2.83 / 3.96	CONTROL
R1	-	-	7 / 2.95	1.52 / 3.58	
Pre	-	-	-	.82 / 2.95	
Post	-	-		-	

S.R. = Critical Value of Studentized Range
*Denotes significance at .05 level.

the control group did not. All three exercise groups decreased in flexibility significantly between the first two week retention interval.

Between the first and second retention test, the ballistic and PNF group displayed a shoulder flexibility mean decrease which was found to be statistically significant. The static group was able to maintain sufficient shoulder flexibility during these same tests, and no significant flexibility loss was revealed. During the entire four week retention interval all three exercise groups demonstrated significant mean decreases in shoulder flexibility.

The differences were found in the comparisons made between the pre- and second retention test. The PNF and static groups showed no significant loss in flexibility over the course of the study. The ballistic group was unable to retain any significant amounts of shoulder flexibility.

The total change in shoulder flexibility, between the tests, over the course of the experiment was found not to be statistically significant for the control group.

Comparisons of Neck Flexibility

Raw data for the neck measurements may be found in Appendix B Tables 2 - 17. In Table 30 is shown the results of the analysis of variance test for the neck flexibility group mean scores. As can be seen, a significant F probability was disclosed.

Table 30

Analysis of Variance on Neck Flexibility Measures

Source	SS	df	MS	F
Between groups	275168.94	78		
Between	99771.01	3	33257.00	14.22
Within	175397.93	75	2338.64	
Within Tests	211044.04	234		
Between	40732.06	9	4525.78	5.98
Within	170211.98	225	756.50	

*2.48 and 1.92, respectively, are needed for significance beyond .05.

The Newman-Keuls method was used to compare differences between the groups. Results from this analysis may be found in Table 31, along with an illustration of the differences between the groups and tests presented in Figure 26.

During the pre-test measurement, there were no significant differences found between the groups.

Figure 26

Neck Flexibility Mean Changes

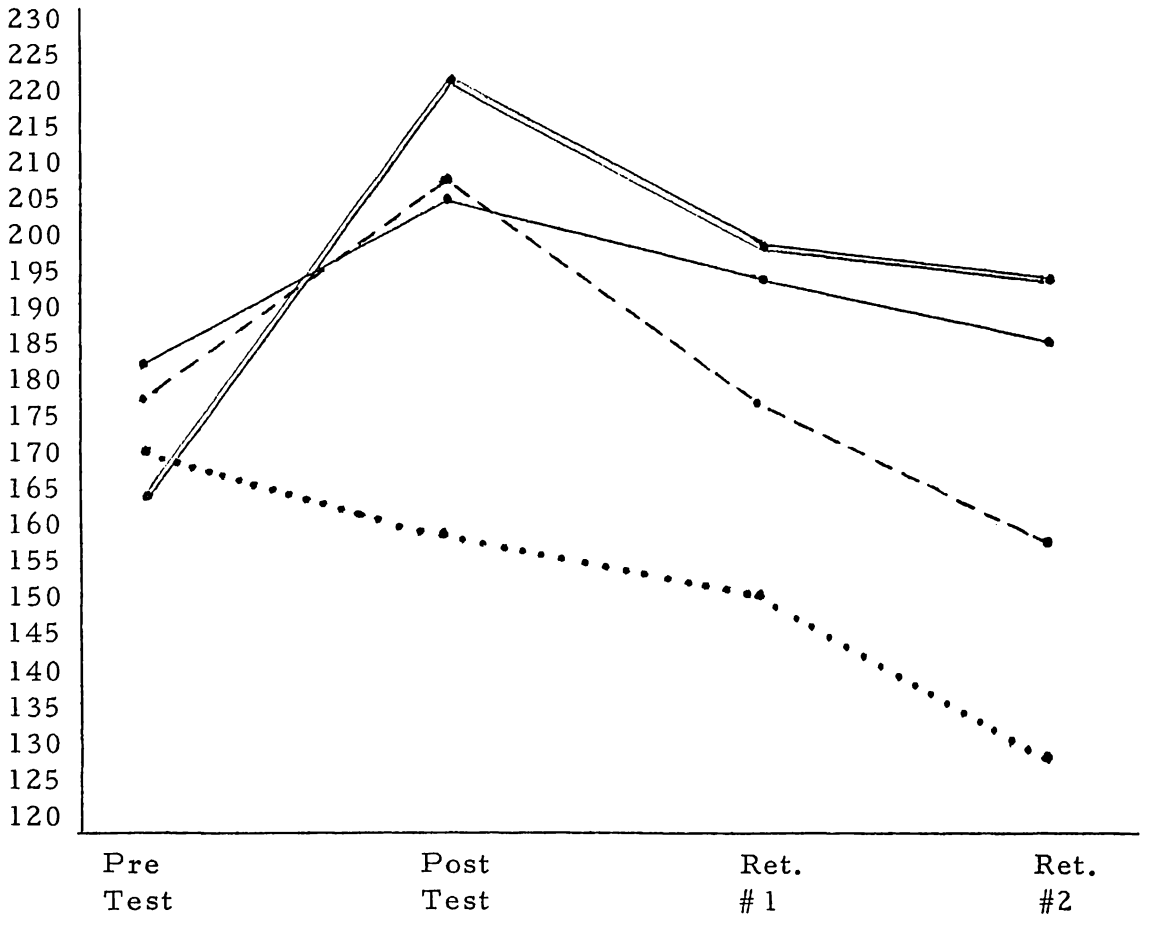


Table 31

Neck Flexibility Differences between the Groups
(Newman - Keuls)

		Q Value / S.R.	Q Value / S.R.	Q Value / S.R.	
Group-	P	C	B	S	
Mean-	164.06	170.09	177.95	181.53	
P	-	98 / 2.95	2.26 / 3.58	2.84 / 3.96	PRE-TEST
C		-	1.28 / 2.95	1.86 / 3.58	
B	-		-	.58 / 2.95	
S		-	-	-	
	C-158.61	S - 207.95	B - 208.63	P - 220.39	
C		8.03 / 2.95*	8.13 / 3.58*	10.04 / 3.96*	POST-TEST
S	-		.11 / 2.95	2.02 / 3.58	
B	-			1.91 / 2.95	
P	-			-	
	C-151.7	B - 178.32	S - 196.05	P - 200.78	
C		4.33 / 2.95*	7.21 / 3.58*	7.98 / 3.96*	RET. #1
B			2.88 / 2.95	3.65 / 3.58*	
S	-	-	-	77 / 2.95	
P	-		-	-	
	C-129.78	B - 158	S - 188.05	P - 196.44	
C	-	4.59 / 2.95*	9.47 / 3.58*	10.84 / 3.96*	RET. #2
B	-	-	4.89 / 2.95*	6.25 / 3.58*	
S	-	-	-	1.36 / 2.95	
P	-	-	-	-	

S.R. = Critical Value of Studentized Range
*Denotes significance at .05 level.

In analysis of the post-test measures, all three exercise groups differed significantly from the control group. No statistically significant differences were found between any of the three exercise groups.

The first retention test once again revealed significant differences between the exercise groups and the control. The PNF group differed significantly over the ballistic group, with no difference found when compared to the static group.

The final retention test again ranked the exercise groups significantly higher than the control group. As was the case in the first retention test, the PNF and static groups did not differ significantly from each other. The ballistic group displayed a neck flexibility group mean that was significantly lower than the PNF and static group means.

Table 32 displays the differences between the tests which were obtained by the Newman-Keuls multiple comparison technique. Figure 26 exhibits a graphic pattern of the tests demonstrated by each group. In comparing the pre- and post training tests, all three exercise groups increased significantly in neck flexibility. Between these tests, the control group decreased in neck flexibility, but the decrease was not significant.

The first two week retention interval showed a significant neck flexibility loss in the ballistic and PNF groups. The static

Table 32

Neck Flexibility Differences between the Tests
(Newman - Keuls)

		Q Value / S.R.	Q Value / S.R.	Q Value / S.R.	
Group-	R2	Pre	R1	Post	
Mean-	158	177.95	178.32	208.63	
R2	-	3.24 / 2.95*	3.3 / 3.58	8.23 / 3.96*	BALLISTIC
Pre	-		.06 / 2.95	4.99 / 3.58*	
R1	-		-	4.93 / 2.95*	
Post	-			-	
	Pre-181.53	R2 - 188.05	R1 - 196.05	Post - 207.95	
Pre	-	1.06 / 2.95	2.36 / 3.58*	4.3 / 3.96*	STATIC
R2	-	-	1.30 / 2.95	3.24 / 3.58	
R1	-	-	-	.19 / 2.95	
Post	-		-	-	
	Pre-164.06	R2 - 196.44	R1 - 200.78	Post - 220.39	
Pre	-	5.27 / 2.95*	5.97 / 3.58*	9.16 / 3.96*	PNF
R2	-	-	7 / 2.95	3.89 / 3.58*	
R1	-	-	-	3.19 / 2.95*	
Post	-	-	-	-	
	R2-129.78	R1 - 151.61	Post - 158.61	Pre - 170.09	
R2		3.56 / 2.95*	4.69 / 3.58*	6.55 / 3.96*	CONTROL
R1	-	-	1.12 / 2.95	2.99 / 3.58	
Post	-	-		1.87 / 2.95	
Pre	-	-	-	-	

S.R. = Critical Value of Studentized Range
*Denotes significance at .05 level.

group, once again maintained sufficient flexibility, showing no significance in the mean decrease.

Between the two retention measures all three exercise groups showed a mean decrease in neck flexibility, but was not found to be statistically significant. During these final two weeks, the control and ballistic groups displayed a significant loss in neck flexibility.

Over the course of the four week retention interval the control, ballistic, and PNF groups exhibited significant mean losses in neck flexibility, the static group did not. The control and ballistic groups were not only unable to retain flexibility during the ten week experiment, but displayed a significant mean loss below the pre-test mean. The PNF and static groups were found to have significantly obtained a neck flexibility mean gain and retention over the course of the study.

Summary of Findings

In all analysis of variance tests significant F ratios were found and many significant differences between and within the groups and tests were found. The Newman-Keuls method was used to compare differences between and within the groups.

Ankle Flexibility

Between Groups - There was a significant difference found between the ballistic and static groups in the pre-test. This was the only instance in which any of the groups differed in the pre-test group measurement analysis. The investigator considered this difference to be due to chance variables. All other groups were not significantly different from one another.

The PNF and static groups were significantly different from the ballistic and control groups in the post- and two retention test measures.

Within Groups - All three exercise groups revealed a significant increase in ankle flexibility after six weeks of training. The three exercise groups did not reflect a significant flexibility loss when comparisons of the pre- and second retention tests were made.

Hip Flexibility

Between Groups - The pre-test revealed no significant differences between any of the groups. In the post-test, all three exercise groups gained significantly in hip flexibility following training.

The PNF and static groups revealed no significant differences between each other in the final retention test. However,

the ballistic group was significantly different from the PNF and static groups in this final retention test.

Within Groups - Between the pre- and post-tests all three exercise groups showed a significant flexibility mean increase. Over the four week retention interval, the PNF and static groups showed no significant hip flexibility mean losses, the ballistic group did.

The PNF and static groups recorded no significant loss in flexibility over the course of the ten week experiment, the ballistic group did display a significant loss.

Trunk Flexibility

Between Groups - In the pre-test, no significant differences were found between the group means. The post-test measurement revealed all three exercise groups as having significantly increased in trunk flexibility following six weeks of training.

In the first retention test no significant difference between the PNF and static groups were found. In this same test, no significant differences were found between the control and ballistic groups. However, the ballistic group was significantly different than the PNF and static groups.

The group comparisons made on the second retention test revealed the same results found in the first retention test.

Within Groups All exercise groups increased significantly in trunk flexibility between the pre- and post-test measures. Between the post- and final retention test, the PNF and static groups did not exhibit a significant mean loss in trunk flexibility, the ballistic group did.

Over the course of the ten week study, the PNF and static groups did not exhibit significant flexibility losses of the trunk, the ballistic group did.

Shoulder Flexibility

Between Groups None of the groups differed significantly in the pre-test measurement. In the post-test measure all three exercise groups differed significantly from the control group, but did not reveal significant differences between each other.

In the first retention test, the PNF and static groups were not significantly different, and the PNF and ballistic groups were not significantly different. However, the static and ballistic groups did show significant differences between each other.

Within Groups - All three exercise groups showed significant gains in shoulder flexibility between the pre- and post-tests.

All three exercise groups displayed significant shoulder flexibility losses during the four week retention interval. Between

the first and second retention tests, the PNF and ballistic groups reported significant shoulder flexibility losses, the static group did not.

The PNF and static groups revealed no significant mean loss in shoulder flexibility between the pre- and final retention tests. The ballistic group showed a significant shoulder flexibility mean loss over the ten week experiment.

Neck Flexibility

Between Groups - In the pre-test measure, no significant differences were found between the groups. In the post-test measurement, the control group was found to be significantly different from all three exercise groups. In this same measure, no significant differences were found between any of the three exercise groups.

In the first retention test, the control group differed significantly from the other three groups. No statistically significant difference was found between the static and ballistic groups, and no difference was found between the PNF and static groups. However, a significant difference between the PNF and ballistic group was revealed.

In the second retention test all groups differed significantly

from one another, with the exception of the PNF and static, these two groups did not differ from each other.

Within Groups All three exercise groups increased in neck flexibility over the six week training period.

The PNF and ballistic groups showed a significant neck flexibility loss during the first two week retention interval. Between the post- and first retention test the static group displayed no significant mean loss in flexibility of the neck.

None of the exercise groups decreased significantly in neck flexibility during the second two week retention interval. The control group did show a significant neck flexibility loss during this same period.

Over the four week retention interval the PNF, ballistic and control groups showed a significant decrease in neck flexibility. The static group did not exhibit a statistically significant loss in neck flexibility over this same four week period.

In a final comparison between the pre- and second retention tests, the PNF group revealed a significant retention in neck flexibility. No significant neck flexibility differences occurred between these two tests for the static group. The ballistic and control groups showed a significant loss in flexibility over the ten week period and the second retention mean score was below that of the pre-test mean.

Overall the control group was always found to significantly different from the three exercise groups in the post-test "group" comparisons and the pre- to post-test "test" measurements.

Discussion of Findings

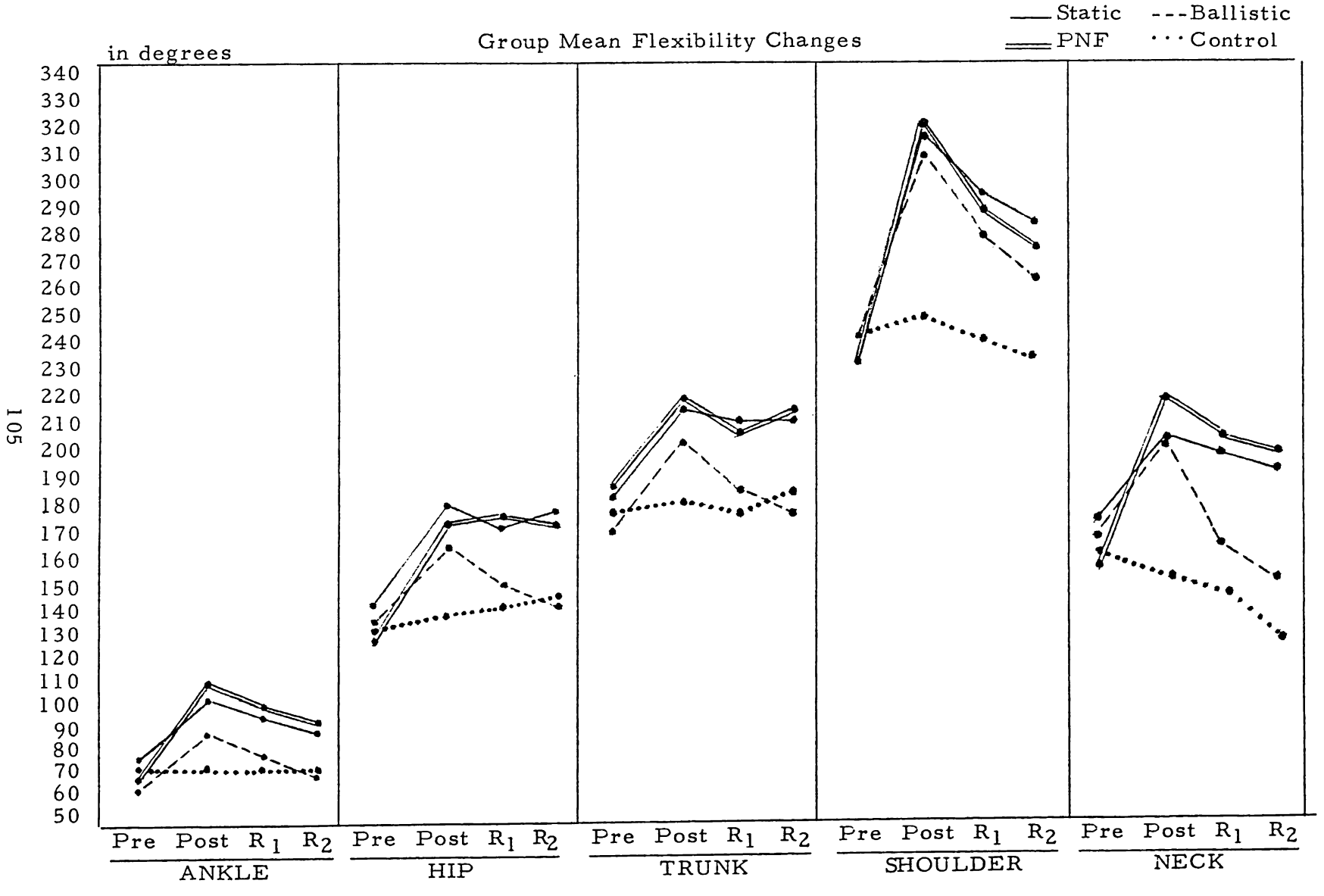
Figure 27 presents a graphic interpretation of the interaction of the group and test means found between and within all the measures.

Comparisons Between Groups

There were no significant differences found between any of the groups in the pre-test measurement except in the ankle pre-test measure. The ballistic and static groups displayed significant differences between each other. Because these groups and not been exposed to any type of treatment prior to the pre-test, and because the reliability of the measurement procedure was high, the variability shown by these two groups in this one pre-test was considered by the investigator to be due to chance variables.

Over the scope of the study, the PNF and static exercise groups significantly showed the largest mean gains in and retention of flexibility of all five variables tested. Although the ballistic group recorded significant gains in flexibility and its retention, this group still statistically showed a significant difference when compared to the performance of the static and PNF stretch groups. These findings did

Figure 27


Group Mean Flexibility Changes
in degrees
Static
Ballistic
PNF
Control
340
330
320
310
300
290
280
270
260
250
240
230
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
105
Pre Post R1 R2
ANKLE
Pre Post R1 R2
HIP
Pre Post R1 R2
TRUNK
Pre Post R1 R2
SHOULDER
Pre Post R1 R2
NECK

not support findings of other investigations comparing these three exercise methods. (14, 25) Holt, Travis and Okita (25) found the PNF technique to be significantly better than either the ballistic and static stretch techniques. These investigators used a sit and reach method to measure flexibility. Since the sit and reach method has been found to measure back and leg flexibility this measurement technique could not be used in this study. (35) The sit and reach test has also been found to favor the ballistic-type movement, because the score is actually read at the subjects extreme point, while the joint in motion reaches its maximum stretch. (24) The flexibility favors static flexibility because the dial is actually read when the joint is not in motion. (24) The difference in measuring instruments may be attributed to the variance in findings between this study and the Holt, Travis and Okita study.

Analysis of variance and the Newman-Keuls revealed participation in a six week training program yielded significant flexibility gains in all three exercise groups. The PNF was ranked first in degrees of range in motion obtained over all the measures. The static group was rated second.

Although the PNF and static groups were comparable in the retention of flexibility involving all areas measured, the static group was able to maintain the greatest flexibility gains in degrees over the four week retention interval in the hip, trunk, and shoulder measures.

It is important to note, that in each instance when the ballistic group's flexibility fropped either with the PNF or static group, the degrees of range in motion between the two were extreme. This is exemplified in the four week retention interval in which case the PNF group decreased only 24 degrees and the ballistic group dropped 51 degrees in total neck flexibility.

Studies have been found to test the effects of the PNF method (14, 25), however the investigator was unable to find any studies which tested the retention of this flexibility method. Holland (24) noted the lack of retention studies in relation to flexibility testing.

Comparisons Within Groups

Participation in a six week training program yielded significant ($P < .05$) gains in each of the three exercise groups, in the attainment of ankle, hip, trunk, shoulder and neck flexibility. All three exercise groups showed a significant loss during the four week retention interval. This pattern of flexibility change is typical of what might be expected in exercise groups participating in a physical training program. (12, 13)

The difference in the groups appeared in the comparison of the pre- and final retention test. The PNF and static groups were able to maintain exceedingly high flexibility scores when comparing

the pre- to the final retention tests. This was most evident in both the hip and trunk measures. In these same measures, neither the static or PNF groups decreased in flexibility between the post- and final retention test enough to note any statistical significance. The ballistic group showed a significant loss in hip and trunk flexibility between the pre- and final tests. This group also significantly decreased in flexibility between the four week retention interval. The ballistic group significantly differed from both the static and PNF groups in this instance.

Throughout the course of the four measurement periods there was no consistency to the pattern shown by the control group in relation to the tests. With the exception of few instances which were explained in the statistical procedure, the control group showed no statistically significant differences between the flexibility means on any of the test comparisons. Because this group was not exposed to flexibility exercises, and because of the high reliabilities and consistency of measurement, this variability exhibited by the control group was considered to be due to chance variables or the activities the subjects participated in during class time.

Comments on Flexibility Variables

In examining Figure 27, the joint exhibiting the greatest gains

in flexibility was obtained in the shoulder. Second to the shoulder were flexibility gains of the hip, third was the trunk, fourth the neck and finally the ankle. Twietmeyer (52) using similar stretching techniques on the neck, hip and trunk, reported different results. He revealed the greatest gains were in the flexibility of the neck. In this study the greater gains obtained in the shoulder, trunk and hip may be due to the fact that these joint areas are more freely movable because of the ball and socket joint arrangement.

The static stretch techniques used in this study were taken from the Twietmeyer (52) study. However the gastrocnemius stretch exercise, folded leaf with arm and head variations exercise, the shoulder stretch exercise and the candle exercise were added. This may also be a contributing factor to the differences found between these two studies.

Another difference in flexibility gains may be due to the repetition element involved during the exercise sessions. Twietmeyer only had his subjects perform the exercise only once using the same length of time. This investigation required each exercise to be performed once in the beginning of training and then gradually increase to three repetitions by the fourth week of training. The increments in length of time for each exercise was the same procedure used by Twietmeyer.

In analyzing the retention of the hip and trunk flexibility, the PNF and static groups exhibited gains which were attained and maintained throughout the remainder of the four week retention interval. This was found to be statistically significant. These gains in and retention of hip and trunk flexibility might be strongly indicative of the exercises and training method used.

Comments on the Proprioceptive Neuromuscular Facilitation Technique

The exercises in this study were designed by the investigator to enhance flexibility of the ankle, shoulder, hip, trunk and neck. The exercises for the hip and trunk were taken from a study by Holt, Okita, and Travis. (25) The modification which these investigators used was the same theory used to design the exercises for this study. The results of this investigation revealed significant flexibility gains and retention using this technique. The PNF group surpassed all other groups in the overall performance and retention of every flexibility variable tested upon completion of the six and four week training and retention periods. The Holt, Okita, and Travis study yielded similar results. The investigator proposes two probable reasons for this technique being superior to that of the ballistic and static group. They are:

1) The use of resistance adds a possible strength increase. This is exhibited by the isometric-type exercise used when the

flexors are concentric and maintaining. It has been found in other investigations (12, 23) that strength commensurate with flexibility attains high degrees of flexibility as opposed to isolating flexibility as a sole parameter to fitness.

2) The stretch reflex is suppressed when the muscles relax and then gradually stretch to the full range of motion.

CHAPTER V

SUMMARY - CONCLUSIONS - RECOMMENDATIONS

The purpose of this study was to compare three types of exercise designed to improve the range of motion in selected joints of the body. Retention capabilities of each type of exercise, was a subproblem to this investigation. Ballistic stretch, static stretch and a modified version of proprioceptive neuromuscular facilitation (PNF) exercises were compared using 37 male and 42 female subjects.

Procedure

The subjects were 79 members of four physical education classes at Topeka High School in Topeka, Kansas. Each class hour was assigned an exercise by random drawing.

The ballistic stretching exercise group contained nineteen subjects, the static group - nineteen, the PNF group - eighteen, and the control group contained twenty-three subjects. Classes were held five days a week.

The ballistic and static stretching groups participated in a six week training program consisting of nine basic yoga and stretch

exercises. The PNF stretch group performed a series of seven exercises devised by the investigator to closely compare to the same exercises performed by the ballistic and static groups. The flexibility training sessions were conducted five days a week for six weeks. Gradual increase in length of time held in the exercise position and repetition was used in training ofr the FNF and static groups. The control group did not participate in any type of flexibility training during the course of the study.

The Leighton tests and flexometer were used to measure the flexibility of each subject prior to and after the six week retention period. Measurements were taken of neck flexion-extension, hip flexion-extension, ankle dorsi-plantar flexion and trunk and shoulder flexion-extension. After two practice trials (not recorded) the third trial was recorded at each testing session, this was recorded as the subject's flexibility score.

Analysis of variance and the Newman-Keuls multiple comparison method were used to analyze the data. The .05 level of significance was choosen. Analysis of variance was used for two purposes: (1) to find the differences in flexibility means between the groups, and (2) to find the differences in flexibility means within the groups.

A Newman-Keuls method was selected to compare the difference between and within the pre- and second retention means, post- and first

retention means, and post- and second retention means.

CONCLUSIONS

The results of this study appear to support the existance of certain consistent trends in the direction of positive attainment and retention in range of motion using the static stretch theory. Both static and PNF techniques possess characteristics derived from this theory. Many research investigations have obtained similar results. (12, 24, 25, 31, 47) The ballistic also achieved significant gains in flexibility during the training period. However, the ballistic retention means were significantly below the mean scores of the PNF and static groups. In three of the measures tested the three groups did not differ significantly, the mean scores in degrees were greatest in the PNF exercise group, the static group were less and lowest was the ballistic mean scores.

Relative to the present study and within the assumptions and limitations, the following conclusions were reached:

1) Participation in either static, ballistic or PNF stretching exercises are effective in increasing flexibility.

2) The PNF and static exercise methods are superior to the ballistic group exercise method.

3) Both the PNF and static groups are superior in retaining flexibility for at least four weeks after exercise.

RECOMMENDATIONS

As an outcome of this investigation the following recommendations for further study were made:

1) Additional studies, using these three exercise methods are needed. The length of the retention interval, if increased, could reveal significant results.

Testing of a lengthened retention interval until flexibility reaches its original starting point could also be of interest in a study comparing these three stretch methods.

2) A training group needs to be tested using a combination of static and ballistic stretch. If the subjects were to stretch to their full flexibility limits slowly then bounce carefully to gain greater stretch, the results, if compared to the groups tested in this study, could be significant in flexibility gains.

3) Additional studies, using these three exercise methods are needed in comparing the flexibility differences between males and females.

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APPENDIX A

Pilot Study Data

THE JOINT MEASUREMENT CHART

Name.....
Date of Birth..... Height..... Weight.....
Handedness..... Age..... Sex.....
Leg Length..... Trunk Length.....

Tests	Ankle	Hip	Trunk	Shoulder	Neck	Date	Motion
Pre							Extension
							Flexion
							Range
Post							Extension
							Flexion
							Range
R-2							Extension
							Flexion
							Range
R-1							Extension
							Flexion
							Range

Table 1

Raw Scores: Reliabilities of Pilot Study

ANKLE		HIP		TRUNK		SHOULDER		NECK		
Test	Retest	Test	Retest	Test	Retest	Test	Retest	Test	Retest	Sub.
72	73	197	199	200	198	250	250	178	177	1
79	77	200	201	189	193	247	246	183	185	2
82	79	140	140	153	151	249	248	173	176	3
76	73	125	124	136	138	244	244	176	182	4
72	71	155	156	164	164	263	265	153	156	5
r = .927		r = 999		r = .995		r = .989		r = .928		

Used sum of the squares correlation for small n.

APPENDIX B

Tables of Flexibility Raw Data

Table 2

Raw Data : Flexibility Raw Scores for Pre-Test

Group: Ballistic

EXTENSION					FLEXION					TOTAL RANGE					
Ankle	Hip	Trunk	Shoul-der	Neck	Ankle	Hip	Trunk	Shoul-der	Neck	Ankle	Hip	Trunk	Shoul-der	Neck	Subject No.
12	21	37	60	107	47	95	112	193	65	59	116	149	253	172	1
16	43	41	47	93	51	66	80	210	85	67	109	121	257	178	2
8	36	46	40	92	60	104	120	163	84	68	140	166	203	176	3
11	29	39	65	95	50	93	120	195	79	61	122	159	260	174	4
15	62	82	53	84	54	117	126	191	67	69	179	208	244	151	5
12	30	58	66	104	48	100	101	185	66	60	130	159	251	170	6
11	34	56	55	105	33	128	156	184	77	44	162	212	239	182	7
13	47	48	65	111	54	115	131	182	59	67	162	179	247	170	8
15	23	40	65	106	51	87	121	186	93	66	110	161	251	199	9
11	42	47	71	82	44	88	116	180	76	55	130	163	251	158	10
22	22	55	56	96	38	63	151	201	76	60	85	206	257	172	11
14	31	46	33	100	37	91	112	184	85	51	122	158	217	185	12
12	18	38	70	96	47	69	111	178	76	59	87	149	248	172	13
18	34	33	62	107	46	87	141	186	39	64	121	174	248	146	14
37	44	70	40	112	55	116	165	186	71	92	160	235	226	183	15
12	48	53	51	86	56	110	135	180	64	68	158	188	231	150	16
8	59	44	58	84	39	90	126	183	73	47	149	170	241	157	17
14	40	48	52	98	44	91	119	182	52	58	131	167	234	150	18
21	39	63	63	105	64	115	123	196	78	85	154	186	259	183	19

*in degrees

Table 3

Raw Data : Flexibility Raw Scores for Post-Test

Group: Ballistic

EXTENSION					FLEXION					TOTAL RANGE					
Ankle	Hip	Trunk	Shoul-der	Neck	Ankle	Hip	Trunk	Shoul-der	Neck	Ankle	Hip	Trunk	Shoul-der	Neck	Subject No.
29	47	86	110	134	56	125	159	229	104	85	172	245	339	238	1
27	56	59	119	138	53	71	86	247	101	80	127	145	366	239	2
26	39	54	98	126	69	129	152	236	108	95	168	206	334	234	3
23	36	71	79	114	69	94	117	212	89	92	130	188	291	203	4
26	81	101	119	109	66	117	144	252	98	92	198	245	371	207	5
17	43	68	124	107	52	117	146	246	105	69	160	214	370	212	6
15	52	76	92	112	53	141	149	223	92	63	193	215	315	204	7
22	55	70	114	118	64	125	143	229	109	86	180	213	343	227	8
39	45	63	118	114	62	122	145	238	123	101	167	208	356	237	9
28	42	52	107	102	66	105	117	203	80	94	147	169	310	182	10
29	43	59	96	113	63	140	174	214	91	92	183	233	310	204	11
29	47	69	99	98	64	117	142	207	99	93	164	211	306	197	12
23	34	51	99	117	52	104	142	217	88	75	138	193	316	205	13
25	47	67	89	129	47	111	135	228	87	72	158	202	317	216	14
33	50	75	81	114	64	146	161	211	87	97	196	236	292	201	15
19	35	56	83	110	63	126	152	218	87	82	161	208	301	197	16
31	50	51	109	103	76	112	129	214	103	107	162	180	323	206	17
22	53	66	113	128	65	135	132	257	94	87	188	198	370	222	18
22	35	64	85	114	88	124	148	200	83	110	159	212	285	197	19

*in degrees

Table 4

Raw Data : Flexibility Raw Scores for Retention #1

Group: Ballistic

EXTENSION					FLEXION					TOTAL RANGE					
Ankle	Hip	Trunk	Shoul-der	Neck	Ankle	Hip	Trunk	Shoul-der	Neck	Ankle	Hip	Trunk	Shoul-der	Neck	Subject No.
24	55	65	88	114	50	113	147	193	66	74	168	212	281	180	1
22	29	44	96	112	66	77	95	212	83	88	106	139	308	195	2
21	62	71	91	110	74	110	147	209	83	95	172	218	300	193	3
19	36	60	76	101	42	106	132	203	70	61	142	192	279	171	4
18	56	91	80	96	54	108	127	206	79	72	164	218	286	175	5
15	38	37	91	94	48	128	146	187	87	63	166	183	278	181	6
11	41	67	82	116	26	130	174	196	56	37	171	241	278	172	7
19	56	61	76	111	66	121	141	203	64	85	177	202	279	175	8
26	34	54	87	117	77	103	41	186	86	103	137	95	273	203	9
28	46	55	79	94	55	100	111	198	80	83	146	166	277	174	10
24	33	53	62	107	53	132	147	207	82	77	165	200	269	189	11
14	22	43	63	86	56	104	134	189	81	70	126	177	252	167	12
15	26	41	86	104	45	106	132	201	76	60	132	173	287	180	13
31	34	40	87	110	32	113	144	211	55	63	147	184	298	165	14
33	40	82	77	108	66	121	162	97	90	99	161	244	174	198	15
16	34	53	80	105	65	122	150	218	62	81	156	203	298	167	16
26	27	46	87	100	74	114	127	196	81	100	141	173	283	181	17
26	54	70	86	119	61	116	130	182	51	87	170	200	268	170	18
18	49	61	74	134	76	115	129	217	42	94	164	190	291	176	19

*in degrees

Table 5

Raw Data Flexibility Raw Scores for Retention #2

Group: Ballistic

EXTENSION					FLEXION					TOTAL RANGE					
Ankle	Hip	Trunk	Shoul-der	Neck	Ankle	Hip	Trunk	Shoul-der	Neck	Ankle	Hip	Trunk	Shoul-der	Neck	Subject No.
14	37	60	92	104	56	111	143	207	61	70	148	203	299	165	1
20	30	55	82	106	52	80	96	216	79	72	110	151	298	185	2
20	32	63	81	110	64	109	141	192	72	84	141	204	273	182	3
13	32	52	72	94	42	96	127	197	72	55	128	179	269	166	4
17	72	103	73	101	58	106	129	205	66	75	178	232	278	167	5
10	33	43	79	101	50	110	123	178	61	60	143	166	257	162	6
13	36	64	77	78	52	121	154	187	56	65	157	218	264	134	7
19	48	56	67	115	73	112	135	214	59	92	160	191	281	174	8
14	109	52	79	109	51	79	41	179	66	65	188	93	258	175	9
19	11	52	71	83	57	110	100	175	64	76	121	152	246	147	10
16	28	51	55	94	49	125	141	201	62	65	153	192	256	156	11
14	31	45	77	83	35	117	153	172	84	49	148	198	249	167	12
13	20	37	82	97	47	82	112	197	74	60	102	149	279	171	13
30	26	43	73	101	25	104	132	190	82	55	130	175	263	183	14
23	52	75	73	109	73	122	161	191	73	96	174	236	264	182	15
12	32	42	76	98	59	119	138	189	55	71	151	180	265	153	16
21	33	44	69	94	69	105	123	169	62	90	138	167	238	156	17
19	64	71	81	101	54	122	137	186	42	73	186	208	267	143	18
18	52	55	60	106	72	100	125	208	55	90	152	180	268	161	19

*in degrees

Table 6

Raw Data : Flexibility Raw Scores for Pre-Test

Group: Static

EXTENSION					FLEXION					TOTAL RANGE					
Ankle	Hip	Trunk	Shoul-der	Neck	Ankle	Hip	Trunk	Shoul-der	Neck	Ankle	Hip	Trunk	Shoul-der	Neck	Subject No.
25	34	57	54	94	47	99	143	196	84	72	133	200	250	178	20
27	33	49	63	107	36	107	140	184	76	63	140	189	247	183	21
28	30	27	55	91	51	95	126	194	82	79	125	153	249	173	22
17	39	59	55	115	65	116	147	189	61	82	155	206	244	176	23
19	40	52	80	70	57	128	127	183	83	76	168	179	263	153	24
15	24	41	31	105	51	107	151	196	86	66	131	192	227	191	25
16	21	25	37	85	49	86	129	172	66	65	107	154	209	151	26
16	27	30	70	96	54	95	129	211	77	70	122	159	281	163	27
19	36	89	61	115	57	108	140	211	92	76	144	229	272	207	28
13	30	54	62	76	64	96	126	200	81	77	126	180	262	157	29
18	35	50	55	104	42	91	136	192	85	60	126	186	247	189	30
21	21	42	56	112	60	113	140	194	83	81	134	182	250	195	31
26	55	59	65	93	59	137	160	203	58	85	192	219	268	151	32
46	23	49	55	70	34	78	116	176	95	80	111	165	231	165	33
22	36	42	71	80	58	94	108	202	77	80	130	150	273	157	34
21	44	68	49	76	47	129	152	190	74	68	173	220	239	150	35
33	37	42	61	90	56	128	148	196	95	92	165	190	257	185	36
14	43	64	56	102	53	101	117	181	66	67	144	181	137	168	37
25	54	46	65	116	46	114	131	184	84	71	168	177	249	200	38

*in degrees

Table 7

Raw Data Flexibility Raw Scores for Post-Test

Group: Static

EXTENSION					FLEXION					TOTAL RANGE					
Ankle	Hip	Trunk	Shoul-der	Neck	Ankle	Hip	Trunk	Shoul-der	Neck	Ankle	Hip	Trunk	Shoul-der	Neck	Subject No.
34	53	63	105	106	59	148	161	225	104	93	211	224	330	210	20
42	59	72	117	117	65	138	148	214	103	107	197	220	331	220	21
37	43	54	88	100	66	120	123	216	106	103	163	177	304	206	22
24	48	67	109	112	78	116	159	218	104	102	164	226	327	216	23
35	52	81	118	109	71	143	156	236	113	106	195	237	354	222	24
37	96	72	110	120	57	130	159	218	89	94	226	231	328	209	25
26	37	46	116	95	59	99	150	207	95	82	136	196	323	190	26
29	56	61	109	119	70	139	67	256	94	99	195	228	365	213	27
30	79	98	116	123	76	166	161	239	110	106	245	259	355	233	28
24	74	68	105	114	71	122	137	227	91	95	196	205	332	205	29
41	51	63	92	93	61	119	148	231	123	102	170	211	323	216	30
36	50	55	115	109	69	129	142	223	95	105	179	197	338	204	31
39	76	94	113	110	71	128	142	237	81	110	204	236	350	191	32
29	36	67	99	98	66	111	148	219	91	95	147	215	318	189	33
36	58	69	103	104	64	122	146	240	84	100	180	215	343	188	34
34	64	84	115	104	68	146	162	245	93	102	210	246	360	197	35
53	52	65	115	133	56	160	166	219	93	109	212	231	334	226	36
39	49	71	102	109	59	121	141	222	103	98	170	212	324	212	37
54	79	67	97	124	59	169	171	240	120	113	248	238	337	244	38

*in degrees

Table 8

Raw Data : Flexibility Raw Scores for Retention #1

Group: Static

EXTENSION					FLEXION					TOTAL RANGE					
Ankle	Hip	Trunk	Shoul-der	Neck	Ankle	Hip	Trunk	Shoul-der	Neck	Ankle	Hip	Trunk	Shoul-der	Neck	Subject No.
21	50	66	90	113	73	114	139	203	83	94	164	205	293	196	20
41	71	75	93	104	55	129	148	201	87	96	200	223	294	191	21
20	34	46	72	106	68	115	131	202	78	88	149	177	274	184	22
19	39	59	87	110	78	114	174	207	119	97	153	233	294	229	23
16	51	71	82	104	56	146	156	203	84	72	197	227	285	188	24
22	50	82	97	104	63	122	151	227	106	85	172	233	324	210	25
18	32	43	104	86	61	98	147	202	94	79	130	190	306	180	26
19	44	60	87	110	74	121	149	269	84	93	165	209	356	194	27
21	77	96	88	122	77	142	151	239	96	98	219	247	327	218	28
18	61	83	81	104	68	105	118	215	88	86	166	201	296	192	29
11	42	63	84	84	56	122	145	210	101	67	164	208	294	185	30
46	40	51	110	140	53	121	140	209	71	99	161	191	319	211	31
33	62	73	98	112	66	143	157	210	77	99	205	230	308	189	32
43	41	55	70	84	34	97	131	205	83	77	138	186	275	167	33
19	62	77	98	97	76	116	126	225	79	95	178	203	323	176	34
41	81	86	94	100	61	136	158	209	84	102	217	244	303	184	35
39	43	56	105	124	52	136	162	221	92	91	179	218	326	216	36
20	48	68	93	100	63	121	144	208	89	83	169	212	301	189	37
27	64	65	98	109	56	149	154	209	98	83	213	219	307	207	38

*in degrees

Table 9

Raw Data Flexibility Raw Scores for Retention #2

Group: Static

EXTENSION					FLEXION					TOTAL RANGE					
Ankle	Hip	Trunk	Shoul-der	Neck	Ankle	Hip	Trunk	Shoul-der	Neck	Ankle	Hip	Trunk	Shoul-der	Neck	Subject No.
25	45	62	71	114	66	127	156	195	85	91	172	218	266	199	20
29	51	62	83	92	49	122	143	206	92	78	173	205	287	184	21
42	24	41	76	86	44	112	120	201	82	86	136	161	277	168	22
19	39	58	67	110	72	115	169	201	112	101	254	227	268	222	23
18	56	70	104	113	63	145	170	209	109	81	251	240	313	222	24
22	49	56	76	90	66	123	157	203	96	88	172	213	279	186	25
16	29	36	102	86	56	97	135	201	83	72	126	201	303	169	26
12	51	66	83	102	57	141	155	212	84	69	192	221	295	186	27
20	75	75	100	110	73	132	156	124	99	93	207	231	224	209	28
15	60	71	84	104	78	108	125	209	67	93	168	196	293	171	29
11	39	57	71	79	41	110	139	199	100	52	149	196	270	179	30
24	35	72	104	112	66	125	195	218	87	90	160	267	322	199	31
19	47	54	92	99	53	128	143	216	62	72	175	197	308	161	32
47	42	57	62	87	39	102	140	202	92	86	144	197	264	179	33
20	64	54	97	92	56	114	121	207	66	76	178	175	304	158	34
33	70	74	73	100	54	132	158	207	65	87	202	232	280	165	35
37	40	50	97	110	53	132	156	201	92	90	172	206	298	202	36
18	56	63	93	97	65	115	135	211	82	83	171	198	304	179	37
27	64	65	98	109	56	149	154	209	98	83	213	219	307	207	38

*in degrees

Table 10

Raw Data Flexibility Raw Scores for Pre-Test

Group: Proprioceptive
Neuromuscular Facilitation

EXTENSION					FLEXION					TOTAL RANGE					
Ankle	Hip	Trunk	Shoul-der	Neck	Ankle	Hip	Trunk	Shoul-der	Neck	Ankle	Hip	Trunk	Shoul-der	Neck	Subject No.
11	24	56	52	102	71	117	146	197	74	82	141	202	249	84	39
16	29	39	49	66	20	94	126	179	101	36	123	165	228	167	40
19	12	39	53	89	49	107	141	196	82	68	119	180	249	171	41
6	32	59	42	73	54	81	120	181	74	60	113	179	223	147	42
14	32	50	59	86	43	79	122	189	74	57	111	172	248	160	43
29	31	62	74	68	43	100	150	186	82	72	131	212	260	150	44
16	41	51	51	96	45	94	121	191	74	61	135	172	242	170	45
34	60	80	60	110	66	135	146	206	71	100	195	226	266	181	46
23	45	57	63	86	66	112	150	194	94	89	157	207	257	180	47
26	59	74	61	100	32	101	128	173	95	58	160	202	234	195	48
13	19	46	31	89	59	106	136	190	69	72	125	182	221	158	49
11	45	55	37	64	54	109	124	205	92	65	64	179	242	156	50
19	26	36	42	94	50	90	124	205	95	69	116	160	247	189	51
39	35	60	52	99	39	109	144	183	92	78	144	204	235	191	52
18	26	38	51	92	40	56	110	201	86	58	82	148	252	178	53
21	32	41	43	122	63	111	135	202	78	84	143	176	245	200	54
7	30	39	59	36	35	57	127	192	102	42	87	166	251	138	55
21	23	61	31	73	51	116	130	194	65	72	139	191	225	138	56

*in degrees

Table 11

Raw Data : Flexibility Raw Scores for Post-Test

Group: Proprioceptive
Neuromuscular Facilitation

EXTENSION					FLEXION					TOTAL RANGE					
Ankle	Hip	Trunk	Shoul-der	Neck	Ankle	Hip	Trunk	Shoul-der	Neck	Ankle	Hip	Trunk	Shoul-der	Neck	Subject No.
43	46	71	128	120	81	147	164	249	120	124	193	235	377	240	39
22	37	53	92	104	62	106	135	218	102	84	143	188	310	206	40
42	19	42	101	126	78	128	156	236	109	120	147	198	337	235	41
30	39	61	130	113	86	110	146	219	104	116	149	207	349	217	42
18	48	68	90	113	65	89	137	220	71	83	137	205	310	184	43
31	52	80	114	123	72	141	169	223	92	103	193	249	337	215	44
39	42	69	89	114	64	98	159	222	116	103	140	228	311	230	45
44	86	102	123	129	82	178	179	280	120	126	264	281	303	249	46
42	46	70	110	109	74	136	167	240	119	116	182	237	350	228	47
33	94	93	124	120	84	150	161	280	124	117	244	254	404	244	48
29	52	68	104	114	62	121	152	208	113	91	173	220	312	227	49
26	41	63	115	107	70	111	149	229	111	96	152	212	344	148	50
32	49	63	146	116	59	113	139	236	104	91	162	202	382	220	51
42	45	83	104	120	55	135	165	246	118	97	180	248	350	238	52
23	49	51	104	114	66	79	114	210	113	89	128	168	314	227	53
56	45	62	110	129	68	145	161	229	108	124	190	223	339	237	54
22	49	60	82	89	44	107	120	227	121	66	156	180	309	210	55
42	43	78	76	110	71	128	156	244	102	113	171	234	320	212	56

*in degrees

Table 12

Raw Data : Flexibility Raw Scores for Retention Test #1

Group: Proprioceptive
Neuromuscular Facilitation

EXTENSION					FLEXION					TOTAL RANGE					
Ankle	Hip	Trunk	Shoul-der	Neck	Ankle	Hip	Trunk	Shoul-der	Neck	Ankle	Hip	Trunk	Shoul-der	Neck	Subject No.
32	64	74	97	108	76	133	150	225	116	108	197	224	322	224	39
27	43	44	84	100	60	109	138	185	100	87	152	182	269	200	40
20	44	42	73	116	74	145	164	210	93	94	189	206	283	209	41
18	37	45	100	140	66	101	118	222	60	84	138	163	322	200	42
27	40	66	87	111	47	116	142	204	57	74	156	208	291	168	43
27	55	87	104	115	60	141	166	221	94	87	196	253	325	209	44
28	45	68	82	117	57	124	143	212	89	85	169	211	294	206	45
41	85	84	103	118	81	175	177	159	123	122	260	261	262	241	46
21	38	55	77	98	72	137	168	220	101	93	165	223	297	199	47
29	86	76	91	110	68	121	155	204	111	97	207	231	295	221	48
17	51	59	57	104	66	125	155	193	68	83	176	214	250	172	49
20	45	60	62	101	68	114	135	218	92	88	159	195	280	193	50
33	34	59	96	104	72	101	126	243	84	105	135	185	339	188	51
38	50	70	104	118	64	131	175	206	102	102	181	245	310	220	52
20	42	43	89	114	56	123	87	206	97	76	165	130	295	211	53
28	33	59	86	120	68	156	166	229	84	96	189	225	315	204	54
38	39	64	74	93	51	111	130	206	85	89	150	194	280	178	55
25	40	53	52	76	47	115	151	202	88	92	165	198	266	171	56

*in degrees

Table 13

Raw Data Flexibility Raw Scores for Retention Test #2

Group: Proprioceptive
Neuromuscular Facilitation

EXTENSION					FLEXION					TOTAL RANGE					
Ankle	Hip	Trunk	Shoul-der	Neck	Ankle	Hip	Trunk	Shoul-der	Neck	Ankle	Hip	Trunk	Shoul-der	Neck	Subject No.
24	53	85	98	122	91	136	154	219	105	115	189	239	317	227	39
31	31	46	77	101	40	97	137	191	97	71	128	183	268	198	40
36	47	69	76	109	53	142	166	207	92	89	189	235	283	201	41
22	30	34	92	130	70	122	140	205	60	92	152	174	297	190	42
18	51	69	73	110	55	103	144	197	63	73	154	213	270	173	43
34	61	92	96	106	51	147	165	222	94	85	208	257	318	200	44
20	40	53	72	106	62	124	156	197	93	82	164	209	269	199	45
26	81	97	94	118	70	167	181	149	107	96	248	278	243	225	46
19	32	56	86	96	77	150	176	202	88	96	182	232	288	185	47
23	76	83	97	105	66	120	125	210	109	89	196	208	307	214	48
13	36	65	56	106	66	124	152	202	82	79	160	217	258	188	49
26	58	70	82	89	57	127	158	207	102	83	185	228	289	191	50
22	31	58	81	96	63	101	117	224	83	85	132	175	305	179	51
28	53	68	95	112	62	135	167	193	105	90	188	235	188	217	52
17	38	64	70	105	49	86	115	96	91	66	124	179	166	196	53
41	50	47	78	132	70	161	154	208	81	111	211	201	286	213	54
44	41	39	84	71	41	111	141	212	105	85	152	180	296	176	55
25	40	53	52	76	47	115	151	202	88	72	155	201	254	164	56

*in degrees

Table 14

Raw Data Flexibility Raw Scores for Pre-Test

Group: Control

*in degrees

EXTENSION					FLEXION					TOTAL RANGE					
Ankle	Hip	Trunk	Shoul-der	Neck	Ankle	Hip	Trunk	Shoul-der	Neck	Ankle	Hip	Trunk	Shoul-der	Neck	Subject No.
14	21	36	44	76	47	63	125	198	60	61	84	161	242	136	57
11	45	37	65	95	40	91	125	181	53	81	136	162	246	148	58
15	47	79	67	93	58	121	165	193	75	73	168	244	260	168	59
9	32	61	66	81	52	102	127	179	79	61	134	188	245	160	60
22	34	42	59	86	51	85	116	186	64	73	119	158	235	150	61
11	43	62	52	89	31	95	130	183	70	42	138	192	235	159	62
11	31	48	59	87	56	87	135	180	61	67	118	183	239	148	63
15	37	47	57	87	48	97	126	198	83	63	134	173	255	170	64
17	27	50	63	100	57	101	138	217	72	74	128	188	280	172	65
22	40	71	84	69	64	119	143	207	78	86	159	214	291	147	66
9	48	56	52	67	65	79	136	179	90	74	127	192	231	157	67
11	37	42	65	98	64	90	109	200	81	75	127	151	265	179	68
21	55	79	66	101	70	97	126	177	74	91	152	205	243	175	69
16	39	44	57	93	65	100	126	190	77	81	139	170	247	170	70
15	22	26	75	80	58	115	121	194	62	73	137	147	269	142	71
15	32	57	45	111	53	109	143	182	91	68	141	200	227	202	72
7	29	36	47	80	49	99	128	210	85	56	128	164	257	165	73
11	39	29	71	109	70	107	138	198	91	81	146	167	269	200	74
19	26	31	54	112	60	125	149	214	100	79	151	180	268	232	75
14	31	46	46	90	46	109	146	191	90	60	140	192	237	180	76
21	32	47	59	90	63	89	152	205	81	84	121	199	264	171	77
17	32	38	69	90	41	84	133	181	70	58	116	171	250	160	78
19	27	25	55	77	38	77	110	184	71	57	104	135	239	148	79

Table 15

Raw Data : Flexibility Raw Scores for Post-Test

Group: Control

*in degrees

EXTENSION					FLEXION					TOTAL RANGE					
Ankle	Hip	Trunk	Shoul-der	Neck	Ankle	Hip	Trunk	Shoul-der	Neck	Ankle	Hip	Trunk	Shoul-der	Neck	Subject No.
34	36	55	50	87	32	70	107	194	70	66	106	162	244	157	57
14	49	47	79	87	63	101	117	186	62	77	150	164	265	149	58
16	71	72	76	88	59	123	149	198	71	75	194	221	274	159	59
10	55	70	80	82	55	102	129	184	82	65	157	199	264	164	60
17	54	55	62	87	71	92	135	185	81	88	146	180	247	168	61
9	39	46	56	86	42	109	114	178	66	51	148	160	234	152	62
11	24	44	87	66	43	72	127	176	94	54	96	171	263	160	63
35	45	54	72	82	44	109	135	181	84	79	154	189	253	166	64
35	30	52	84	110	46	110	135	210	64	81	140	187	294	174	65
20	44	63	64	85	57	133	155	193	82	77	177	218	257	167	66
19	41	69	76	95	34	111	147	183	84	53	152	216	259	179	67
16	41	70	81	104	49	103	103	196	80	65	144	173	277	184	68
19	55	68	76	98	65	122	149	155	76	84	177	217	231	174	69
23	36	53	71	85	36	106	122	181	72	59	142	175	252	157	70
16	35	44	83	73	55	111	147	196	72	71	146	191	279	145	71
19	31	47	82	107	49	109	130	186	91	68	140	177	268	198	72
9	20	35	81	76	60	109	127	190	102	69	129	162	271	178	73
26	37	34	70	103	66	113	142	197	96	92	150	176	267	199	74
15	19	52	76	115	59	111	161	193	64	74	130	213	269	179	75
15	36	55	60	82	65	111	134	195	102	80	147	189	255	184	76
19	32	51	65	104	51	109	151	204	53	70	136	202	269	157	77
14	44	46	62	92	47	89	129	180	51	61	133	175	242	143	78
18	34	42	78	92	42	72	110	180	45	60	106	152	258	137	79

Table 16

Raw Data : Flexibility Raw Scores for Retention #1

Group: Control

*in degrees

EXTENSION					FLEXION					TOTAL RANGE					
Ankle	Hip	Trunk	Shoul-der	Neck	Ankle	Hip	Trunk	Shoul-der	Neck	Ankle	Hip	Trunk	Shoul-der	Neck	Subject No.
36	34	34	51	77	42	74	124	193	63	78	108	158	244	140	57
13	47	39	78	94	64	93	119	186	63	77	140	158	264	157	58
15	72	66	76	87	59	132	151	197	76	74	204	217	273	163	59
11	52	60	72	82	53	101	121	183	80	64	153	181	255	162	60
23	36	52	61	88	59	84	118	186	69	82	120	170	247	257	61
12	41	50	61	77	36	102	112	177	61	48	143	162	238	138	62
11	26	46	67	66	51	82	131	174	87	62	108	177	241	153	63
22	47	56	66	86	41	117	129	183	81	63	164	185	249	167	64
19	37	54	89	107	52	117	129	209	73	71	154	183	298	180	65
18	46	66	62	72	61	134	152	197	83	79	180	218	259	155	66
21	46	68	69	95	46	109	146	184	90	67	155	214	253	185	67
15	40	46	73	97	62	101	107	192	79	77	141	153	265	176	68
18	56	73	81	102	70	121	127	173	81	88	177	200	254	183	69
21	39	49	66	97	59	102	127	187	73	80	141	176	253	170	70
15	37	29	79	81	57	117	137	192	79	72	154	166	271	160	71
21	33	52	47	104	48	114	146	183	92	69	147	198	230	196	72
10	27	36	77	80	57	106	126	189	100	67	133	162	266	180	73
16	38	31	69	104	68	114	138	180	93	84	152	169	249	197	74
17	20	42	72	113	60	114	149	196	101	77	134	191	268	214	75
17	32	54	59	79	62	107	137	187	86	79	139	191	246	165	76
24	33	48	58	93	62	93	151	197	78	66	126	199	255	171	77
16	36	42	67	91	46	82	130	170	72	62	118	172	237	163	78
19	32	39	59	81	39	79	112	182	71	58	111	151	241	152	79

Table 17

Raw Data Flexibility Raw Scores for Retention Test #2

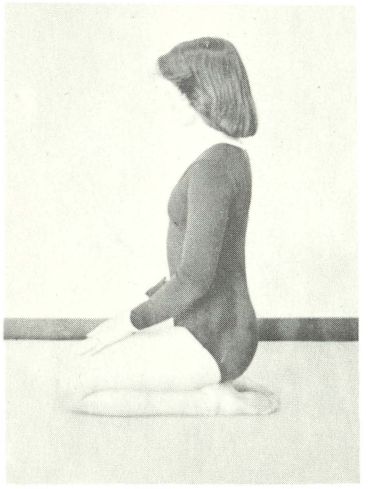
Group: Control

*in degrees

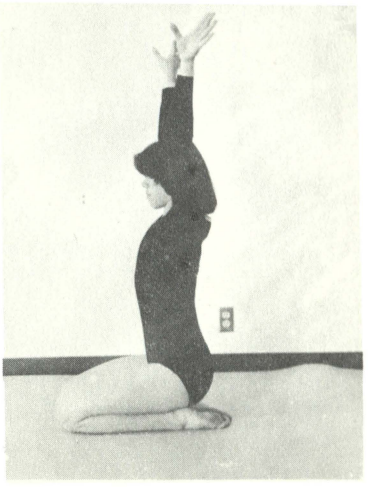
EXTENSION					FLEXION					TOTAL RANGE					
Ankle	Hip	Trunk	Shoul-der	Neck	Ankle	Hip	Trunk	Shoul-der	Neck	Ankle	Hip	Trunk	Shoul-der	Neck	Subject No.
29	29	46	63	87	47	69	129	194	60	76	98	175	257	147	57
15	52	59	64	87	63	118	129	183	62	78	170	188	247	149	58
18	47	75	83	100	66	133	156	203	73	84	180	231	286	173	59
12	46	60	69	81	57	97	126	181	78	69	143	186	250	159	60
25	35	52	61	96	56	79	89	183	56	81	114	141	244	152	61
14	41	52	65	94	50	104	116	179	44	64	145	168	244	138	62
14	50	62	71	80	49	97	120	175	64	63	147	182	246	144	63
20	45	64	76	93	52	99	131	192	87	72	144	195	268	180	64
32	33	55	95	104	57	114	145	212	90	89	145	200	307	194	65
14	51	65	92	83	70	132	156	193	83	84	183	221	285	166	66
24	53	70	78	87	48	102	142	171	40	72	155	212	249	127	67
22	56	52	82	98	61	103	120	193	81	83	159	172	275	179	68
15	71	74	79	115	70	133	162	175	76	85	204	236	254	191	69
22	32	44	70	98	61	121	142	185	57	83	153	186	255	155	70
16	43	50	79	66	66	120	145	181	81	82	163	195	260	147	71
24	34	56	92	100	51	127	150	180	98	75	161	206	272	198	72
12	34	43	73	73	55	108	128	183	83	67	142	171	256	156	73
15	41	34	67	102	68	110	140	184	101	83	151	174	251	203	74
15	41	82	82	120	64	111	143	192	53	79	152	225	274	173	75
16	35	40	71	71	50	110	143	176	72	66	145	183	247	143	76
32	50	54	71	74	44	110	153	193	79	76	160	207	264	153	77
15	34	40	61	89	44	87	131	169	69	59	121	171	230	148	78
20	31	42	62	93	41	79	112	183	66	61	110	154	245	159	79

APPENDIX C

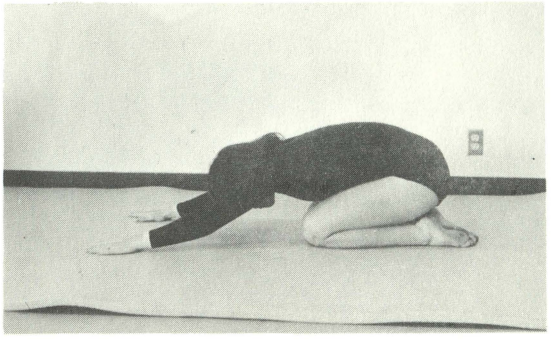
Exercises



Beginning Position



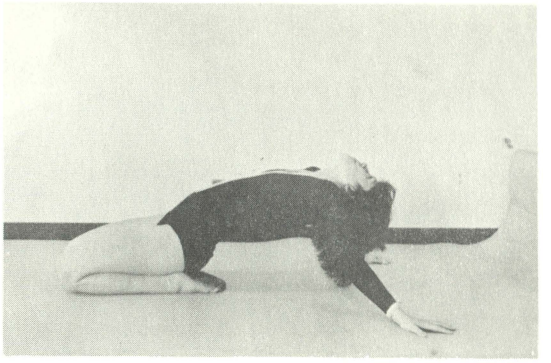
Upward Stretch Position



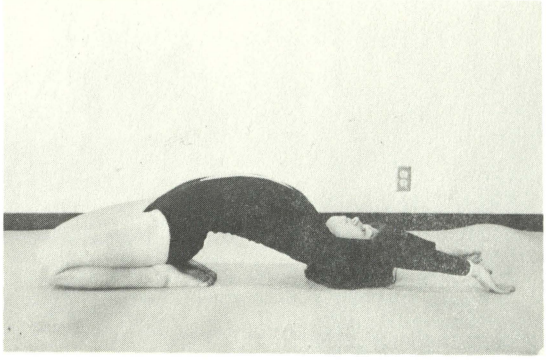
Forward Stretch Position

Figure 1

"The Kneeling Position"
Beginning Position



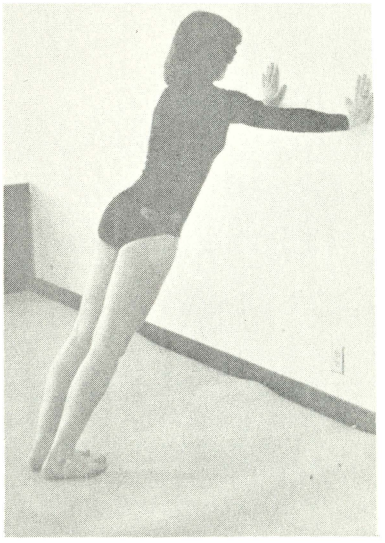
Exercise Position



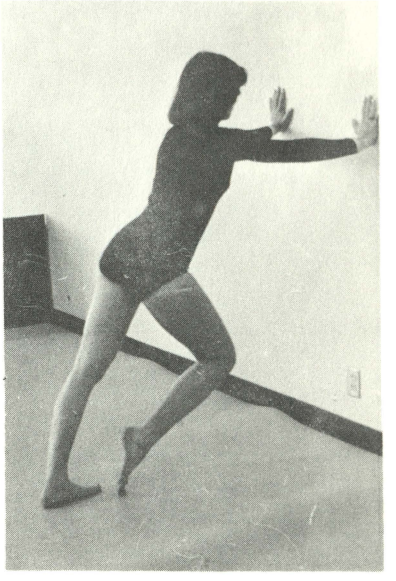
UltimateExercise Position

Figure 2

"The Kneeling Position"
Exercise Position



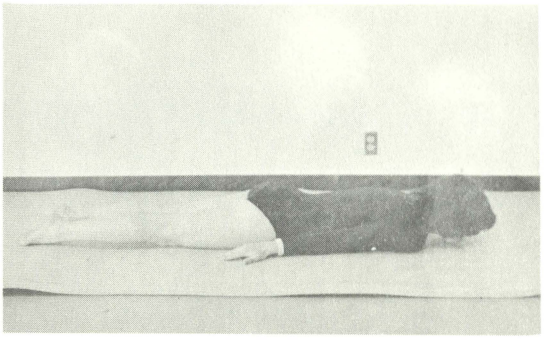
Beginning Position



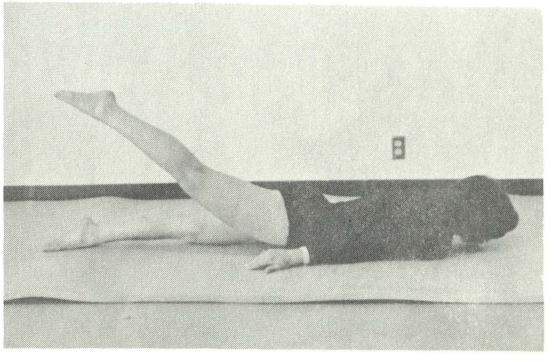
Exercise Position

Figure 3

"Gastrocnemius Stretch"



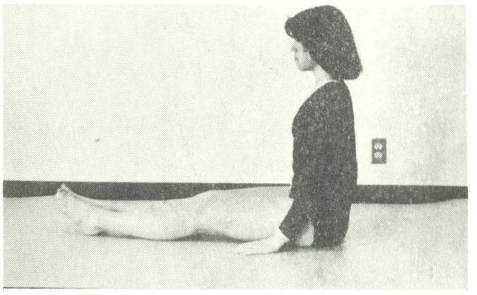
Beginning Position



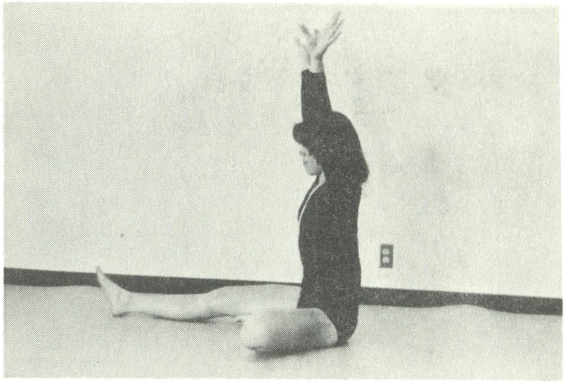
Exercise Position

Figure 4

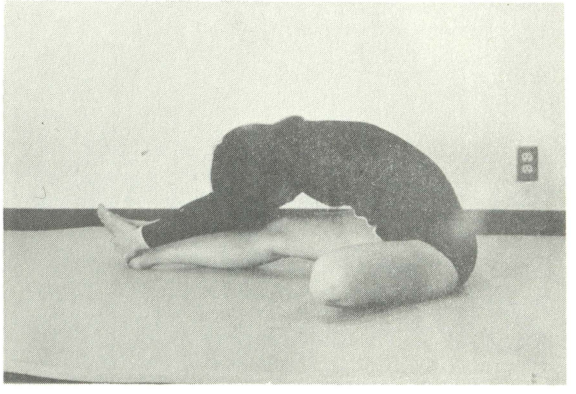
"Half - Locust"



Beginning Position



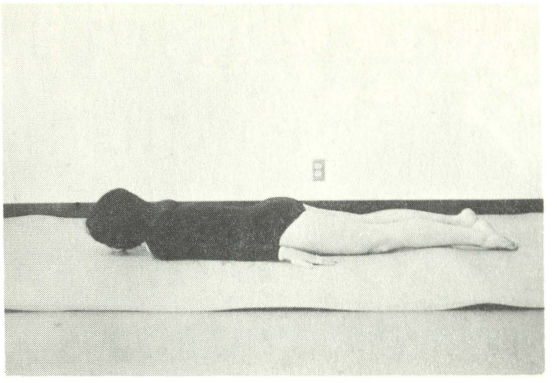
Stretch Position



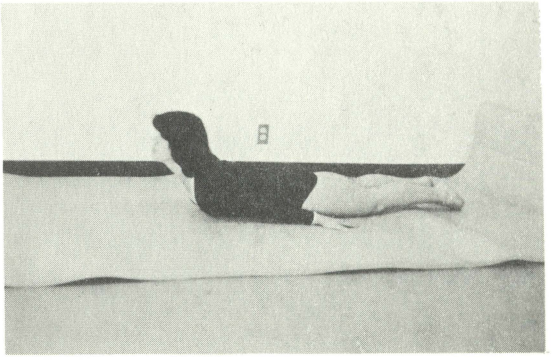
Exercise Position

Figure 5

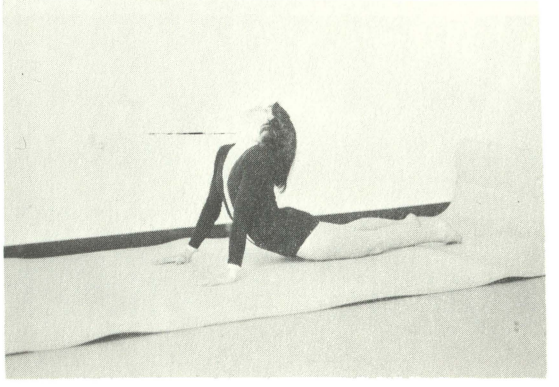
"Swan"



Beginning Position

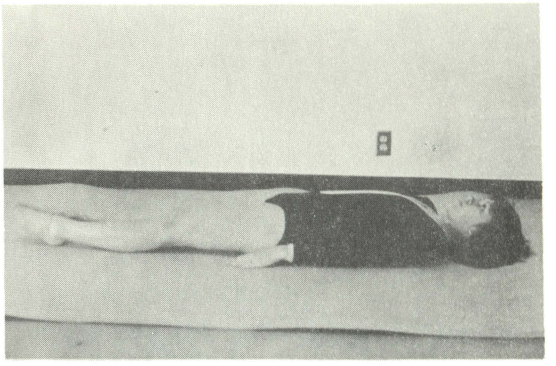


Exercise Position
(Part One)

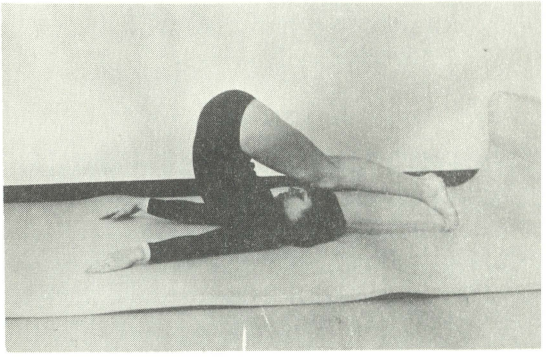


Exercise Position
(Part Two)

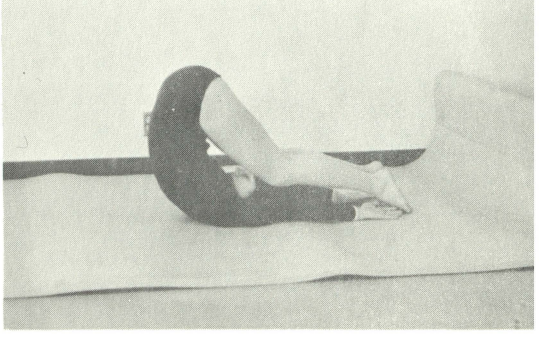
Figure 6
"The Snake"



Beginning Position

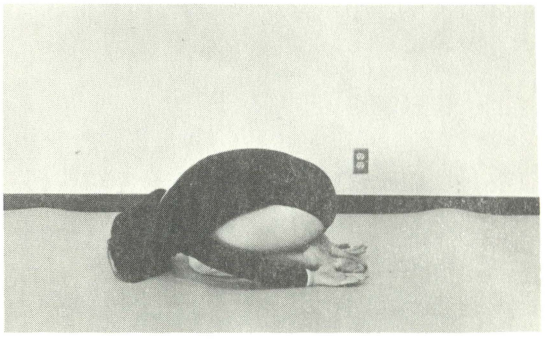


Exercise Position
(Part One)

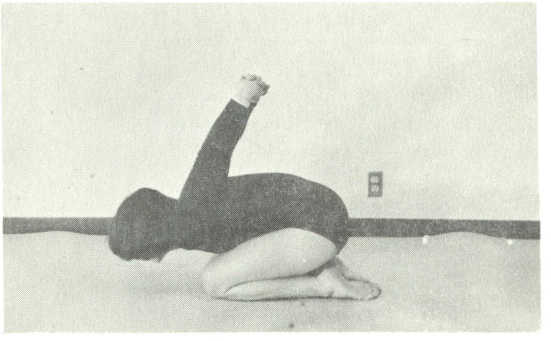


Exercise Position
(Part Two)

Figure 7
"The Plough"



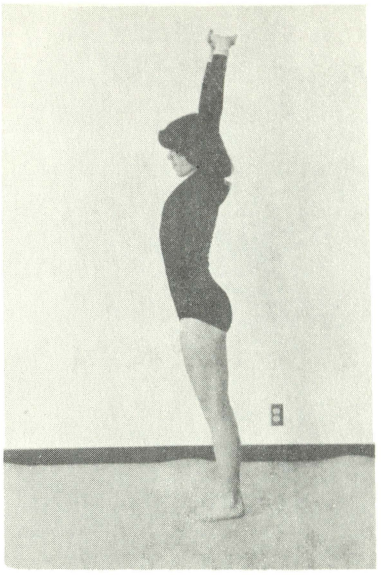
Beginning Position



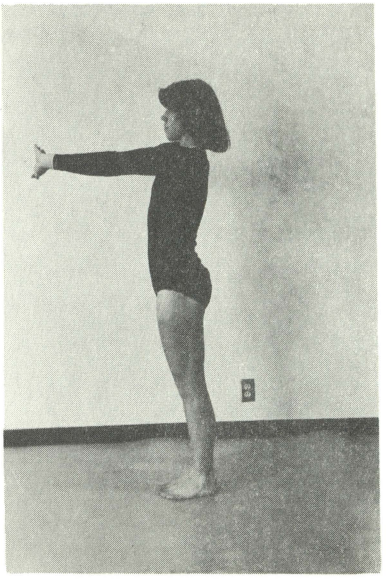
Exercise Position

Figure 8

"The Folding Leaf"
with arm and head
raising variations



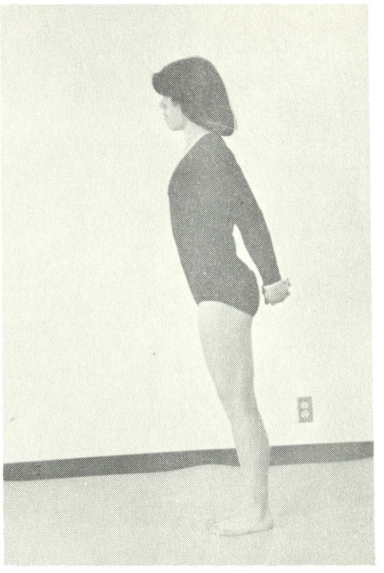
Exercise Position



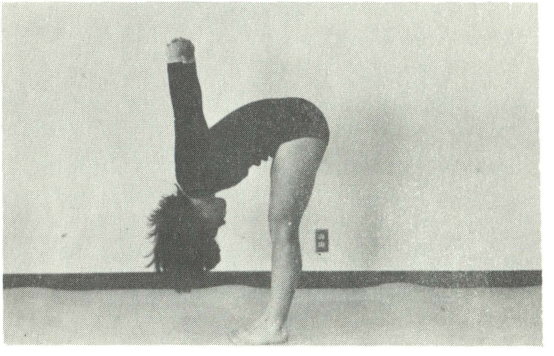
Beginning Position

Figure 9

"Shoulder Stretch"
Part One



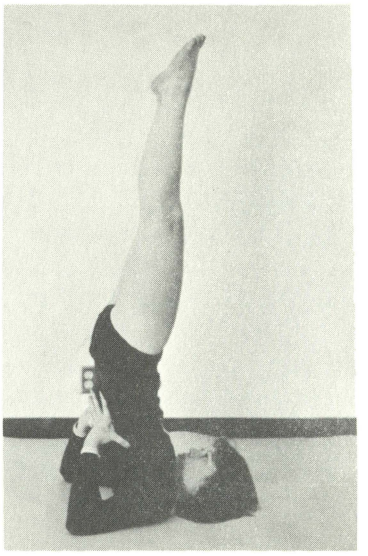
Beginning Position



Exercise Position

Fiugre 10

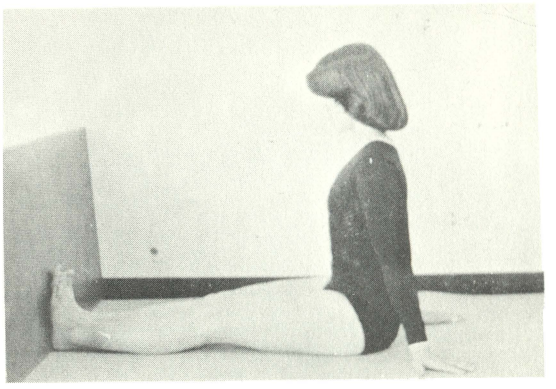
"Shoulder Stretch"
Part Two



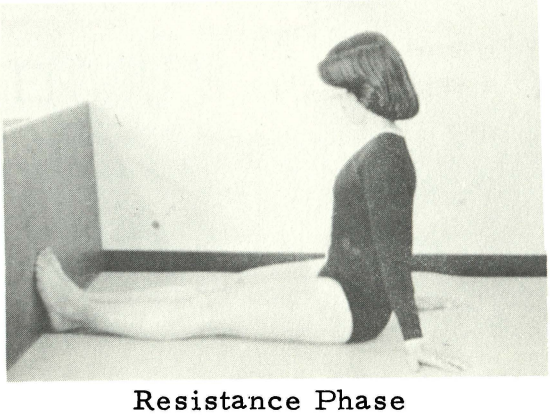
Exercise Position

Figure 11

"The Candle"



Stretch Phase

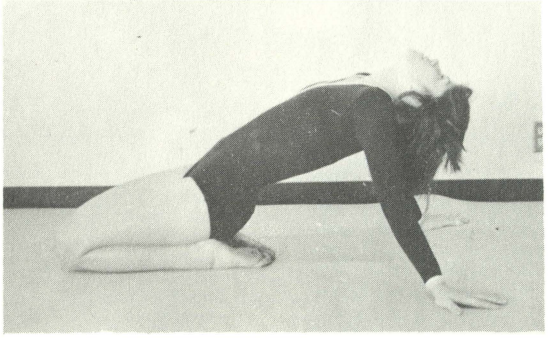


Resistance Phase

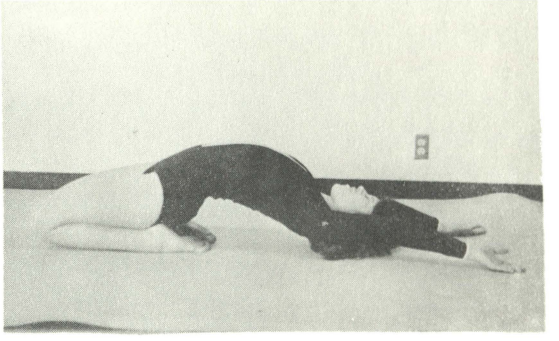
Figure 12

"Ankle Stretch"
PNF Method

Beginning Position



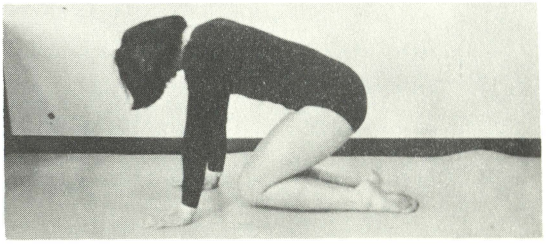
Exercise Position



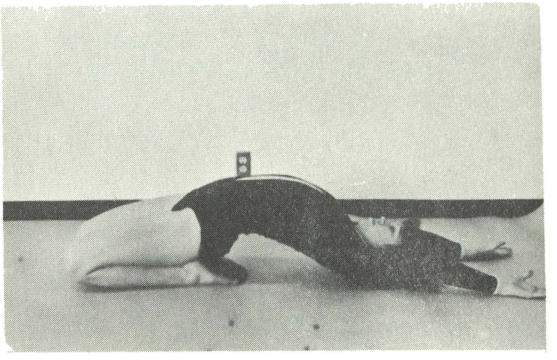
Ultimate Exercise Position

Figure 13

"The Kneeling Position"
PNF Method



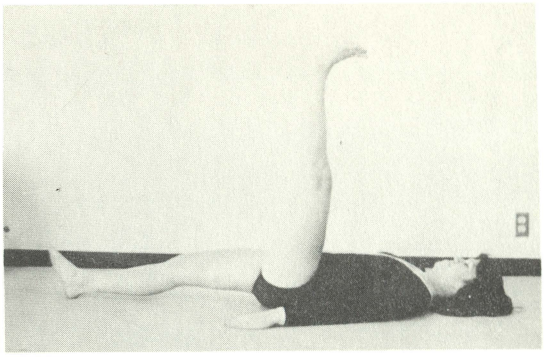
Resistance Phase



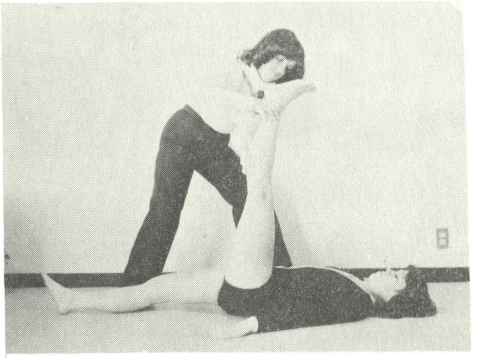
Exercise Position

Figure 14

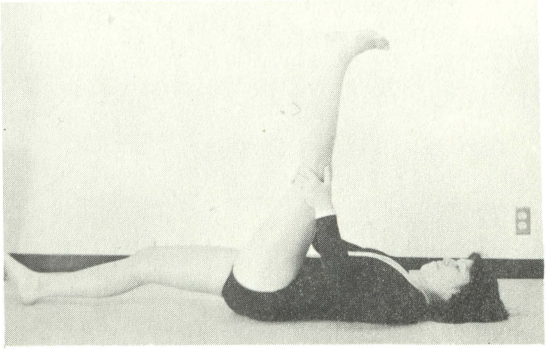
"The Kneeling Position"
PNF Method
(Equivalent to One Repetition)



First Stretch Phase



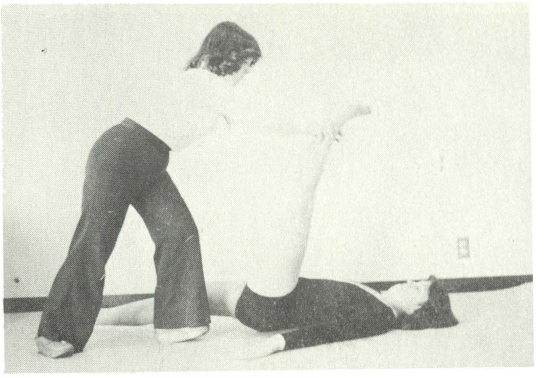
First Resistance Phase



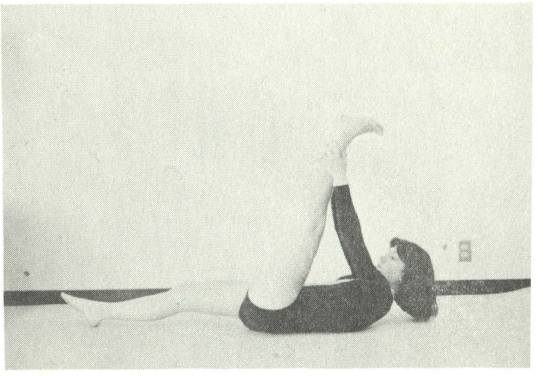
Second Stretch Phase

Figure 15

"Hip Stretch"
PNF Method



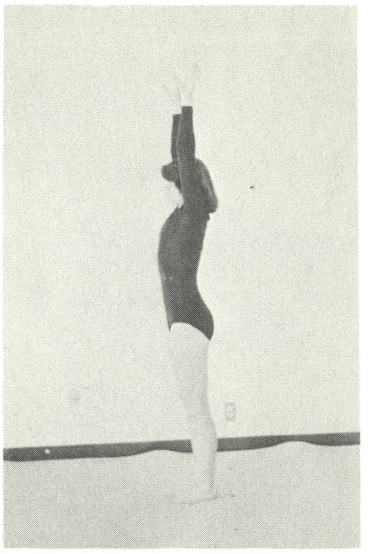
Second Resistance Phase



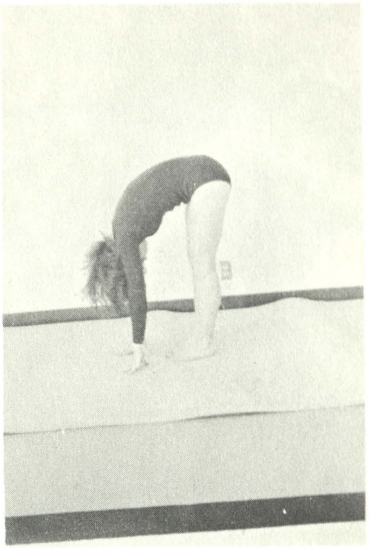
Final Stretch Phase

Figure 16

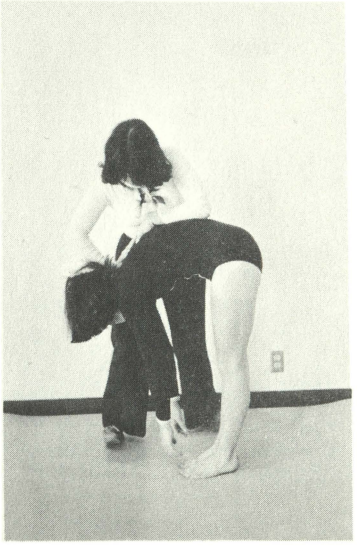
"Hip Stretch"
PNF Method
(Equivalent to One Repetition)



Beginning Position



First Stretch Phase



First Resistance Phase

Figure 17

"Trunk Stretch"
PNF Method

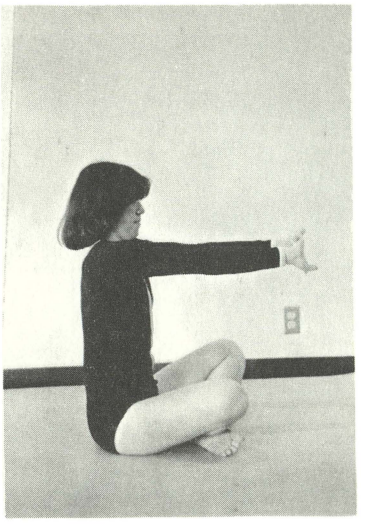
Second Stretch Phase

Second Resistance Phase

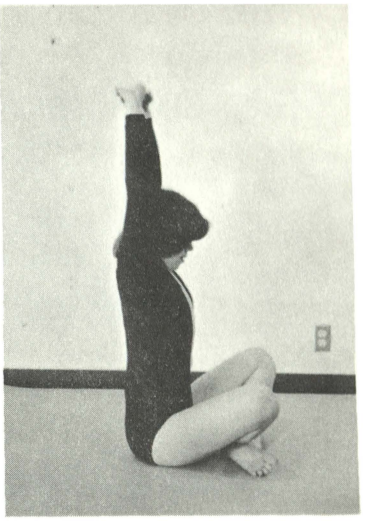
Final Stretch Phase

Figure 18

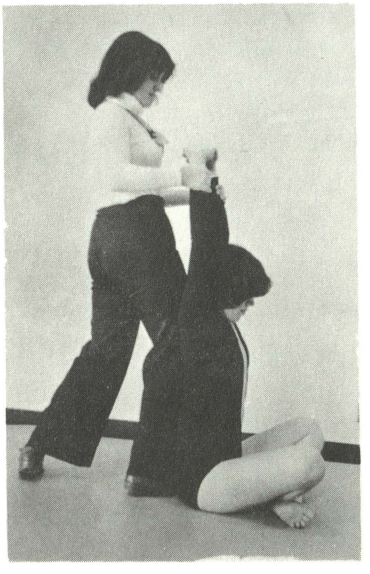
"Trunk Stretch"
PNF Method
(Equivalent to One Repetition)



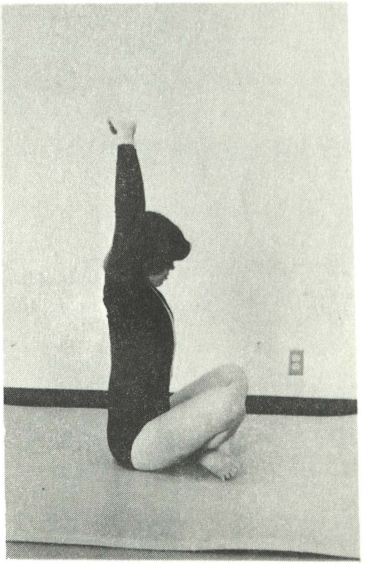
Beginning Position



First Stretch Phase



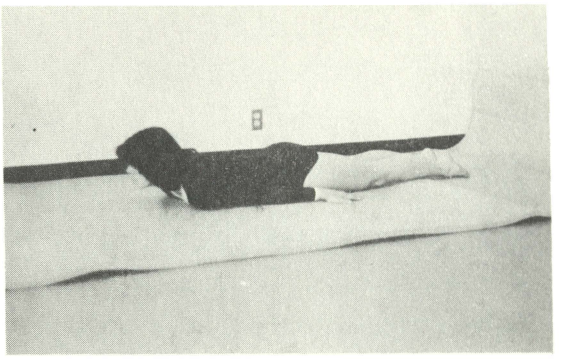
Resistance Phase



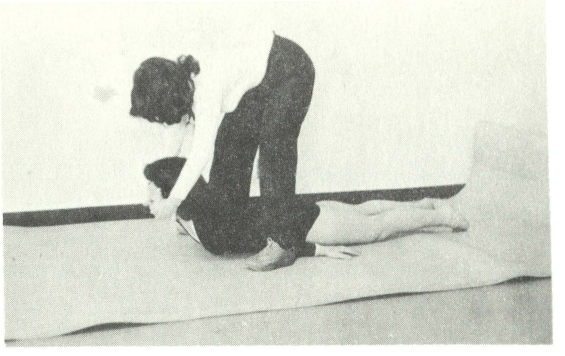
Final Stretch Phase

Figure 19

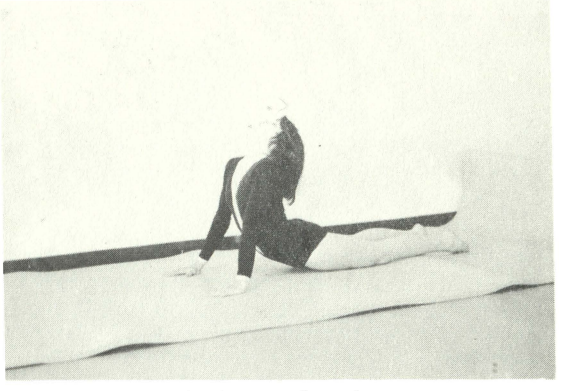
"Shoulder Stretch"
PNF Method
(Equivalent to One Repetition)



First Stretch Phase

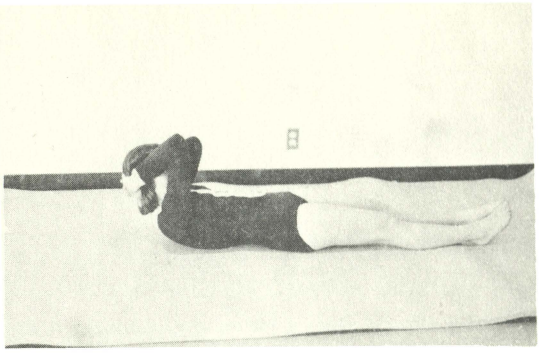


Resistance Phase

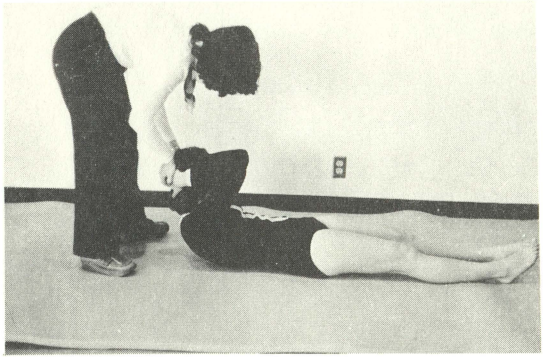


Final Stretch Phase

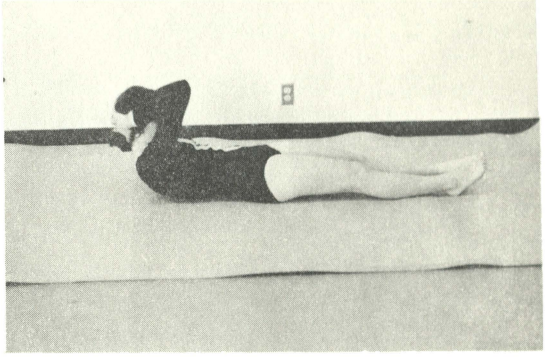
Figure 20
"Neck Stretch"
of the anterior muscles. (PNF Method)
(Equivalent to One Repetition)



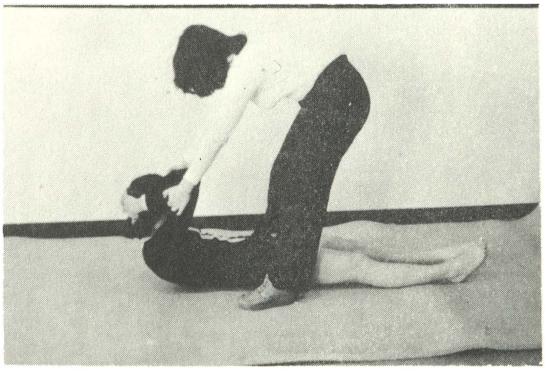
First Stretch Phase



First Resistance Phase



Second Stretch Phase



Second Resistance Phase
To complete this exercise, one more stretch phase was added.

Figure 21
"Neck Stretch"
of the posterior muscles. (PNF Method)
(Equivalent to One Repetition)