The Effects of Dynamic Range of Motion Exercises and Static Stretching on Strength and Range of Motion of the Hip Joint

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THE EFFECTS OF DYNAMIC RANGE OF MOTION EXERCISES AND STATIC STRETCHING ON STRENGTH AND RANGE OF MOTION OF THE HIP JOINT

by

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AND STATIC STRETCHING ON STRENGTH AND
RANGE OF MOTION OF THE HIP JOINT

This thesis is approved as a creditable and independent
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Abstract
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The effects of dynamic range of motion exercises and static stretch on hip flexibility and hip strength were examined. One-hundred and one college-age male and female students were divided into three groups: dynamic range of motion (D'ROM) (n=32), static stretch (ST) (n=34), and control (C) (n=35). All subjects were measured before and after treatment for hip flexibility, using a Leighton flexometer, and for hip strength, using a cable tensiometer. Treatment consisted of two specific hip flexibility exercises performed twice a week for seven weeks by the D'ROM and ST groups. The gain scores of the dependent variables, hip flexibility and hip strength, were each analyzed by a two-way ANOVA (sex x treatment). Tukey's HSD test was used for all pairwise comparisons. Zero-order and partial correlation coefficients were calculated between flexibility and strength for pretest, posttest, and gain measures for all groups, including a pooled D'ROM-ST group (D-S). D'ROM had a significantly greater increase of hip flexibility than ST (p<.05) and C (p<.05). D'ROM had a significantly greater increase of hip strength than C (p<.05). Females had a significantly greater increase of hip strength than males.
Interaction was not significant. Significant partial correlations (p<.05), controlling for sex, were found for ST (.605) and D-S (.438) for pretest measures. A significant zero-order correlation (p<.05) was found for D'ROM (-.385) for posttest measures. D'ROM exercises have a significant effect on developing flexibility and strength at the hip joint. Increases in hip strength may not be related to increases in hip flexibility for both D'ROM exercises and static stretch.
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CHAPTER 1

INTRODUCTION

Efficiency of movement is dependent upon normal ranges of motion (Davis & Logan, 1961; Holt, Travis & Otika, 1970). Physical educators and physical therapists, therefore, have done a considerable amount of research in developing effective programs through which flexibility can be gained. It is a commonly and generally recognized belief that flexibility is an important factor in human performance (Beaulieu, 1981; Klafs and Arnheim, 1973; Liverman, 1970; Montoye, 1978), as well as an essential component of physical fitness (Cooper & Fisher, 1978; Cureton, 1941; Mathews & Fox, 1976). Evidence indicates that maintenance of good joint mobility decreases the incidence of injuries in athletics, and consequently is of concern to the physical education profession (Beaulieu, 1981; Cureton, 1941; DeVries, 1980; Mathews & Fox, 1976).

Numerous stretching techniques have been developed to produce greater range of movement in joints, and have resulted in pronounced improvement. The three most common modes used to improve flexibility are ballistic methods, static stretch techniques, and proprioceptive neuromuscular facilitation (PNF). All methods have shown significant increases in range of motion (Bridell, 1969; Cornelius & Hinson, 1980; DeVries, 1962; Hartley, 1980; Holt et al., 1970;
Liverman, 1970; Long, 1971; McCue, 1953; Moore & Hutton, 1978; Rivera, 1979; Tanigawa, 1972; Tweitmeyer, 1972; Weber & Kraus, 1949). Static exercises are believed to be the safest method of the three, as recent studies indicate that a greater chance of tissue damage may occur with the ballistic and PNF exercises (Beaulieu, 1981).

Dynamic range of motion training (D'ROM) is designed to improve range of motion by developing strength of contraction over a full range of motion, an already accepted value (Dominguez & Gajda, 1982). Because these exercises develop strength and flexibility simultaneously, they are thought to be a more efficient mode of stretching. D'ROM exercises are also viewed as a safer technique since the exercises never exceed the ligamentous capability of the joint. Consequently, the stability of the joint is never threatened. To date, no research has been conducted to study the effects of the D'ROM exercises.

Statement of the Problem

The major focus of this study was to compare the effects of static stretch exercises and dynamic range of motion exercises on hip flexibility and hip strength. The relationship between hip flexibility and hip strength was also examined.
Significance of the Study

Flexibility, defined as the range of possible movement about a joint or sequence of joints, has been a great concern to coaches and teachers in physical education (Holland, 1968). Many authorities in sports medicine consider flexibility one of the most important objectives in conditioning athletes (Klafs & Arnheim, 1973). Studies have shown that more flexible athletes are generally the better performers (Beaulieu, 1981; Montoye, 1978), and are physically more adaptable to almost any game situation (Klafs & Arnheim, 1973). An average degree of range of motion is believed to be essential in the performance of certain skills and in the success of athletic endeavors (Liverman, 1970; Mathews & Fox, 1976). Athletes who gain improved flexibility and increased range of joint movements are thought to be able to use their bodies more effectively and efficiently (Klafs & Arnheim, 1973).

Many investigators have emphasized the importance of joint mobility in the prevention of injury in athletics (Beaulieu, 1981; DeVries, 1980; Mathews & Fox, 1976). Authorities believe that flexibility exercises are a basic factor in the prevention of injuries in many sports (Cureton, 1941; O’Niel, 1976). Muscle strains, joint injuries and torn or strained collagenous tissues occur more easily if an athlete has poor or limited flexibility (Klafs & Arnheim, 1973; Wilmore, 1977). Jackson (1978) presented conflicting evidence, however, in his research of 2300 West Point cadets. No significant relationship was found between joint injuries and joint flexibility.
Exactly how much flexibility an individual should possess has not been scientifically proven. Recent studies postulate that there is an ideal or optimum range of flexibility for the prevention of injury (Davis & Logan, 1961; Holland, 1968). Too great an increase in flexibility may destroy the supporting function of the ligaments and joint capsule (Rasche & Burke, 1978). Continuous stretching of ligaments may produce laxity of the collagen tissues which have the ability to resist jerks or snaps, but will succumb to prolonged pressure (Dominguez & Gajda, 1982; Holland, 1968). Extreme flexibility may predispose cause of injury to joints, while lack of normal flexibility may result in tearing of connective tissue (Holland, 1968). Clinical observations and biomechanical analyses have found that joint looseness adversely affects performance in sports (Montoye, 1978). DeVries (1980) hypothesized that flexibility of motion may be of much greater importance in performance than the ability to achieve extreme degrees of range of motion. While excessive flexibility is not to be sought, it is important to attempt to establish and maintain normal ranges of movement (Drew, 1949; Rasche & Burke, 1978).

There is general agreement among researchers that flexibility can be improved with regular flexibility training. Presently, research has been concentrated on studying the effects of ballistic, static, and PNF stretching techniques. The question of which method is most advantageous has drawn conflicting conclusions by investigators. Preference of static methods over ballistic methods has been stated by most researchers because of the possibility of damage to
the soft tissues of the muscle and joint (DeVries, 1980; Jensen & Fisher, 1972; Mathews & Fox, 1976). While some studies have found greater improvements with PNF techniques over static and ballistic methods, recent research suggests that during PNF exercises, stretch occurs with more tension in the muscle increasing the risk of injury to the tissues of the joint (Beaulieu, 1981; Moore & Hutton, 1978). In addition, some of the popular passive stretches have been placed in a "high risk" category because of the probability of exceeding the capabilities of the soft tissues surrounding the joint (Dominguez & Gajda, 1982; Saega, Quedenfeld, Moyer & Butler, 1981).

In an attempt to develop flexibility exercises that will effectively improve range of motion without the risk of damage to the soft tissues of the joint, Gajda (1982) designed the D'ROM program. D'ROM exercises are considered to be a safer method of increasing range of motion than the three previosly mentioned techniques. Because the body segment is not carried past the range that the agonist muscle has the strength to pull it through, joint integrity is always maintained. In addition, it is a commonly recognized belief that strengthening the muscles around a joint will increase the stability of that joint and lessen the chance of injury (Davis & Logan, 1961; Dominguez & Gajda, 1982; Drew, 1949; Rasche & Burke, 1978). The potential range of motion that any athlete is encouraged to achieve with D'ROM exercises is never allowed to destroy the ligamentous capabilities of any joint. It is based on the principle that actual range of motion, considering only muscle strength, should equal the potential range of
motion, considering bone and ligamentous factors (Dominguez & Gajda, 1982). Passive stretching will not accomplish this task since it does not develop the strength to move the body segment through the joint’s range of motion. Drew (1949) suggested that flexibility should not exceed strength. Dominguez and Gajda (1982) claim that flexibility should not be a goal in itself, but rather the result of muscle strengthening and training.

The D’ROM system of training is considered to be a more time efficient mode of stretching because it is accomplished with a strength training program. Unlike the other three methods, the muscle group antagonist to the muscle to be stretched carries the limb through the full range of motion utilizing a concentric contraction. An isometric contraction holds the limb in the upper limits of movement, and an eccentric contraction of the muscle allows the leg to be lowered. Training geared toward flexibility should include strength components, as the strength of the antagonist muscle is a factor in determining a joint’s range of motion (Klafs & Arnheim, 1973; Scott, 1942). In order to develop flexibility at a specific joint, the joint must be exercised regularly through the full range of motion (Davis & Logan, 1961; Leighton, 1960; Tanigawa, 1972). The strength of the muscles utilized in the D’ROM exercises can be increased and developed simultaneously with flexibility (Dominguez & Gajda, 1982).

To date, no research has been published on the D’ROM program, and no evidence has been presented to support the claims on the effectiveness of the exercises on range of motion. In addition, no
studies have compared any of the three popular modes of stretching with the D'ROM program. The need for investigation into this type of active stretch is evident. The passive static stretch was chosen for comparison because of its popularity as well as the considerable amount of research indicating that passive static stretch is an effective method for improving range of motion.

Many conflicting beliefs exist in the area of flexibility and in the exercises designed to increase this factor. The theory that one should possesss the strength to move a limb through its potential range of motion has been supported by many authorities, yet little research has been conducted to study or develop exercises involving active stretch. Although it is not within the scope of this study to examine the effects of stretching exercises on the tissues of the joint, recent evidence indicating the occurrence of tissue damage during the execution of ballistic, static and PNF exercises further support the need to study the effect of increasing and maintaining flexibility by an alternative method.
Hypotheses

The following hypotheses were investigated:

1. There is no significant difference in mean gain scores of hip flexibility among the static, D'ROM, and control groups.

2. There is no significant difference in mean gain scores of hip strength among the static, D'ROM, and control groups.

3. There is no significant difference in mean gain scores of hip flexibility between males and females.

4. There is no significant difference in mean gain scores of hip strength between males and females.

5. There is no significant difference in the relationship of hip flexibility and hip strength between the static and D'ROM groups.

6. There is no significant difference in the relationship of hip flexibility and hip strength between the pooled D'ROM-static experimental group and the control group.
Scope

Two methods of increasing range of motion, static stretches and D'ROM exercises, and their effects on hip flexibility and hip strength were investigated in this study. One-hundred and one college-age males and females enrolled in P.E. 100 social dance classes at South Dakota State University acted as subjects. The treatment phase took place the last seven weeks of the 1982 spring semester. Pretests of hip flexibility and hip strength were given the week preceding spring break, and posttests were administered the last week of the spring semester. The Leighton flexometer was used to measure range of motion. The cable tensiometer was used for strength measurements. Treatment was administered twice weekly at the beginning of the class period, and included two range of motion exercises for hip flexion.

Limitations

The following limitations have been acknowledged by the investigator:

1. The motivation of each subject to put forth maximal effort during treatment and testing periods could not be controlled and may have varied for each subject.

2. All subjects were students enrolled in elective social dance classes which are part of the physical education requirement at South
Dakota State University. Generalization of findings to other populations may not be appropriate.

3. Intact classrooms were randomly assigned to treatments rather than random selection and assignment of students to groups.

Terminology

The following terms have been defined for this study:

Agonist

The agonist refers to a muscle or group of muscles which cause a motion. The agonist is often called the "mover", and opposes the muscle being stretched.

Antagonist

The antagonist muscle or muscle group are those which cause the opposite movement of the agonist muscle. In the movement of flexion, for example, the flexors are the agonists and the extensors are the antagonists.

Autogenic Inhibition

Autogenic inhibition is a neurological response to the stretch or contraction of the muscle tendon. The response causes a relaxation of the stretched or contracted muscle, and simultaneously facilitates the contraction of the opposing muscle.
**Ballistic Stretch**

The ballistic method of stretch uses the momentum of the body segment to push the articulation past its normal range of motion. Ballistic stretches are commonly known as "bouncing stretches".

**D'ROM Exercises**

Dynamic range of motion exercises involve an active static stretch which uses the contraction of the opposing muscle group to carry the body segment to the upper limits of motion.

**Flexibility**

The range of possible movement about a joint or sequence of joints is generally referred to as flexibility.

**PNF Exercises**

Proprioceptive neuromuscular facilitation involves a method of stretch in which the muscle to be stretched is contracted, then relaxed, and followed by an immediate stretch.

**Range of Motion**

Range of motion refers to the range of possible movement about a joint or sequence of joints. This term is used interchangeably with flexibility.
**Reciprocal Inhibition**

Reciprocal inhibition is a neurological response to the contraction of the muscle fibers, causing its antagonist to relax. This response occurs automatically in movements elicited by the stretch reflex.

**Static Stretch**

Static stretch involves a method in which tension is slowly applied to the muscle until it is stretched to the desired limit. The lengthened position is then maintained.

- **Active static stretch.** Active static stretch refers to an unassisted movement that requires voluntary muscle contraction to move the joint to its maximal range.

- **Passive static stretch.** Passive static stretch refers to an assisted movement in which an external force, such as gravity, body momentum or manual assistance, is used to move the joint to its maximal range.

**Stretch Reflex**

The stretch reflex is a neurological response to the stretch of muscle fibers causing a contraction of the same fibers.
CHAPTER 2

REVIEW OF LITERATURE

Rising awareness of the importance of an optimal range of flexibility in athletics has stimulated an increased interest into methods utilized to increase range of motion. Those involved in physical education and athletics are not only concerned with a method that will effectively increase and maintain optimal flexibility, but a method that will maintain joint stability as well. The role of musculotendinous receptors in stretching exercises has been of interest to researchers in an attempt to identify a stretching technique that will effectively utilize these receptors to aid in stretching. The conflicting results of studies comparing the various stretching techniques as well as recent evidence of the possibility of soft tissue damage in certain stretching exercises, warrants the need for further research in this area. The literature pertaining to the study has been organized accordingly:

1. Sources of resistance to joint motion.
2. The role of musculotendinous receptors in stretching.
3. Methods of increasing range of motion.
4. Effects of receptors in selected range of motion exercises.
5. Review of related studies on range of motion exercises.
7. Summary of related literature.
Sources of Resistance to Joint Motion

Studies have documented that the principle sources of passive resistance at the normal extremes of joint motion are (a) connective tissue, tendons, ligaments, and the joint capsule; (b) muscle and fascial sheath; and (c) skin and the shape of a joint's articular surface (DeVries, 1980; Drew, 1949; Jensen & Fisher, 1972; Wells, 1976). In addition, Scott (1942) believes that the degree of elasticity and pliability of the opposing muscle, the degree of relaxation of the opposing muscle, and the strength of the opposing muscle to produce movement are also contributors to a joint's degree of range of motion. Drew (1949) has stated that flexibility or lack of it is due to unequal ligamentous action. Chapman (1971) concluded that the soft tissues of the body are more easily modifiable through training. Johns and Wright (1962) measured the torque of cats' metacarpophalangeal joints to estimate the resistance provided by various anatomical structures. Their analyses demonstrated that ligaments and the joint capsule contributed 47% to the total torque required to move the joint in mid range of movement. Passive muscle motion accounted for 41%, while the tendons and skin contributed 10% and 2%, respectively. Connective tissue, therefore, is the primary target of range of motion exercises (DeVries, 1980; Jensen & Fisher, 1972; Mathews & Fox, 1976; Sapega et al., 1981).

Hartley (1980) described two approaches toward increasing range of motion: (a) decrease the resistance of the soft supportive
tissues of the muscle and joint, and (b) increase the force (strength) of the opposing muscle to actively move the segment through the range of motion. Hartley (1980) further suggests that the resistance of the soft tissues can be decreased in two ways: (a) actual physical lengthening of the soft tissues, or (b) relaxation of the muscle under stretch.

**Role of Musculotendinous Receptors in Stretching**

Most investigators have been concerned with two types of musculotendinous receptors which are part of the neurological system, and the role and effect of these receptors on the various range of motion exercises.

**Golgi Tendon Organ**

The first type of musculotendinous receptor, the golgi tendon organ, is a specialized receptor located between the muscle and muscle tendon (Kreighbaum & Barthels, 1981). The golgi tendon organ responds to the stretch of the muscle tendon (Clarke, 1975; Jensen & Fisher, 1972). The stretch may be produced by the active contraction of the associated muscle, the active contraction of the opposing muscle, or the passive stretch produced by an external force (Kreighbaum & Barthels, 1981). This receptor is more sensitive to stretch caused by contraction than to passive stretch (Kreighbaum & Barthels, 1981; Patton & Mortensen, 1971). The golgi tendon organ responds by
inhibiting the contraction of the stretched muscle (Clarke, 1975; Jensen & Fisher, 1972; Kreighbaum & Barthels, 1981; Patton & Mortensen, 1971). This response is called "autogenic inhibition". It relieves the tension that has been produced at the joint, and simultaneously excites the opposing muscle group (Kreighbaum & Barthels, 1981; Patton & Mortensen, 1971). The stretched muscle will then stretch more fully and more easily (Patton & Mortensen, 1971). This response also facilitates contraction of the antagonist (Clarke, 1975; Kreighbaum & Barthels, 1981).

**Muscle Spindle**

The muscle spindle, located between the individual muscle fibers, is the second type of musculotendinous receptor (Kreighbaum & Barthels, 1981). This receptor responds to the stretch of the muscle fibers themselves rather than the stretch of the muscle tendon (Clarke, 1975; DeVries, 1980; Kreighbaum & Barthels, 1981; Mathews & Fox, 1976; Wells & Luttgens, 1976). Muscle spindles have a much lower threshold of response than the golgi tendon organs, and will respond to either passive or active stretch. This response is called the "stretch reflex". When the spindle becomes stretched, a discharge is evoked causing the muscle that was stretched to contract (Clarke, 1975; DeVries, 1980; Jensen & Fisher, 1972; Kreighbaum & Barthels, 1981). The amount and rate of contraction elicited from the stretch reflex is proportionate to the amount and rate of stretching (DeVries, 1980).
The muscle spindles also respond to the contraction of the muscle fibers, causing its antagonist to relax. This is called "reciprocal inhibition" (Clarke, 1975; Kreighbaum & Barthels, 1981; Wells & Luttgens, 1976). The antagonist muscles, therefore, remain relaxed and the agonists contract without opposition. Reciprocal inhibition operates automatically in movements elicited by the stretch reflex (DeVries, 1980; Jensen & Fisher, 1972). According to Wells and Luttgens (1976), not all investigators are in agreement with respect to the operation of reciprocal inhibition in volitional movements. Some believe muscles antagonist to each other contract concurrently under certain conditions (Moore & Hutton, 1978; Wells & Luttgens, 1976). Others believe that simultaneous contraction of opposing muscles, when it does occur, indicates poor skill. They support the idea that skillful performance is characterized by an absence of cocontraction of the opposing muscles (Wells & Luttgens, 1976).

Methods of Increasing Range of Motion

Numerous stretching techniques have been developed by the physical education profession and physical therapists to increase and maintain flexibility. These techniques include (a) ballistic methods, (b) static stretch methods, and (c) proprioceptive neuromuscular facilitation (PNF). The ballistic methods, commonly known as "bouncing stretches", use the momentum of the body segment to push the articulation past its present range of motion (Kreighbaum & Barthels,
1981). Static stretches can be categorized into two groups, passive or active stretch. Passive stretches use an external force, such as gravity, a wall, floor or partner, to slowly apply tension to the muscle to be stretched. This causes the muscle to be stretched beyond the actual range of motion. Active stretches require voluntary muscle contraction to move the joint to its maximal range. The muscle is stretched to the upper limits of the joint's normal range of motion. In both cases, the muscle is then maintained in the lengthened position for a set number of seconds. PNF procedures, originally designed for rehabilitation of paralytic patients, have been modified to facilitate normal subjects (Holt et al., 1970; Rivera, 1979). This method requires a contraction against an immovable force of the muscle to be stretched, relaxation of that muscle, followed by an immediate stretch of the same muscle (Holt et al., 1970; Houglum, 1975). Although passive stretch is used most often in the last phase of this procedure, some studies have also examined the use of an active stretch (Cornelius & Hinson, 1980; Hartley, 1980; Markos, 1972; Moore & Hutton, 1978).

The D'ROM exercises, developed by Bob Gajda (1982) of the Sports Performance and Rehabilitation Institute in Carol Stream, Illinois, are considered active static stretches because they utilize a contraction of the opposing muscle to pull the body segment through the range of motion. In addition, "terminal flicks" within the last 10-15 degrees of movement are executed to develop endurance at the terminal range where most injuries occur. D'ROM training emphasizes the development of the ability to actively control the joint through potential range of
motion. The program is designed to improve performance by increasing actual range of motion to the fullest potential range of motion, but not beyond anatomical possibilities. The exercises are based on the development of strength to carry the limbs to the upper limits of musculoskeletal range of motion in all joints rather than using an external object or the force of gravity to do so. D'ROM exercises are of a static nature because tension is slowly applied throughout the entire range of motion.

"High Risk" Stretching Exercises

Some of the popular passive stretch exercises are now believed to be detrimental to the collagenous tissues of the joints (Davis & Logan, 1961; Dominguez & Gajda, 1982; Rasche & Burke, 1978; Sapega et al., 1981). Using some external object or the force of a partner to move the limb through the range of motion, passive stretch often results in exceeding the capabilities of the ligaments, tendons, and muscles surrounding the joint. This places considerable force on the structures being stretched and increases the risk of injury at that joint. Ligaments tend to resist jerks and snaps, but will succumb to prolonged pressure (Dominguez & Gajda, 1982). Although an optimal level of flexibility has not yet been defined through research, investigators do agree that an extreme degree of flexibility may result in joint looseness (Davis & Logan, 1961; Dominguez & Gajda, 1982; Rasche & Burke, 1978; Sapega et al., 1981). Dominguez and Gajda (1982) warn that bending a joint beyond the ability to control it with
muscular strength risks either the tearing of the muscle, tendons or ligaments that support the joint, or damaging the joint surface itself through abnormal pressure placed upon the joint. The following hip exercises have been termed as "high risk" by Dominguez and Gajda (1982) and Sapega et al. (1981).

**Hurdler's Stretch.** Shelton campaigned for 30 years against the hurdler's stretch, claiming that it causes myofascial strain in the groin and laxity of the medial collateral ligaments of the knee (Dominguez & Gajda, 1982). The hurdler's stretch also puts enormous stress on the meniscus cartilage in the knee (Dominguez & Gajda, 1982).

**Toe Touches.** Standing toe touches, another common exercise for the hip joint, were studied by Floyd and Silver (1951) by use of electromyography (EMG). Recordings showed that in the fully flexed position, the erectores spinea were relaxed and it was concluded that ligaments alone were concerned with maintaining the position. They hypothesized that injury to the annulus fibrous was caused by excessive strain on the ligaments. Blackburn and Portney (1981), in studying the effects of Williams' flexion exercises, found similar results. An anterior pelvic tilt produced greater EMG activity than posterior tilt at all vertebral levels. Blackburn and Portney (1981) concluded that the use of standing and anterior pelvic tilt position should be avoided, especially in subjects with back problems. Sapega et al. (1981) also warned that the force of gravity pulling on the trunk places an
excessive load on the spine and lower back muscles. Dominguez and Gajda (1982) have claimed that both toe touches and the sit and reach exercise may stretch the posterior longitudinal ligament beyond its normal anatomical bounds, putting stress on the sciatic nerve.

**Ballet stretches.** Ballet stretches, in which force is applied after the leg has been extended at a 90 degree angle or greater, may also endanger the joint's stability (Dominguez & Gajda, 1982; Sapega et al., 1981). If the individual does not have a sufficient degree of flexibility to carry the leg through the obtained range, a substantial amount of pressure is put upon the ligaments. Ballet stretches can cause the sciatic nerve to stretch beyond its normal length which may cause sciatica or pyriformis syndrome, spasms of the pyriformis which irritate and pinch the sciatic nerve (Dominguez & Gajda, 1982).

**Effects of Receptors on Selected Range of Motion Exercises**

Investigators involved in flexibility research have reached diverse and conflicting conclusions in regard to the effect of the musculotendinous receptors on the various range of motion exercises. Although many studies have shown that both static and ballistic methods are effective in producing a significant increase in range of motion (Cureton, 1941; DeVries, 1962; Riddle, 1979), most researchers prefer the static stretch method because there is less danger of exceeding the extensibility limits of connective tissues, and energy requirements are
lower (DeVries, 1980; Jensen & Fisher, 1972; Mathews & Fox, 1976). In addition, the static stretches are most effective at implementing reciprocal inhibition (DeVries, 1980; Wilmore, 1977). Ballistic methods, because of the speed of the stretch, continually activate the stretch reflex (Aten & Knight, 1963; Jensen & Fisher, 1972; Kreighbaum & Barthels, 1981; Seavey, 1980). The intensity of the stretch reflex is much less for static stretch because the velocity of the stretch is reduced by slowly applying tension to the muscle. According to Schultz (1979), static stretch has two effects on the proprioceptive organ system: (a) depression of the monosynaptic response, thus reducing the stretch reflex, and (b) activation of the golgi tendon organs, further depressing large muscle tonicity.

PNF exercises have been described by Tanigawa (1972) as a method of promoting or hastening the response of the neuromuscular mechanism through stimulation of the proprioceptors. It is believed that maximally contracting the muscle, followed by a brief period of relaxation, will increase the muscle's range of motion. Recent findings, although inconclusive, have cast doubt on the lengthening reaction of a contracted muscle (Moore & Hutton, 1978). The tension in the contracted muscle activates reciprocal inhibition. It is believed this contraction also causes the golgi tendon organs to fire and autogenic inhibition, in turn, relaxes the muscle. No physiological information is available, however, as to how long this inhibition persists (Kreighbaum & Barthels, 1981; Tanigawa, 1972). Recent research suggests that PNF methods promote lingering facilitation of the muscle contracted,
resulting in stretch occurring with more tension in the muscle and
threatening a greater chance of injury (Beaulieu, 1981; Moore & Hutton,
1978). EMG studies have shown that for most subjects, the lowest
levels of innervation during passive stretch were attained by static
stretch (DeVries, 1980), although Moore and Hutton (1978) concluded
that complete relaxation is not required for effective stretch. In fact,
the study found greater gains in flexibility with the method producing
the greatest EMG activity.

Slow, mild stretch invokes reciprocal inhibition signaling a
muscle to relax so it can be stretched further safely (Beaulieu, 1981).
Static stretch also produces the least amount of tension (Moore &
Hutton, 1978). Seavey (1980) suggested that when the agonist and
antagonist are approximately equal in muscle mass, the principle of
reciprocal inhibition can be employed through PNF procedures to gain
maximum stretch. However, when the muscles are not equal in
strength, a long sustained stretch is best.

To date, no research has been published comparing any of the
three modes of stretching with D'ROM exercises. Jensen and Fisher
(1972) state that a dynamic type of range of motion exercise is
preferred over a passive stretch because it is more applicable to
performance. Dynamic flexibility is described as the range of motion
that occurs as a result of contraction of the muscles which control the
joint. The object of dynamic exercise is to increase the range through
which the body part can move by its own force (Dominguez & Gajda,
1982; Jensen & Fisher, 1972). Because D'ROM exercises are static in
nature, the velocity of the stretch reflex will be reduced to a minimum. Logan (1970) suggested that the opposing muscle should be actively contracted during the lengthening process to dampen the stretch reflex for the muscle being stretched. The contraction of the agonist muscle pulling the limb through the range of motion, elicits reciprocal inhibition which will simultaneously relax the antagonist muscle and thus aid in stretching. In addition, D'ROM exercises should share the advantages of the PNF procedures. As described earlier, the golgi tendon organs respond to tension produced by contraction of the associated muscle or to the contraction of the opposing muscle. Because D'ROM exercises utilize a contraction of the opposing muscle, autogenic inhibition will inhibit the contraction of the stretched muscle, allowing that muscle to be stretched to a greater degree. This same response will simultaneously enhance the contraction of the opposing group allowing the limb to be carried through a greater range as well. PNF exercises stress the importance of immediately following the initial contraction phase with the relaxation and stretch phases because it is unknown how long the golgi tendon response is in effect (Kreighbaum & Barthels, 1981; Tanigawa, 1972). This does not need to be of concern with the D'ROM exercises since contraction and stretch occur simultaneously. Moore and Hutton (1978) found greater EMG activity and a greater increase in range of motion when an agonist contraction (opposite of the muscle to be stretched) was utilized after the relaxation phase. Theoretically, voluntary activation of the quadriceps promotes additional reciprocal inhibition of the hamstrings (Moore &
Hutton, 1978; Patton & Mortensen, 1971). It was also hypothesized that the agonist contraction may have produced a larger total hip flexion torque (Moore & Hutton, 1978).

**Review of Related Studies on Range of Motion Exercises**

Numerous studies have been conducted to compare the effectiveness of ballistic, static and PNF methods to increase flexibility. Ballistic methods have shown significant increases in range of motion (Bridell, 1969; DeVries, 1962; Tweitmeyer, 1972; Weber & Kraus, 1949). Static stretch programs significantly increased flexibility as well (Bridell, 1969; DeVries, 1962; Holt et al., 1970; McCue, 1953; Tweitmeyer, 1972). Little evidence has been presented by researchers to indicate any significant difference in increased range of motion obtained by using either static or ballistic techniques. Weber and Kraus (1949) concluded that ballistic methods were 200% more effective in stretching the hamstring muscles and 100% more effective in stretching the back-hamstring-soleus muscle group. No significant difference was found between the two methods or a combination of the two methods in research conducted by DeVries (1962), Liverman (1970), Long (1971), Riddle (1956), and Tweitmeyer (1972), although all methods significantly increased range of motion.

In addition to comparing the effects of static stretch and ballistic stretch on range of motion at the hip joint, Liverman (1970) also studied the effects of increased flexibility on the development of
power in the lower limbs. Increased joint mobility did not deter the development of power in the lower limbs; in fact, a definite trend toward an increase in power was noted when flexibility was increased.

Minimal documentation and research exists regarding neuromuscular facilitation as it relates to range of motion training for athletes (Houglum, 1975). Conflicting results have been found among seven studies. Holt et al. (1970) compared the effects of ballistic, static stretch, and a modified PNF technique. The investigators administered the three treatments to all groups (N=24) in different orders to control for treatment order effect. PNF was found to have significantly greater mean gains than the ballistic and static methods.

Moore and Hutton (1978) studied the effects of three types of hamstring exercises on female gymnasts (N=21): (a) a modified PNF technique called "contract-relax", (b) a modified PNF technique called "contract-relax" with agonist contraction (CRAC), and (c) a passive static stretch. All subjects performed each of the three methods to produce hamstring stretch while being examined through electromyography. EMG recordings indicated greater hamstring activity with the CRAC exercises. This technique produced the largest gains in hip flexion. It was concluded that the CRAC method caused cocontraction in the stretched muscle, and that complete relaxation was not required for active stretch.

Tanigawa (1972) compared PNF procedures (hold and relax) to passive stretch in the mobilization of tight hamstring muscles for male subjects (N=30). PNF procedures resulted in significantly greater
increases in range of motion and at a faster rate. A number of subjects reported pain when passive mobilization was applied. It was concluded that a pain stimulus can produce a reflex spasm of the local muscle and cause it to shorten; thus, the response may prevent further gain in range of motion.

Rivera (1979) compared static, ballistic, and PNF exercises and found a significant difference between the PNF and static techniques and the ballistic methods in mean gains of range of motion and in retention of flexibility. However, no significant difference was found between the PNF and static stretch procedures.

Hartley (1980) studied the effect of six stretching methods on range of motion and strength gain of the hip joint of women. Three passive methods, two active methods, and one method combining passive and active stretch were used. The techniques included: (a) ballistic and hold, (b) active PNF, (c) passive PNF, (d) prolonged static stretch, (e) passive stretch and active hold, and (f) relaxation. Subjects (N=119) exercised three days per week for three weeks, approximately 10 minutes per day. All groups showed significant gains in flexibility. No differences were found among groups; therefore, no difference was found between PNF and ballistic methods, or between active and passive stretch. There was no significant difference among groups in hip strength gain which did not support the hypothesis that active methods would have greater improvements in strength gain over passive methods. Strength was measured with a cable tensiometer with the leg at a 45 degree angle. Hartley (1980) considered the possibility
that measuring hip strength at a 45 degree angle was not appropriate, and that actual strength gains may have taken place at a different position.

Markos (1979) examined the effects of two PNF techniques on increasing range of hip flexion of women. Subjects (N=30) were divided into contract-relax, hold-relax, and control groups. Both PNF techniques were applied at the point of limitation of the range of motion and required active resisted contraction. The contract-relax group used an isontonic contraction, and the hold-relax group used an isometric contraction. Increases in range of motion in the contract-relax group were significantly greater than in the hold-relax and control groups.

Cornelius and Hinson (1980) examined the influence of maximum voluntary isometric contraction of the hip extensors on its subsequent extensibility. College-age males (N=30) were measured for passive flexibility of the hip joint following six different treatments, all of which were preceded by a passive flexibility maneuver of the agonist: (a) control, (b) concentric contraction of the antagonist, (c) three second isometric contraction of the agonist, (d) three second isometric contraction of the agonist and concentric contraction of the antagonist, (e) six second isometric contraction of the agonist, and (f) six second isometric contraction of the agonist and concentric contraction of the antagonist. The control group differed significantly from mean scores recorded during the other five treatments. No other significant differences were noted. A maximum voluntary isometric
contraction used prior to a flexibility maneuver was found to influence subsequent extensibility.

**Measurement Instruments for Flexibility and Strength**

**Range of Motion Measurements**

Of the instruments to measure flexibility, a device called the flexometer has had the most general acceptance in physical education and related areas. The instrument was designed by Leighton (1955) to measure movement of body segments in degrees. The Research Council of the Association for Health, Physical Education and Recreation found the flexometer more nearly met the following criteria than any other instrument: (a) the units of measurement are universal, (b) the measurement is not affected by the length of body segments, (c) conformity to the structure of the body segment is not required, and (d) the instrument is applicable to the flexibility measures of all segments (Montoye, 1978). Because the flexometer eliminates the concern of establishing the true axis of motion within the joint, error due to inaccurate placement is eliminated (Lusin, Gajdosik & Miller, 1979). The flexometer is considered an objective, reliable and valid instrument for measuring joint motion (Harris, 1969; Leighton, 1955; Lusin et al., 1979; Montoye, 1978; Mathews & Fox, 1976). Leighton (1955) derived a correlation coefficient between .913 - .966 for each of 30 measures taken on 120 boys. Investigators have reported the following reliability coefficients of 30 different measures: .911 - .972
(Hupperich, 1950), .916 - .997 (Grey, 1955), .929 - .988 (Laubach & McConville, 1966), and .901 - .983 (Forbes, 1950).

It is recognized that problems such as standardization of procedures still exists (Montoye, 1978). Odgers (1969), in an attempt to make the procedures more standard, modified Leighton's test for hip flexion and hip extension by strapping the thighs of his subjects to a table to help immobilize the hip and knee joints. Van Anne (1962) placed the flexometer on the lateral side of the ankle, rather than at waist level, in an attempt to measure hip flexion. Instead of having the subject bend forward at the waist as described by Leighton (1955), the subject took a supine position on a table and flexed the hip by raising the right leg. A reliability coefficient of .93 was reported by Van Anne (1962) in her pilot study of 30 subjects. Hartley (1980) measured hip flexibility with Leighton's flexometer with subjects in a supine position on the floor. The left leg was stabilized with a strap at mid-thigh, and the right leg was splinted straight with a wood slat. The flexometer was attached to the proximal end of the splint on the lateral side of the right thigh. Moore and Hutton (1978), using the same supine position, used a Bike cartilage brace to stabilize the knee of the raised leg and a strap securing the opposite thigh to the table to stabilize the pelvis. They found this technique of knee and hip stabilization to be effective and reliable when taking measurements with an electrogoniometer and potentiometer. Munns (1978) took five measures at each joint using the flexometer, and found that repeated trials did not show significant improvement, thus, disregarding the possibility of a learning effect with repeated measures.
**Strength Measurements**

In 1952, Clarke (1970) introduced the cable tensiometer as an instrument to measure static strength at specified angles in the major joint actions of the body. The tensiometer was adapted from an instrument designed to measure the tension of aircraft cable. The tensiometer has a cable which is attached to the testing table and to the part of the body to be measured. This cable passes through the tensiometer which measures the amount of tension on the cable. As the subject applies force against the cable by means of an isometric contraction, the tensiometer registers the amount of force exerted. The tension is then converted into pounds using a calibration chart.

Clarke (1959) compared the effectiveness of the cable tensiometer, the Wakim-Porter strain gauge, the spring scale and the Newman myometer for recording strength. The cable tensiometer had the greatest precision for measuring strength as reflected by objectivity coefficients of .90 and above. An objectivity coefficient of .90 was reported for the hip flexion test.

**Summary of Related Literature**

One of the principle sources of resistance at the normal extremes of joint motion is connective tissue, which is most easily modifiable through training and the primary target of range of motion exercises. Range of motion may be increased by either decreasing the resistance of soft tissue or increasing the strength of the opposing muscle.
The golgi tendon organ and the muscle spindles are receptors that respond to the stretch of muscle fibers and muscle tendons. The golgi tendon organ responds with a process called "autogenic inhibition" which inhibits the contraction of the stretched muscle. The muscle spindles respond with the "stretch reflex", which causes the muscle that was stretched to contract. The muscle spindles also respond to the contraction of muscle fibers, causing its antagonist to relax.

The three most common methods for increasing range of motion include ballistic, static, and PNF methods. D'ROM exercises have recently been designed, in addition to these methods, and are considered an active static stretch. The hurdler's stretch, toe touches, sit and reach exercise, and ballet stretches are all passive hip flexibility exercises that have been termed as "high risk" exercises. Ballistic methods are thought to activate the stretch reflex while static stretches reduce the stretch reflex and activate the golgi tendon organ. PNF exercises are believed to activate reciprocal inhibition although no information is available as to how long this inhibition persists. Conflicting evidence indicates that static stretch produces the lowest levels of innervation, yet it is believed that complete relaxation is not required for effective stretch.

In comparing the effectiveness of the three common modes of increasing flexibility, both static and ballistic methods significantly increased range of motion in studies comparing the two methods. Studies designed to compare the effects of all three methods of stretch resulted in conflicting conclusions ranging from no significant
differences among groups, to PNF and static methods significantly increasing flexibility over ballistic methods, and finally to PNF procedures being superior to both static and ballistic methods. In studies comparing active PNF to passive PNF procedures, results once again differed, with no difference found between procedures in contrast to active methods being significantly better than passive methods. To date, no studies have been conducted to study the effects of the D'ROM exercises, or to compare the D'ROM exercises with any of the accepted modes of increasing range of motion.
CHAPTER 3

METHODS AND PROCEDURES

The purpose of the study was to compare two methods for increasing range of motion. The methods and procedures used in the research have been organized accordingly:

1. Subjects.
2. Technique for measurement of flexibility.
3. Technique for measurement of strength.
4. Data collection.
5. Explanation of treatments.

Subjects

One hundred and nine college-age male and female students enrolled in P.E. 100 social dance classes at South Dakota State University consented to partake in this investigation. One hundred and one subjects participated in the exercises sessions as well as the pretest and posttest measurement sessions. Eight subjects were lost throughout the course of the study. Two subjects were injured in activities not associated with the class or exercises, two subjects were excluded from further participation due to absences, and three subjects
did not attend the posttest measurement session. Any subject missing two or more exercise sessions was dropped from the study.

Three sections of the social dance classes were randomly assigned to one of three groups: (a) D'ROM, composed of 16 females and 16 males, (b) static stretch, composed of 16 females and 18 males, and (c) control, composed of 17 females and 18 males. An informed consent was required of all participants (see Appendix A).

**Technique for Measurement of Flexibility**

Van Anne's (1962) modification of Leighton's procedures in measuring hip flexion was followed. With the subject in a supine position on a table, the flexometer was placed on the lateral side of the ankle of the right leg. The subject was placed on the table so that the ankles were extended past the end of the table, preventing the flexometer from touching the table during measurements. A knee splint with velcro closures was applied to the right leg to hold the knee in passive extension. The left thigh was strapped securely to the table to stabilize the pelvis. Once the instrument was secured, the dial was locked. The subject was then instructed to flex the hip as completely as possible. At the uppermost range of movement, the pointer was locked into position. The reading was taken to the nearest degree and the measurement was recorded. This procedure was repeated three times for each subject. The average of three trials was used as the measurement for analyses.
Technique for Measurement of Strength

The cable tensiometer, as described by Clarke (1970), was used for the hip strength tests. The cable tensiometer was calibrated by the investigator preceding pretest measurements, midway through pretest measurements, and preceding posttest measurements. Hip flexion was measured according to Clarke's (1970) procedures. The subject assumed a supine position on the testing table, with the left knee extended on the table. The right knee was extended over the table slit with the strap around the lower third of the thigh. The pulling assembly was hooked to the strap attached beneath the subject through the slit on the table. The subject's arms were folded on the chest, and the assistant braced the shoulders of the subject to prevent lifting of the upper body. The proper chain link was selected so that the cable was taut. The trigger of the tensiometer was then opened and placed between the two sectors of the riser. The trigger was closed and held in the hand of the investigator while testing. The subject was instructed to pull on the cable as much as possible while attempting to flex the hip. A reading was taken to the nearest unit of measurement and recorded. The pointer was then returned to zero. This procedure was repeated three times for each subject. The unit of measurement was converted to pounds for each of the trials using a calibration chart. The average of the second and third trial was used as the measurement for analyses.
Data Collection

A pilot study was conducted prior to the pretest to standardize methodology and determine the number of trials required for reliable strength measurement. Fifteen subjects were measured according to the procedures described previously for the flexometer and cable tensiometer, with the exception of the placement of the left leg for the strength test. Subjects were instructed to flex the hip and knee of the left leg comfortably with the foot resting on the table. In this position, subjects were able to push against the table with the left foot, resulting in a lifting of the hips and a greater strength measurement. It was concluded that using an extended position for the left knee reflected a truer measurement of hip flexion strength of the right leg.

The cable tension test was repeated for five trials to determine if a decrease in measurement occurred with subsequent trials due to fatigue. The first trial resulted in a significantly lower measurement than the other four trials. Trials two and three in the pilot study were the most consistent with an intraclass correlation coefficient of .976. The mean square within subjects was used as the error term in calculating the coefficient. Therefore, three trials were used for the strength pretest and posttest with the first trial being disregarded, and the mean of the second and third trials being used in all analyses.
During the pretest and posttest 29 subjects, 10 from the static group, 10 from the control group, and nine from the D'ROM group, were randomly selected to be tested twice in order to establish test-retest reliability. Fifteen of the 29 subjects were randomly chosen to be tested for the pretest on two consecutive days. The other 14 subjects were tested on two consecutive days during the posttest. An intraclass correlation coefficient was computed, as before, to determine reliability. As shown in Tables 1 and 2, a reliability coefficient of .875 was found for flexibility measures during the pretest, and a reliability of .969 was found for pretest strength measures. A .987 reliability coefficient was computed for posttest flexibility measures, along with a reliability coefficient of .790 for the posttest strength measures.

### TABLE 1
Pre Test-Retest Reliability Measures

<table>
<thead>
<tr>
<th>Measure</th>
<th>Mean</th>
<th>SD</th>
<th>n</th>
<th>Reliability</th>
</tr>
</thead>
<tbody>
<tr>
<td>First Day Flexibility</td>
<td>87.60</td>
<td>10.66</td>
<td>15</td>
<td>.875</td>
</tr>
<tr>
<td>Second Day Flexibility</td>
<td>93.75</td>
<td>11.14</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>First Day Strength</td>
<td>95.34</td>
<td>43.20</td>
<td>15</td>
<td>.969</td>
</tr>
<tr>
<td>Second Day Strength</td>
<td>95.11</td>
<td>40.61</td>
<td>15</td>
<td></td>
</tr>
</tbody>
</table>

**Note.** Mean square within subjects was used as the error term in the computation of the intraclass reliability coefficient. Flexibility measures are reported in degrees of flexion. Strength measures are reported in pounds exerted. Different groups of subjects were used in the pre and post test-retest.
<table>
<thead>
<tr>
<th>Measure</th>
<th>Mean</th>
<th>SD</th>
<th>n</th>
<th>Reliability</th>
</tr>
</thead>
<tbody>
<tr>
<td>First Day Flexibility</td>
<td>87.40</td>
<td>12.96</td>
<td>14</td>
<td>.987</td>
</tr>
<tr>
<td>Second Day Flexibility</td>
<td>87.59</td>
<td>13.41</td>
<td>14</td>
<td></td>
</tr>
<tr>
<td>First Day Strength</td>
<td>102.16</td>
<td>29.97</td>
<td>14</td>
<td>.790</td>
</tr>
<tr>
<td>Second Day Strength</td>
<td>97.37</td>
<td>23.30</td>
<td>14</td>
<td></td>
</tr>
</tbody>
</table>

**Note.** Mean square within subjects was used as the error term in the computation of the intraclass reliability coefficient. Flexibility measures are reported in degrees of flexion. Strength measures are reported in pounds exerted. Different groups of subjects were used used in the pre and post test-retest.

The testing procedures used for all pretest and posttest measurements were as follows: (a) all subjects were given an explanation and demonstration of the testing procedure; (b) all measurements were taken by the investigator on the subject's right side; (c) three trials were used in measuring both hip flexion and hip strength; (d) the flexibility test for hip flexion was proceeded by the hip flexion strength test; (e) no warm-up exercises were allowed, and the temperature of the room was held constant for all subjects; and (f) a graduate student assisted in stabilizing the shoulders of subjects during the strength test, and in recording all measurements.
Explanation of Treatment

All subjects were measured for range of motion and strength during the week preceding the 1982 spring break. The treatment phase began the second week after spring break, and consisted of seven weeks of range of motion exercises. The control group did not partake in any of the designated exercises. There were two exercise sessions per week, with each session consisting of approximately five minutes of range of motion exercises. All instructions for the exercises were taped and played at the beginning of the class period. A metronome, set at 46 beats per minute, was used in constructing the tape, so that all exercises were synchronized within groups and between groups. The posttest was completed within the final week of the spring semester.

D'ROM Treatment

The D'ROM group performed two hip flexion exercises, as described by Gajda (1982). The first hip flexion exercise required the subject to lie in a supine position and to raise one leg at a time by flexing the hip as completely as possible. Both knees were locked with the hands folded over the abdomen throughout the exercise. The second hip flexion exercise was performed in a side-lying position. The subject was allowed to rest the head on the extended arm against the floor. The opposite arm was used to stabilize the body during the exercise by planting the palm of the hand against the floor in front of
the chest. The upper leg was flexed at the hip as completely as possible, raising the leg toward the shoulders. Again, both knees were kept locked throughout the exercise. Both exercises were performed to the following counts given on the tape: Raise 2, 3, 4 and hold 2, 3, 4 and lower 2, 3, 4. On the fifth repetition, ten flicks were performed in which the subject quickly flicked the leg within the last 10-15 degrees of movement. The counts given for the fifth repetition were: Raise 2, 3, 4 and flick 2, 3, 4, 5, 6, 7, 8, 9, 10 and lower 2, 3, 4.

**Static Treatment**

The static group performed two hip flexion exercises, as described by Anderson (1980). During the first exercise, the subject assumed a sitting position with one leg extended and the other flexed with the sole of the foot against the thigh of the extended leg. Subjects were instructed to keep the knee of the extended leg locked, and to keep the back straight. Both hands were allowed to reach toward the foot of the extended leg, but contact with the leg or foot was prohibited. The second exercise required the subject to sit with both legs extended and a comfortable distance apart. Again, the subject slowly bent forward from the hips toward the foot of the extended leg, with both knees locked, back straight, and hands reaching toward the extended foot. The static stretch exercises were performed to the following counts: Lower 2, 3, 4 and hold 2, 3, 4 and up 2, 3, 4. Each exercise was repeated five consecutive times for each side of the body, beginning with the right side.
**Control Group**

The control group did not participate in the treatment phase, and was only involved in the pretest and posttest measurements of hip flexibility and hip strength.

**Statistical Analyses**

The Statistical Package for the Social Sciences (SPSS) at South Dakota State University was used to analyze all data (Nie, Hull, Jenkins, Steinbrenner & Bent, 1975). The two criterion variables, hip flexibility and hip strength, were each analyzed by a two-way ANOVA where the independent variables were sex and treatment. SPSS subprogram ANOVA (option 9) was used in the analysis of variance. The criterion values were determined by calculating the difference between pre and posttest scores for flexibility and strength, respectively (Campbell & Stanley, 1966; Kenny, 1975; Kirk, 1968; Lindman, 1974). Tukey's HSD test was calculated to test all pairwise comparisons. A probability level of $p<.05$ was established as the significance level for all analyses.

Correlation coefficients were calculated for all groups between posttest flexibility and posttest strength measures, and between flexibility gains scores and strength gain scores. A t-test for the difference between correlation coefficients was proposed to test the relationship between the D'ROM group and the static group, and the difference between the pooled D'ROM-static group and the control
group. Preliminary examination of descriptive statistics indicated males and females responded differently to treatment. Therefore, a decision was made to calculate partial correlation coefficients controlling for sex. A more detailed explanation is given in chapter 4.
CHAPTER 4

RESULTS AND DISCUSSION

The purpose of this investigation was to compare the effects of static stretch exercises and D'ROM exercises on flexibility and strength of the hip joint. The relationship between hip flexibility and hip strength was also examined. University students (N=101) were divided into three groups: (a) static, composed of 34 subjects, (b) D'ROM, composed of 32 subjects, and (c) control, composed of 35 subjects.

Hip flexibility and hip strength were the two criterion variables measured. Each criterion variable was analyzed by a two-way analysis of variance where sex and treatment were the factors of a 2 x 3 factorial design. Gain scores of both flexibility and strength were used in the calculations of each analysis. Tukey's HSD test was utilized to test all pairwise comparisons with a p<.05 significance level used for all comparisons. Zero-order and partial correlation coefficients, controlling for sex, were calculated for each group between hip flexibility and hip strength of pretest, posttest, and gain score measures.

Analysis of the data and summary of the results are presented in four sections: (a) hip flexibility, (b) hip strength, (c) relationship between hip flexibility and hip strength, and (d) discussion of the results.
Flexibility

The descriptive statistics for gain scores of flexibility measures are presented in Table 3. As indicated, the D'ROM group had the greatest increases between pre and posttest measures of flexibility with a mean gain of 9.37 degrees (SD=7.01). The control group increased flexibility by 1.50 degrees (SD=6.52), and the static group had the least increase in flexibility with a mean gain score of 1.07 degrees (SD=8.39). Males across groups had slightly greater gain scores in flexibility with 3.96 degrees (SD=8.18) as the mean gain score compared to a gain of 3.73 degrees (SD=8.30) for females across groups.

The results of the two-way ANOVA for mean gain scores are presented in Table 4. No significant interaction was reported between sex and treatment; F(2,95)=1.06, p>.05. A significant difference was found among groups for the flexibility mean gain scores; F(2,95)=13.15, p<.001. No significant difference was found between sexes; F(1,95)=.09, p>.05.

Tukey's HSD test revealed a significant difference between flexibility gain scores for the D'ROM group with an increase of 9.37 degrees, and the static group with an increase of 1.07 degrees. A significant difference also as well, between the static group and control group with occurred between the D'ROM group and the control group which had a gain of 1.50 degrees. No significant difference was found between the static group and the control group, with gain scores of 1.07 degrees and 1.50 degrees, respectively.
### TABLE 3
Means and Standard Deviations for Pretest, Posttest, and Gain Scores of Flexibility Measures

<table>
<thead>
<tr>
<th>Group</th>
<th>Pre Mean</th>
<th>Pre SD</th>
<th>Post Mean</th>
<th>Post SD</th>
<th>Gain Mean</th>
<th>Gain SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>D'ROM females</td>
<td>84.82</td>
<td>13.58</td>
<td>94.19</td>
<td>13.19</td>
<td>9.37</td>
<td>7.01</td>
</tr>
<tr>
<td>females n=16</td>
<td>90.18</td>
<td>10.44</td>
<td>98.39</td>
<td>12.13</td>
<td>8.21</td>
<td>6.68</td>
</tr>
<tr>
<td>males n=16</td>
<td>79.46</td>
<td>14.51</td>
<td>89.99</td>
<td>13.21</td>
<td>10.53</td>
<td>7.34</td>
</tr>
<tr>
<td>Static females</td>
<td>86.32</td>
<td>15.98</td>
<td>87.39</td>
<td>16.16</td>
<td>1.07</td>
<td>8.39</td>
</tr>
<tr>
<td>females n=16</td>
<td>90.52</td>
<td>13.99</td>
<td>90.77</td>
<td>15.80</td>
<td>0.25</td>
<td>10.06</td>
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<tr>
<td>males n=18</td>
<td>82.59</td>
<td>17.08</td>
<td>84.39</td>
<td>16.31</td>
<td>1.80</td>
<td>6.79</td>
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<tr>
<td>Control females</td>
<td>84.60</td>
<td>10.72</td>
<td>86.10</td>
<td>11.31</td>
<td>1.50</td>
<td>6.52</td>
</tr>
<tr>
<td>females n=17</td>
<td>83.78</td>
<td>12.19</td>
<td>86.58</td>
<td>12.72</td>
<td>2.80</td>
<td>6.05</td>
</tr>
<tr>
<td>males n=18</td>
<td>85.37</td>
<td>9.42</td>
<td>85.65</td>
<td>10.61</td>
<td>0.28</td>
<td>6.88</td>
</tr>
<tr>
<td>Females across</td>
<td>88.07</td>
<td>12.44</td>
<td>91.80</td>
<td>14.22</td>
<td>3.73</td>
<td>8.30</td>
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<td>groups n=49</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Males across</td>
<td>82.59</td>
<td>13.95</td>
<td>86.55</td>
<td>13.42</td>
<td>3.96</td>
<td>8.18</td>
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<td></td>
<td></td>
<td></td>
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<td></td>
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</tbody>
</table>

Note. All measures are reported in degrees of flexion.
TABLE 4
Analysis of Variance Table for Flexibility Gain Scores

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex</td>
<td>5.09</td>
<td>1</td>
<td>5.09</td>
<td>0.09</td>
</tr>
<tr>
<td>Group</td>
<td>1431.67</td>
<td>2</td>
<td>715.84</td>
<td>13.15*</td>
</tr>
<tr>
<td>Sex by Group</td>
<td>115.55</td>
<td>2</td>
<td>57.77</td>
<td>1.06</td>
</tr>
<tr>
<td>Residual</td>
<td>5171.45</td>
<td>95</td>
<td>54.44</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>6720.65</td>
<td>100</td>
<td>67.21</td>
<td></td>
</tr>
</tbody>
</table>

* p<.05

**Hip Strength**

The descriptive statistics for gain scores of strength, presented in Table 5, indicate that the D'ROM group had the greatest gains in strength with a mean gain score of 18.23 pounds (SD=22.03). The static group had the next greatest increase in strength with 9.92 pounds (SD=22.66), while the control group increased strength by 5.19 pounds (SD=13.36). Females had a greater increase in strength than males with mean gain scores of 16.01 (SD=22.56) and 6.11 (SD=20.16), respectively.

The results of the two-way ANOVA for strength are presented in Table 6. No significant interaction was reported between sex and treatment; F(2,95)=.01, p>.05. A significant difference was found among groups; F(2,95)=3.16, p<.05, and sexes; F(1,95)=5.39, p<.02. Females increased strength significantly more than males with a mean gain score of 16.01 pounds as compared to a score of 6.11 pounds for males.
### TABLE 5
Means and Standard Deviations for Pretest, Posttest, and Gain Scores of Strength Measures

<table>
<thead>
<tr>
<th>Group</th>
<th>Pre Mean</th>
<th>Pre SD</th>
<th>Post Mean</th>
<th>Post SD</th>
<th>Gain Mean</th>
<th>Gain SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>D'ROM</td>
<td>92.09</td>
<td>29.71</td>
<td>110.32</td>
<td>31.28</td>
<td>18.23</td>
<td>22.03</td>
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<tr>
<td>females n=16</td>
<td>76.79</td>
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<td>100.25</td>
<td>33.68</td>
<td>23.45</td>
<td>26.09</td>
</tr>
<tr>
<td>males n=16</td>
<td>107.39</td>
<td>29.96</td>
<td>120.39</td>
<td>25.74</td>
<td>13.00</td>
<td>16.26</td>
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<td>Static</td>
<td>87.53</td>
<td>31.95</td>
<td>97.45</td>
<td>30.94</td>
<td>9.92</td>
<td>22.66</td>
</tr>
<tr>
<td>females n=16</td>
<td>67.42</td>
<td>21.87</td>
<td>82.11</td>
<td>30.84</td>
<td>14.69</td>
<td>16.87</td>
</tr>
<tr>
<td>males n=18</td>
<td>105.41</td>
<td>28.99</td>
<td>111.09</td>
<td>24.51</td>
<td>5.68</td>
<td>26.55</td>
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<tr>
<td>Control</td>
<td>92.06</td>
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<td>97.25</td>
<td>33.62</td>
<td>5.19</td>
<td>13.36</td>
</tr>
<tr>
<td>females n=17</td>
<td>67.63</td>
<td>17.18</td>
<td>77.87</td>
<td>29.88</td>
<td>10.24</td>
<td>23.01</td>
</tr>
<tr>
<td>males n=18</td>
<td>115.14</td>
<td>29.53</td>
<td>115.55</td>
<td>26.28</td>
<td>0.41</td>
<td>14.21</td>
</tr>
<tr>
<td>Females across groups n=49</td>
<td>70.55</td>
<td>20.12</td>
<td>86.56</td>
<td>32.33</td>
<td>16.01</td>
<td>22.56</td>
</tr>
<tr>
<td>Males across groups n=52</td>
<td>109.39</td>
<td>29.21</td>
<td>115.50</td>
<td>25.30</td>
<td>6.11</td>
<td>20.16</td>
</tr>
</tbody>
</table>

**Note.** All measures are reported in pounds exerted.

The Tukey procedures, using the mean gain scores for strength in pairwise comparisons, revealed a significant difference between the D'ROM group and the control group with the mean gain scores being 18.23 and 5.19 pounds, respectively. No significant difference resulted between the scores of 18.23 pounds and 9.92 pounds.
TABLE 6
Analysis of Variance Table for Strength Gain Scores

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>SS</th>
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<th>MS</th>
<th>F</th>
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<td>3.16*</td>
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<td>4.32</td>
<td>0.01</td>
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<tr>
<td>Residual</td>
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<td>95</td>
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<td>47624.14</td>
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<td>476.24</td>
<td></td>
</tr>
</tbody>
</table>

* p<.05

for the D'ROM and the static group. No significant difference occurred, as well, between the static group and control group with mean gain scores of 9.92 and 5.19 pounds, respectively.

**Relationship Between Hip Flexibility and Hip Strength**

Correlation coefficients were computed for all groups between hip flexibility and hip strength of pretest, posttest, and gain score measures. In addition, correlation coefficients were computed for the pooled D'ROM-static group. A t-test was to be conducted to test the difference between correlation coefficients of the D'ROM group and the static group, as well as the difference between the pooled D'ROM-static group and the control group. After noticing the difference in measures of males and females from examination of descriptive statistics, the decision was made to control for sex and calculate partial correlation.
coefficients. The resulting data from these calculations, along with the significant difference found between sexes for strength measures, invalidated the proposed use of the t-test. Zero-order and partial correlation coefficients controlling for sex of pretest, posttest, and gain score measures are presented in Table 7.

**TABLE 7**

Zero-order and Partial Correlation Coefficients of Hip Flexibility and Strength Measures

<table>
<thead>
<tr>
<th>Group</th>
<th>Pretest Measures</th>
<th>Posttest Measures</th>
<th>Gain Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Zero</td>
<td>Partial</td>
<td>Zero</td>
</tr>
<tr>
<td>D'ROM</td>
<td>-.021</td>
<td>.242</td>
<td>-.385*</td>
</tr>
<tr>
<td>n=32</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Static</td>
<td>.316</td>
<td>.605*</td>
<td>.172</td>
</tr>
<tr>
<td>n=34</td>
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<tr>
<td>Control</td>
<td>.262</td>
<td>.297</td>
<td>.117</td>
</tr>
<tr>
<td>n=35</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pooled D'ROM-static</td>
<td>.168</td>
<td>.438*</td>
<td>-.021</td>
</tr>
<tr>
<td>n=66</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* p<.05

Zero-order and partial correlation coefficients of pretest measures resulted respectively in -.021 and .242 for the D'ROM group, .316 and a significant .605 (p<.05) for the static group, .262 and .297 for the control group, and .168 and a significant .438 (p<.05) for the pooled D'ROM-static group. Posttest zero-order and partial correlations resulted in coefficients of a significant -.385 (p<.05) and .312 for the
D'ROM group, .172 and .309 for the static group, .117 and .172 for the control group, and -.021 and .087 for the pooled D'ROM-static group, respectively. The results of calculations of zero-order and partial correlation coefficients of gain score measures are respectively .012 and .005 for the D'ROM group, .058 and .079 for the static group, .098 and .050 for the control group, and .122 and .147 for the pooled D'ROM-static group.

**Discussion of the Results**

The results of the two-way ANOVA and Tukey procedures revealed the D'ROM group had significantly greater gains in flexibility than the static group or control group. The D'ROM group also had greater gains in strength than the control group. Although no significant difference resulted between the D'ROM group and the static group in strength gain, the D'ROM group increased strength by 18.23 pounds as compared to 9.92 pounds for the static group. The D'ROM exercises involve active stretching of the joint in which the muscles opposite to those to be stretched, the hip flexors, are contracted to pull the segment through the range of motion. The static exercises involve passive stretching where the external force of the floor is used to move the joint to its maximal range. Hartley (1980) described two ways to increase range of motion: (a) by decreasing the resistance of the soft tissues surrounding the joint, or (b) increasing the strength of the opposing muscle. Passive stretch primarily decreases the
resistance of soft tissue, while active stretch primarily increases the strength of the opposing muscles. Although Hartley (1980) found no significant differences among groups in studying the effects of active and passive stretch on hip flexibility, the results of this study seem to indicate that increasing the strength of the opposing muscle group does effectively increase range of motion over a method designed primarily to decrease resistance of the soft tissues. It may also be possible that the D'ROM exercises decrease the resistance of the soft tissues as well. This decreased resistance may have occurred if the exercises were able to effectively utilize the musculotendinous receptors during stretch. Moore and Hutton (1978) and Patton and Mortensen (1971) contend that a voluntary activation of the quadriceps promotes additional reciprocal inhibition of the hamstrings. The contraction of the quadriceps during the D'ROM exercises could have caused the hamstrings to stretch further without inhibition. Logan (1970) maintains that the opposing muscle should be actively contracted during the lengthening process to dampen the stretch reflex. Once again, the contraction of the quadriceps during the D'ROM exercises may dampen the stretch reflex which can cause a stretched muscle to contract. Kreighbaum and Barthels (1981) stated that the golgi tendon organ is more sensitive to stretch caused by contraction than to passive stretch. The golgi tendon organ, then, would fire more readily in active stretch, utilized by the D'ROM group, as compared to passive stretch, utilized by the static group.
The results of the study support the findings of Moore and Hutton (1978) and Cornelius and Hinson (1980) in comparing active procedures to passive procedures. Moore and Hutton (1978) found greater increases in range of motion when a contraction of the quadriceps was used after the relaxation phase of PNF procedures as compared to passive PNF procedures. Cornelius and Hinson (1980) also reported significantly greater increases in range of motion when a voluntary contraction was used prior to stretch during hip extension.

The fact that the static group did not increase flexibility significantly better than the control group was not supported by other research reviewed for this study. DeVries (1962), Liverman (1970), Long (1971), Riddle (1956), Rivera (1979), and Tweitmeyer (1972) all found static exercises to significantly increase range of motion. A tentative explanation may be that the treatment phase of the present study consisted of exercising only two times per week where other studies exercised subjects three times per week. Exercising twice a week may not have been sufficient enough to result in any significant increases of flexibility for the static group, although the results indicate the time was sufficient for significant increases for the D'ROM group.

The fact that the D'ROM group had greater gains in strength, although not significant, over the static group is not surprising. The D'ROM group used a concentric contraction to raise the leg, an isometric contraction to hold the leg in flexion, and an eccentric contraction to lower the leg to the floor. The static group used the
force of the resistance of the floor to bend toward the extended leg, rather than actively moving the leg through the range of motion. Hartley (1980), expecting to find significant increases in strength with active stretch as compared to passive stretch, reported no significant differences among groups in strength gain. Strength of hip flexion was measured at a 45 degree angle rather than a 90 degree angle as suggested by Clarke (1970). Hartley (1980) considered the possibility that differences in strength gain may have occurred if measured at a different angle. It should be taken into consideration that the treatment phase of Hartley's study consisted of three weeks, three days per week, of exercise. Nine exercise sessions may not have been adequate to result in significant gains. Although subjects in the present study participated in 14 exercise sessions, two sessions per week may not have been sufficient to result in a significant difference between the D'ROM and static group.

In reviewing the significant difference found between males and females in strength gain, two possible explanations should be taken into consideration. Females had a pretest strength mean of 70.55 pounds as compared to the pretest mean for males of 109.39 pounds. The posttest means for hip strength for females and males were 86.56 pounds and 115.50 pounds, respectively. This may demonstrate a "ceiling effect" regarding the fact that females began at a level of 44.96 pounds less than their counterparts. It is apparent that the room for improvement for strength for females exceeds that for males. Secondly, the mere concentric, isometric and eccentric contraction of the hip
flexors against one's own resistance may not be sufficient enough for strength gains in those with higher levels of strength. Dominguez and Gajda (1982) recommend the use of tension bands for the development of strength once a subject becomes proficient with the range of motion exercises. The same range of motion exercises are performed with a tension band placed around the ankles of both feet. This added resistance aids in the development of strength of the hip flexors.

In examining the relationship of hip flexibility and hip strength of posttest measures for zero-order coefficients, it was noted that the D'ROM group had a correlation coefficient of -.385 as compared to a coefficient of .172 for the static group and .117 for the control group. When sex was controlled, the coefficients changed slightly for the D'ROM group, -.385 to -.312, and the control group, .117 to .172. The static group had the greatest difference with the partial correlation coefficient increasing from .172 to .309. These coefficients seem to suggest that at the end of the treatment phase, there was no linear relationship between flexibility and strength measures of subjects in the control group, while subjects in the static group had a slightly positive linear relationship. This may imply that subjects with greater flexibility values also had greater strength values. However, in the D'ROM group there is a slight inverse relationship indicating that subjects with greater flexibility did not have the higher strength values, while subjects with greater strength did not have the higher flexibility values.
Examination of zero-order correlation coefficients of gain scores of flexibility and strength reveal that for all groups, including the pooled D'ROM-static group, correlation coefficients ranged between .012 and .122. Partial correlation coefficients controlling for sex ranged from .005 to .147. These correlation coefficients indicate that for all groups, there was no relationship between gaining flexibility and strength.

Since D'ROM exercises are designed to develop strength and flexibility simultaneously, it was expected that there would be a strong relationship between gain scores of both measures. Four possible explanations should be considered for the resulting relationship of hip flexibility and hip strength for the D'ROM group. First of all, as can be seen in Tables 3 and 5, the strength gain for females across groups is high when compared to males. Females, as a whole, had a significant increase in strength when compared to males. This is not the case with flexibility. Both males and females had comparable gains in range of motion of the hip. The females of the D'ROM group had the greatest increase in strength gain when compared to females in the static and control groups. This overall trend for females would tend to change the rank order of individuals from pre to posttest measures, and therefore lower the relationship between flexibility and strength. The effect of the females' strength gain may be the cause of low coefficients for the static and control group, and may also be reflected in the inverse relationship for the D'ROM group. As presented earlier, females began at a much lower level of strength than males, hence they
had more opportunity for improvement. The possibility exists that females in the D'ROM group may have had significant improvements in strength without the same level of improvement in flexibility. On the other hand, D'ROM exercises may not have been sufficient for the development of significant levels of strength for those entering the program at higher levels; therefore, those who entered at a higher level of strength may have increased flexibility to a greater degree than strength. In both cases, no relationship or an inverse relationship would be expected between strength and flexibility measures.

Secondly, those who entered the study with higher values of flexibility had the opportunity to increase strength to a greater degree than flexibility. Again, the "ceiling effect" must be considered as a tentative explanation. D'ROM exercises are designed to develop an optimal level of flexibility, but not extreme degrees of range of motion (Dominguez & Gajda, 1982). The possibility exists that some subjects may have entered the study with an optimal level of flexibility and they would not be expected to increase range of motion past that level. However, if the same individual did not have sufficient strength to actively control movement throughout the range of motion, it would be expected that a gain in strength would occur. Again, such a case would be expected to result in no relationship or an inverse relationship between hip flexibility and strength.

Thirdly, measurement error and the lower reliability of posttest measures of strength must be taken into consideration. In examining the standard deviations of strength measures across groups
and within sexes from pretest to posttest measures, the difference in variability is reflected in the reliability coefficient (see Table 5). This variability may also be a reflection of the change in rank order of subjects resulting in lower zero-order and partial correlations.

And last of all, as indicated in Table 7, pretest zero-order correlation coefficients of flexibility and strength are higher for the static and control groups than the D'ROM group. The D'ROM group had a negative, although insignificant, relationship for pretest measures of strength and flexibility. When sex is controlled for, partial correlation coefficients indicate a greater linear relationship of flexibility and strength of pretest measures for all groups, with the static group having a significant correlation of flexibility and strength. Although it was not within the scope of the study to consider the relationship of pretest flexibility and strength, further investigation into this area may give some insight into the results reported.

Liverman (1970), in studying the effects of increased flexibility on the development of power in the lower limbs, reported a definite trend toward an increase in power when flexibility was increased. Although the relationship between the two variables was not investigated, the results are similar to the gains of flexibility and strength for the D'ROM group. Very few studies have looked into the effects of increased flexibility on strength, or the effects of increased strength on flexibility. Even fewer studies have dealt with the relationship of the development of strength and flexibility. Most investigators do agree, however, that in order to maintain flexibility
during strength training, the joint must be exercised through the full range of motion (Davis & Logan, 1961; Leighton, 1960; Tanigawa, 1972). Dominguez and Gajda (1982) claim that flexibility should be the result of muscle strengthening.

The D’ROM group had the greatest gains in flexibility and strength when compared to the static and control groups, although there was no relationship between increase of strength and flexibility. It may be postulated that the D’ROM exercises are effective in decreasing the resistance of the soft tissues surrounding the joint as well as increasing the strength of the opposing muscle. The degree to which the D’ROM exercises affect an individual's flexibility and strength may depend upon the level of the individual when entering the program. Those with higher levels of flexibility may have greater increases in strength, while those with higher levels of strength may need to decrease the resistance of the soft tissues of the joint and therefore, may have greater increases in flexibility.
SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

The purpose of this study was to compare the effects of static stretch exercises and D'ROM exercises on hip flexibility and strength. The relationship between hip flexibility and hip strength was also examined.

Hypotheses

The following hypotheses were investigated:

1. There is no significant difference in mean gain scores of hip flexibility among the static, D'ROM, and control groups.

2. There is no significant difference in mean gain scores of hip strength among the static, D'ROM, and control groups.

3. There is no significant difference in mean gain scores of hip flexibility between males and females.

4. There is no significant difference in mean gain scores of hip strength between males and females.

5. There is no significant difference in the relationship of hip flexibility and hip strength between the static and D'ROM groups.

6. There is no significant difference in the relationship of hip flexibility and hip strength between the pooled D'ROM-static experimental group and the control group.
Methodology

One hundred and one college-age male and female students enrolled in P.E. 100 social dance classes at South Dakota State University participated in the study. Three sections of social dance classes were randomly assigned to one of three groups: (a) D'ROM, (b) static, or (c) control. Pretests of hip flexibility and hip strength were given to all subjects in March of the 1982 semester. Hip flexibility was measured using a Leighton flexometer, and strength was measured using a cable tensiometer. The two experimental groups, D'ROM and static, took part in seven weeks of range of motion exercises as designated for their particular group. The treatment was administered twice weekly and included two range of motion exercises for hip flexion. Posttests for hip flexibility and hip strength were administered the last week of the spring semester.

A two-way ANOVA was conducted to analyze each of the two criterion variables, hip flexibility and hip strength, with the independent variables being sex and treatment. Tukey's HSD test was conducted to test all pairwise comparisons. Zero-order and partial correlation coefficients, controlling for sex, were computed between hip flexibility and hip strength of pretest, posttest, and gain score measures. The resulting relationships were then examined.
Findings

Analyses of the data resulted in the following findings:

1. The D'ROM group had significantly greater increases in range of motion of the hip joint than either the static or control groups. No significant difference was found between the static group and control group for gain scores of flexibility.

2. The D'ROM group had significantly greater increases in hip strength than the control group, although no significant difference was found between the D'ROM group and the static group, or between the static group and the control group.

3. Females had significantly greater increases in hip strength than males although no significant difference was found between sexes in gain scores of flexibility.

4. A significant partial correlation coefficient was found between flexibility and strength in pretest measures for the static group and the pooled D'ROM-static group. A significant negative zero-order correlation coefficient was found in posttest measures for the D'ROM group. All other correlations for pretest, posttest, and gain score measures were found to be insignificant for all groups.
Conclusions

On the basis of the results, the following conclusions have been made:

1. D'ROM exercises are more effective than static stretch in increasing flexibility of the hip joint than static stretches, during a seven week period when exercising two times per week.

2. The D'ROM exercises have a significant effect upon strength development at the hip joint.

3. D'ROM exercises may be a more time-efficient warm-up method than static stretches since flexibility and strength are developed simultaneously.

4. Increases in strength are not necessarily related to increases in flexibility with D'ROM and static stretch exercises.

5. D'ROM exercises may decrease the resistance of the soft tissues surrounding the joint as well as increasing the strength of the opposing muscle group.

Implications

Those involved in physical education and athletics may find D'ROM exercises to be advantageous for the development of strength and flexibility of the various joints of the body. Exercise or activity programs that have little time to devote to the development and maintenance of flexibility may benefit from the use of D'ROM exercises.
since results indicate that a few minutes involved in the exercises when repeated twice per week have a significant effect upon flexibility and strength. D'ROM exercises should be looked upon as an alternative to established methods of stretch, specifically ballistic, static, and PNF methods, when considering evidence indicating the possibility of damage to the tissues of the joint when utilizing these other methods.

**Recommendations**

The following recommendations have been made for further investigation into this area:

1. Recent evidence relating possible tissue damage to popular stretching exercises indicates the need to investigate the effects of D'ROM exercises on the soft tissues of the joint.

2. Since this study only compared D'ROM exercises to static stretch exercises, a comparison of D'ROM exercises to PNF exercises on the effect of each method to develop flexibility and strength at the hip joint needs to be conducted.

3. This study investigated the effects of D'ROM exercises and static stretch on flexibility and strength of the hip joint. It would be of interest to investigate these effects at other joints of the body as well.

4. This investigation only examined the immediate effects of D'ROM exercises on the dependent variables. Retention of flexibility and strength at selected joints is another area that needs to be examined.
5. The results of this study indicated that a person's entry level may influence the extent of the effects of D'ROM exercises on the dependent variables. It would be of interest to examine the effects of D'ROM exercises on varying entry levels of flexibility and strength.

6. This study involved performing the designated exercises only two times per week. D'ROM exercises and other stretching methods need to be studied when participation in exercise exceeds two times per week.
REFERENCES


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Dominguez, R.H. & Gajda, R.S. Total body training. N.Y.: Charles Scribner's Sons, 1982.


Tanigawa, M.C. Comparison of the hold-relax procedure and passive mobilization of increasing muscle length. Physical Therapy, 1972, 52, 725-735.


Appendix A

HUMAN RESEARCH CONSENT FORM

The purpose of this research is to compare two types of stretching exercises. The project involves two testing sessions to be scheduled for each individual outside of class. During these sessions, a hip flexibility and hip strength test will be executed. The treatment consists of doing the stretching exercises at the beginning of the class session for a period of seven weeks. The control group will not participate in stretching exercises during class.

I acknowledge that I have been informed of the testing procedures and that the possible risk involved is minimal. In addition, I am aware that I may be informed of my results upon request.

I acknowledge that any questions I have will be answered by the investigator, and that I am able to withdraw from this research at any time. I am aware that participating or withdrawing from this project will not effect my grade in any way. I freely and voluntarily consent to participate in this research being conducted by Carol Kanetzke.

Signature of volunteer______________________________

Date ________________
### Appendix B

**RAW SCORES FOR PRETEST & POSTTEST MEASURES OF FLEXIBILITY & STRENGTH**

<table>
<thead>
<tr>
<th>NUMBER</th>
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<th>STR1</th>
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<th>STR2</th>
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</thead>
<tbody>
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