ABSTRACT

ROBERTSON, S. L. *The effects of a 6-week stretching program, using Flex Bands, on the low back and hamstring flexibility of cardiac rehabilitation patients.* MS in Adult Fitness/Cardiac Rehabilitation, December 1997, 43pp. (J.P. Porcarl)

Flex Bands are made of a rubber material and resemble a large rubber band, measuring approximately 3 1/2 feet long, 1 inch wide, and 1/4 inch thick. They are used to assist the exerciser in performing static and proprioceptive neuromuscular facilitation (PNF) stretching (i.e., the PNF stretches can be achieved without a partner). Thirty stable, male Phase III/IV patients (mean age = 62 years) served as Ss and were assigned to either a control or experimental group. The control group was asked to continue their normal stretching routine (approximately 10 minutes per day/3 days per week) which they had been performing for 3 months prior to the study. The experimental group performed the same stretching program as the control group, except they supplemented several of the stretches with the Flex Band stretches. Both groups were tested before and after the 6 week program for low back and hamstring flexibility using the sit-and-reach test. There was no change (p > .05) in the control group (pre = 12.3 ± 5.6, post = 12.5 ± 5.5), whereas the experimental group had a significant (p < .05) improvement (pre = 11.3 ± 3.5, post = 14.5 ± 2.1) in flexibility.

According to Cooper Clinic norms, both groups were in the lower end of the fair category (30th percentile) for their age group at the beginning of the study. The experimental group improved to the good category (60th percentile) by the end of the study. Thus it appears that the use of Flex Bands is a safe, effective, and innovative method for improving the low back and hamstring flexibility of cardiac rehabilitation patients.
THE EFFECTS OF A 6-WEEK STRETCHING PROGRAM, USING FLEX BANDS, 
ON THE LOW BACK AND HAMSTRING FLEXIBILITY OF 
CARDIAC REHABILITATION PATIENTS

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THESIS FINAL ORAL DEFENSE FORM

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We recommend acceptance of this thesis in partial fulfillment of this candidate's requirements for the degree:

Master of Science in Adult Fitness/Cardiac Rehabilitation

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Date: 7 July 1997
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INTRODUCTION

Physical educators, coaches, and physical therapists have long recognized the importance of flexibility, the ability of a joint to move freely through its full range of motion (ROM)\(^1\). Flexibility is joint specific, therefore a person could have good ROM in one joint and poor ROM in another joint. Improving and maintaining good ROM of the joints is important to enhance quality of life. Participating in a stretching program can help increase a person's flexibility, which may help decrease the chance of muscular injury and soreness, help prevent low back pain and other spinal problems, and help improve and maintain good posture\(^2\).

Flexibility may be especially important in cardiac patients. Heart disease is one of the leading causes of death in the United States and inactivity is one of the risk factors that can be changed in order to lower a person's cardiovascular risk. Unfortunately injuries such as muscle tears and strains, can prevent a person from participating in an exercise program. If improvements in flexibility reduce the risk of injury, then it is important for cardiac patients to implement a proper stretching routine to keep them injury free for continued activity.

Current cardiac rehabilitation programs follow the guidelines established by the American College of Sports Medicine (ACSM). These guidelines suggest that static stretches, held between 10-30 seconds, should be implemented in cardiac flexibility programs. Because static stretching involves a low risk of injury, requires little time and assistance, and is quite effective, ACSM states that static stretching is the safest form of stretching\(^3\).
Although static stretching is thought to be the safest form of stretching exercise, not all researchers agree that it is the best type of flexibility training. Many researchers\textsuperscript{4-7} believe that proprioceptive neuromuscular facilitation (PNF) is the most effective type of stretching program. PNF stretching involves the contract-relax method which most often is achieved with the use of a partner.

Flex Bands (Jump Stretch Inc., Boardman, OH) have been introduced into rehabilitation centers and athletic centers within the past five years. Jump Stretch Inc. stated that use of the Flex Bands results in up to a 20\% increase in flexibility within a 6-week period when used five times per week. Flex Bands are made of a rubber material and resemble rubber bands with dimensions of approximately 3.5 feet long, 1 inch wide, and 1/4 inch thick. They are used to assist in static and PNF stretching. Moreover, PNF stretching can be achieved through the assistance of the Flex Bands instead of a partner.

There has been a minimal amount of research done on the use of Flex Bands by Phase III/IV cardiac rehabilitation patients. This study was performed in order to provide more information on changes in flexibility with the use of Flex Bands. The specific purpose of this study was to determine the effects of a 6-week stretching program, using Flex Bands, on low back and hamstring flexibility in stable Phase III/IV cardiac patients.

METHODS

Subject Selection

Thirty-two male Phase III/IV cardiac rehabilitation patients from the La Crosse Exercise and Health Program (LEHP) volunteered to participate in the study. All of the subjects had been participating in an exercise program for at least 3 months prior to the study. Prior to the beginning of the study, human
subject approval was obtained from the Institutional Review Board at the University of Wisconsin-La Crosse. Subjects were asked to sign an informed consent form prior to the beginning of the study (see Appendix A). An equal number of subjects were placed into experimental and control groups. Subjects who exercised before 4:00 p.m. were placed in the experimental group, and subjects who exercised after 4:00 p.m. were placed into the control group.

**Treatment**

Both the control and experimental groups participated in a stretching program during the 6-week training period. The stretching programs were 12 to 15 minutes in length and were held three times per week. Before the start of the program, the experimental group was taught to properly use the Flex Bands and spent 1 week (three sessions) practicing the stretches.

**Control Group Stretching Program**

The control group continued to perform the stretching program they had been doing for 3 months prior to the study. The control group stretches included: (1) shoulder shrugs, (2) shoulder stretch, (3) triceps stretch, (4) side bends, (5) back hyperextensions/toe touches, (6) trunk rotations, (7) toe raises, (8) butterfly stretch, (9) modified hurdler stretch, (10) bent knee hamstring stretch, (11) low back stretch, (12) straight leg hamstring stretch, (13) hip rotations, (14) quadriceps stretch, (15) cat stretch, (16) upper body stretch, (17) abdominal stretch, and (18) calf stretch. Each of the stretches were held for approximately 5-10 seconds. Pictures of these stretches are provided in Appendix B.

**Experimental Group Stretching Program**

The experimental group continued to do the stretches that the control group was doing but substituted exercises 3, 5, 7, 9, and 12 with the Flex Band
stretching exercises led by the researcher. Most of the Flex Band stretches began with a passive and active-warm up of the muscle. The stretches were then held at the point of tension for 5-10 seconds. Pictures and explanations of these stretches are provided in Appendix C.

**Flexibility Assessment**

The sit-and-reach test was used to determine hamstring flexibility at the beginning and the end of the study. The sit-and-reach test is one of the most commonly used methods to assess hamstring flexibility. According to Verity, the sit-and-reach test is very quick and reliable when adequate warm-up and joint readiness precedes the test. Most research done on the sit-and-reach test has compared the sit-and-reach test to the modified sit-and-reach test. In a study done by Minkler and Patterson the comparison of the sit-and-reach test and the modified sit-and-reach was done to determine the effect of limb lengths on the sit-and-reach test. The results of the study showed that there was a difference in individuals due to limb lengths. However, the authors stated that the sit-and-reach test was reliable in measuring improvements in flexibility of the hamstrings.

As recommended by Stokes et al., a 5-minute warm up of walking around the track was implemented prior to testing. The subjects were then led through their normal stretching routine before being tested. Subjects were measured individually using the sit-and-reach test as described by Verity. All measurements were rounded up to the nearest quarter of an inch. The best of three measurements was recorded as their final score.
**Statistical Treatment of the Data**

The two groups were compared with independent t-tests to determine if the groups were similar at the start of the study. A two-way ANOVA with repeated measures was used to compare responses between groups over the course of the study. Tukey's post-hoc test was used to determine the significance within groups. Significance was measured at \( p < .05 \) for all statistical analyses.

**RESULTS**

Pretest physical characteristics of the subjects are provided in Table 1. Thirty-two male Phase III/IV cardiac rehabilitation participants from the LEHP volunteered to participate in the study. Two subjects in the control group were eliminated from the study for failure to comply with instructions provided in the informed consent. Subject ages ranged from 46-88. There were no significant \( (p > .05) \) differences found between groups for age, height, and weight at the beginning of the study. An independent t-test was used to compare pretest flexibility scores of the experimental and control groups. There was not a significant difference \( (p > .05) \) in flexibility scores between groups at the beginning of the study.
Table 1. Physical Characteristics of the Subjects (M ± SD)

<table>
<thead>
<tr>
<th>Group</th>
<th>n</th>
<th>Age (yr)</th>
<th>Height (in)</th>
<th>Weight (lbs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>14</td>
<td>62.0 ± 7.8</td>
<td>69.0 ± 1.8</td>
<td>193.5 ± 23.4</td>
</tr>
<tr>
<td>Experimental</td>
<td>16</td>
<td>65.1 ± 10.7</td>
<td>70.1 ± 2.5</td>
<td>195.5 ± 30.1</td>
</tr>
</tbody>
</table>

A two-way analysis of variance was used to compare pre- to posttest sit-and-reach measurements between the control and experimental groups. A significant (p < .05) interaction was found from pre- to posttest scores, indicating that the control and experimental group responded differently over the 6-week period. Tukey’s post-hoc tests were used to determine pairwise differences. There was no change (p > .05) in the control group, whereas the experimental group had a significant (p < .05) improvement in flexibility of 3.2 inches. The results of the flexibility testing are presented in Table 2.

Table 2. Pre- and Posttest Flexibility Scores (M ± SD)

<table>
<thead>
<tr>
<th>Group</th>
<th>n</th>
<th>Pretest (in)</th>
<th>Posttest (in)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>14</td>
<td>12.3 ± 5.6</td>
<td>12.5 ± 5.5</td>
</tr>
<tr>
<td>Experimental</td>
<td>16</td>
<td>11.3 ± 3.5</td>
<td>14.5 ± 2.1*</td>
</tr>
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* significantly different from pretest scores (p < .05)
DISCUSSION

The purpose of this study was to determine if using Flex Bands in a stretching program (three times per week for 6 weeks) would result in significant improvements in flexibility of Phase III/IV cardiac rehabilitation patients. It was found that flexibility was improved significantly (p < .05) compared to patients who performed stretches without the use of the Flex Bands.

To the author's knowledge, there has not been a controlled study investigating the effects of Flex Band stretches on flexibility of males over 45 years of age. Flex Bands allow a person to perform PNF stretches without the use of a partner. The stretches performed in the current study implemented the contract-relax and the contract-relax-antagonist-contraction PNF stretching techniques. There has been research conducted on these types of stretching techniques, however these studies were conducted using subjects under 45 years of age. In order to make a general comparison of the effects of PNF stretches and static stretches on flexibility these studies will be used in the discussion.

Studies by Etnyre and Lee⁴, Sady, Wortman, and Blanke⁵, and Prentloe⁶ compared PNF stretching to static stretches and generally found similar results to those of the current study. The PNF stretches were significantly better at increasing flexibility than the static stretches. Although most studies suggest that PNF stretching techniques are superior to static stretching, contradictions and controversies do exist when comparing the two techniques. The influence of isometric exercise and passive stretch on hip joint motion was examined by Medelros et al.¹². They found that after eight treatment days PNF stretching did
not produce a significantly greater increase in flexibility compared to static stretching.

In the previous studies the goniometer and Leighton flexometer were used to measure improvements in flexibility. Both devices have been shown to have good test/retest correlation coefficients for measurements of joint flexibility of the major muscle groups. However, these investigators used well motivated college students as subjects. In an older population of subjects, such as those in the present study, the sit-and-reach test has been found to be more reliable than other simple measures in measuring improvements in flexibility\textsuperscript{13}.

In the current study the experimental group improved a mean of 3.2 inches in their sit-and-reach scores. It is difficult to compare this improvement to other studies that used the Leighton flexometer or goniometer because they compare improvements across a single joint and are measured in degrees, whereas the sit-and-reach test is an accumulation of flexibility across several joints and is measured in inches. However, the scores can be compared to normative data such as the Cooper Clinic norms. According to the Cooper Clinic norms for flexibility\textsuperscript{3}, both groups were in the lower end of the "fair" category (30th percentile) for their age at the beginning of the study. While the control group stayed at the "fair" category (30th percentile), the experimental group improved to the "good" category (60th percentile) by the end of the study. When comparing results, such as those of the current study, with normative tables it is important to understand that the table is a direct representation of the population selected to participate in the study. The Cooper Clinic norms may not adequately represent the population in this study.

The observed increase in flexibility can not be attributed only to the PNF stretches added to the stretching program, but also to the ease of stretching
achieved by the Flex Bands. The Flex Bands provided subjects with something to hold on to, which allowed them to pull themselves deeper into a static stretch. For example, when subjects performed the modified hurdle stretch without the Flex Band, those who could touch their toes with their hands could use their hands to pull them deeper into the stretch, whereas those less flexible were at a disadvantage because they had nothing to pull them deeper into the stretch. The Flex Bands allow those less flexible subjects to have the advantage that the flexible subjects have by reaching their toes.

Flex Bands appear to be effective in improving flexibility of cardiac rehabilitation Phase III/IV patients, but is it safe for these patients to perform the exercises? The effect of isometric stretch on blood pressure has been studied by several investigators. The effects of isometric exercise on cardiac performance were studied by Kivowitz et al. who measured blood pressure responses during a 5-minute hand grip test on 22 patients with heart disease. They found that patients who had good left ventricular reserve had a rise in stroke work with little or no change in left ventricular end diastolic pressure (LVEDP). Patients with poor left ventricular reserve had a fall in stroke-work with little or no change in LVEDP. It was concluded that in patients with severe coronary disease, sustained isometric contraction could precipitate an episode of sustained chest pain or induce ischemia. This study would suggest that isometric exercise is not safe for cardiac patients with poor left ventricular function, however the isometric contraction performed during the PNF stretching technique does not last 5 minutes in length. In the current study, the isometric contraction lasted for no more than 6 seconds, with at least 30 seconds of rest before the next contraction occurred.
Cornelius and Craft-Hamm\textsuperscript{15} also studied the acute effects of PNF flexibility techniques on arterial blood pressure. Sixty men were assigned to one of three stretching groups: (1) hold-relax, (2) contract-relax, and (3) slow-reversal-hold-relax. All stretches lasted 6 seconds and blood pressures were taken at rest and at the end of each stretch. They found that arterial blood pressure did not significantly increase while ROM significantly improved. The authors concluded that the benefits obtained from PNF stretching outweigh the risks of elevated blood pressure.

Cornelius, Jensen, and Odell\textsuperscript{16} also studied the effects of PNF stretching on blood pressure but were able to measure blood pressures during the stretching phase using a Finapres finger cuff. Sixty male and female subjects were assigned to one of three stretching groups. Each group performed a different PNF stretching technique. Measurements of ROM and blood pressure were taken throughout the study. Blood pressures were obtained at rest, at baseline following passive stretching, and during the PNF stretching. One or two trials of the PNF treatments were not found to significantly increase blood pressure, however a third trial significantly increased systolic blood pressure. Since the current study performed only one trial of each Flex Band exercise and isometric contractions were not held for more than 6 seconds, Flex Band exercises appear safe for Phase III/IV cardiac rehabilitation patients.

To conclude, it appears that the use of Flex Bands is a safe and effective method for improving flexibility for Phase III/IV cardiac rehabilitation patients. The use of Flex Bands should allow patients to achieve greater flexibility than the standard static stretches previously recommended for cardiac patients. It is recommended that patients receive instruction on the proper use of the Flex Bands before they perform the exercises on an individual basis.
REFERENCES


APPENDIX A
INFORMED CONSENT FORM
THE EFFECTS OF A 6-WEEK STRETCHING PROGRAM, USING FLEX BANDS, ON THE LOW BACK AND HAMSTRING FLEXIBILITY OF CARDIAC REHABILITATION PATIENTS.

INFORMED CONSENT FORM

I, __________________________ give my informed consent to volunteer to participate in a study involving participation in a stretching program and the measurement of low back and hamstring flexibility. The purpose of the study is to determine if Flex Bands increase flexibility in LEHP participants, with known coronary artery disease.

I will participate in a flexibility assessment test at the beginning and end of the stretching program through the use of the sit-and-reach test. If I am assigned to the experimental group I will participate in a structured stretching program using the Flex Bands, by Jump Stretch Inc., to assist me. If I am assigned to the control group I will continue my regular stretching program for the 6 weeks of the study.

The structured stretching program, for the experimental group will involve both PNF and static stretches which implement the use of the Flex Bands in order to maximize the stretch. I will participate in this stretching program Monday, Wednesday, and Friday for the six weeks of the study. If I am unable to make it to program I will stretch on my own with the Flex Bands. I understand that it is important for me to be at program stretching with the group, therefore if I miss more than three days of program, during the six week period, I will be eliminated from the study.

I have been informed of possible risks of injury involved in a stretching program. Some injuries that may occur are strains, pulls, or tears of the muscle groups involved. I will be asked to stretch my limbs to a point that may cause some discomfort. I understand there is the possibility of this occurring in any stretching program.

I am aware of the benefits of increased flexibility. Increased flexibility will increase the joints range of motion, improve posture, decrease muscle soreness, and help prevent muscle injuries.

I was informed the researcher will answer any questions I have during the course of the study. I am aware that I am allowed to stop activity at any time without penalty.

Concerns about any aspects of this study may be referred to Dr. John Porcarl, room 215 Mitchell Hall, at 785-8684.

_________________________  __________________________
Participant                     Date

_________________________  __________________________
Witness                        Date
APPENDIX B
CONTROL GROUP STRETCHES
(5) Back Hyperextensions/Toe Touches
(6) Trunk Rotations

(7) Toe Raases
(8) Butterfly Stretch
(9) Modified Hurdler Stretch
(10) Bent Knee Hamstring Stretch
(11) Low Back Stretch
(12) Straight Leg Hamstring Stretch
(13) Hip Rotations

(14) Quadriceps Stretch

(15) Cat Stretch

(16) Upper Body Stretch
(17) Abdominal Stretch

(18) Calf Stretch
APPENDIX C

DIRECTIONS FOR EXPERIMENTAL STRETCHES
1. **Triceps** - place the Flex Band on the palm of one of the hands. With the Flex Band in place, bring that arm straight up close to the ear. Next bend the elbow behind the head. With the other arm on the side of the body, slowly bend the elbow bringing the hand towards the band dangling on the low back. Grab the band with the palm of this hand. Slowly warm-up the muscle by extending and flexing at the elbow joint 5 times. After warm-up, with the elbow at full flexion behind the head, grab the band as high as you can with the arm at the side of the body and pull the band downward.
2. **Calves** - sit on the floor with one leg extended and the other leg bent at the knee. Double loop the Flex Band around the foot. With both hands on the band create resistance while trying to point the toes toward the floor; then assist the foot into flexion. Repeat this process 5 times to properly warm-up the muscle. Next contract the calf muscles-point the toes-as the band resists movement; then relax as the band assists the foot into a flexed position to create a stretch in the calf.
3. **Seated Hamstring Stretch** - with the body in the same position as the last stretch, keeping the back straight, lean forward slowly toward the toes, use the Flex Band to assist the body deeper into the stretch. This will stretch the hamstrings, lower back, and calf muscles.
4. **Ankle Stretch** - in the same position as stretch #2 place one side of the band in each hand. Pull the inside band slowly resisting the foot into the inverted position; then pull on the outside band slowly resisting the foot into the everted position (repeat 5 times to warm-up the muscle). Isometrically contract the everters of the foot preventing the band from pulling the foot into the inverted position; then relax the muscles and allow the band to pull the foot into the inverted position. Isometrically contract the inverters of the foot preventing the band from pulling the foot into the everted position; then relax the muscles and allow the band to pull the foot into the everted position. This process will both strengthen and stretch the muscles of the ankle joint.
5. **Hamstring/Back Stretch** - In the same position as described in stretch #2, place the other foot into the loop of the Flex Band. Keeping your back straight, lean forward slowly toward your toes, use the Flex Band to assist you deeper into the stretch. This will stretch your hamstrings, lower back, and calf muscles.
Now place the chin into the chest and round the back out like the body is going to lie down. This will stretch out the muscles of the back.
6. **Hamstring/Buttocks/Hip Stretch** - lie supine with one foot on the floor and the other leg extended in the air. Wrap the band around the foot of the extended leg and draw it toward the body as far as the body allows; then passively bring the foot toward the floor (repeat 5 times to warm-up the muscle). With the leg fully extended in the air and the other leg flat on the floor, try pushing the leg toward the ground as the band resist the movement; then use the Flex Band to assist the leg deeper into the stretch.
Next move the leg across the body. Again try pushing the leg toward the ground as the band resist the movement; then use the Flex Band to assist the leg deeper into the stretch. Repeat this same stretch with the leg on the lateral side of the body.
APPENDIX D

REVIEW OF LITERATURE
REVIEW OF RELATED LITERATURE

Introduction

Flexibility is defined as the ability of a joint to move freely through its full range of motion (ROM). Flexibility is joint specific; a person could have good ROM in one joint while having poor ROM in another joint. Improving and maintaining good ROM is important to enhancing quality of life. Participating in a stretching program can help increase a person's flexibility, help decrease their chances of muscular injury and soreness, help prevent low back pain and other spinal problems, and help improve and maintain good posture. The review of literature will provide information on the physiological characteristics of flexibility, the types of stretching techniques, comparisons of different types of stretching techniques, and special considerations for cardiac rehabilitation patients.

Physiological Characteristics of Flexibility

The Neuromuscular Junction

Nerves and muscles are united at the neuromuscular junction. This area is where information from the central nervous system (CNS) is translated to the muscle. This translation occurs through the neurotransmitter, acetylcholine (Ach), which excites the muscle fiber to contract. Destruction of Ach causes the muscle fiber to relax.

Muscle Spindle

A muscle spindle is the most abundant proprioceptor found in the muscle. Muscle spindles send information to the CNS relating to the degree of stretch within the muscle. Muscle spindles are modified muscle fibers located parallel to the muscle fibers. Therefore when the muscle fibers are stretched
the muscle spindle is also stretched. The stretch on the muscle spindle fibers causes activation of the sensory neurons located around them. This in turn sends impulses to the CNS and then the CNS sends impulses back causing the muscle to contract. As the muscle shortens or contracts, the muscle spindle is no longer stretched therefore sensory impulses cease and then the muscle relaxes.

Muscle spindles are also sensitive to the rate of change in length and the final length attained. If a person picks up a light load with their arms, only a few motor neurons have to be stimulated in order to hold the load. If something is added to the load, making it heavier, the muscle and muscle spindle will respond by stretching. The muscle spindle signals the CNS to recruit more motor neurons making it easier to hold the load.

There are three main ways that a muscle spindle can cause a muscle to contract: (1) by tonic stretch, (2) by phasic stretch, and (3) by the gamma system or gamma loop. The example of the light load is considered tonic stretch. When more weight was added to the load there was a change in the rate or velocity of the stretch. The response of the spindle to the rate and velocity of the stretch is called phasic stretch. The last way in which the spindle can be stretched is by the gamma system. At the ends of the contractile spindle fibers are motor nerves called gamma motor neurons. The motor centers of the cerebral cortex can directly stimulate the gamma neurons. Therefore, a muscle spindle can be activated to contract along with the rest of the muscle allowing it to maintain sensitivity in a contracted muscle. It is the gamma system that allowed for the recruitment of more motor units recruited when the load was increased in the example above.
**Muscle Tone**

Muscle tone is the resiliency and resistance to stretch of a muscle in a relaxed position. Muscle tone is maintained through reflex activity of the nervous system. The myotatic stretch reflex is an internal mechanism found within a muscle. Its purpose is to protect the muscles and joints from being over stretched too quickly. Whenever a muscle is stretched, the aforementioned stretch reflex is initiated.

**Golgi Tendon Organs**

The golgi tendon organ (GTO) is responsible for detecting tension within a tendon. They are located in the tendon near the muscle fiber. Unlike the muscle spindle the GTOs are in series with the muscle and are stimulated with both passive stretch and the contraction of the muscle. The GTO acts as an inhibitory mechanism, and if the tension placed on the tendon is strong enough, it will elicit the inhibitory response. When a maximum contraction is initiated the inverse myotatic reflex, mediated by the GTOs, should cause the muscle to relax.

**Types of Stretching Techniques**

There are three types of stretching techniques: (1) static, (2) ballistic, and (3) proprioceptive neuromuscular facilitation (PNF). It is important to know the differences and similarities of each of the stretching techniques.

**Static Stretching**

Static stretching is one of the most popular types of stretching. It is safe, effective, and convenient. Static stretching is also known as sustained or passive stretching. This type of stretching involves slowly stretching a muscle just beyond its point of tension. Continued pressure holds the stretch into a position for a sustained period. For flexibility benefits, a stretch needs to be
held between 10 and 30 seconds\textsuperscript{3-4}. As the stretch is held the muscle spindles become desensitized and subsequently adapt to the stretch.

Bandy and Irion\textsuperscript{5} studied the effect of time on static stretch on the flexibility of the hamstring muscles. Their study compared three time durations, 15, 30, and 60 seconds, in order to see what length of time a muscle should be sustained in a stretched position in order to see improvements on knee joint ROM. Subjects were 40 men and 17 women with tight hamstrings, defined as 30 degree loss of knee extension measured with the femur held at 90 degree of hip flexion. The subjects were then divided randomly into four groups: control group, 15 second group, 30 second group, and 60 second group. Each group except the control group (who didn't stretch at all) met five times a week for 6 weeks and stretched their hamstrings by holding the stretch for the amount of time assigned to their group. All groups were pre- and posttested with the use of the goniometer. The results of this study showed the 15 second group had very little improvement in flexibility when compared to the control group. The 30 and 60 second groups improved significantly compared to the 15 second group. However, there was no significant difference when comparing the 30 and 60 second groups. Therefore 30 seconds was determined to be the most beneficial duration to hold a static stretch of the hamstring muscles.

**Ballistic Stretching**

Ballistic stretching involves bouncing, rapid, and jerking movements in order to actively produce stretch in a muscle. This type of stretching involves the highest risk for stretching because the ballistic movement could exceed the extensibility of the muscle. Ballistic stretching may cause the myotatic stretch reflex to occur, since the muscle does not get enough time to relax between stretches. This could cause muscle soreness or injury. This type of stretching is
discouraged for an older adult population in the American College of Sports Medicine's (ACSM) guidelines.

**Proprioceptive Neuromuscular Facilitation Stretching**

Proprioceptive Neuromuscular Facilitation (PNF) refers to any of several postisometric relaxation stretching techniques in which a muscle group is passively stretched, then contracts isometrically against resistance while in the stretched position, and then is passively stretched further resulting in increased ROM. PNF usually utilizes a partner to provide resistance against the isometric contraction and then later to passively take the joint through its increased ROM. It may be performed without a partner, although it is usually more effective with a partner's assistance. PNF stretching can involve any of the following three stretching techniques: (1) hold-relax (HR), (2) contract-relax (CR), and (3) contract-relax, antagonist-contraction (CRAC).

The HR method is used if ROM is extremely limited or if active movement causes pain. During HR a partner would hold the limb at the lengthened stretch and then the stretcher resists the partner from moving the limb into a deeper stretch. The CR method is the opposite of the HR method. The partner prevents the stretcher from moving into the shortened range of the target muscle, therefore performing an isometric contraction. Then the stretcher is allowed to passively move into the new range. The CRAC is like the CR but after the isometric contraction the stretcher actively moves the limb into the new position. In all three PNF techniques, when the muscle performing the isometric contraction is relaxed, it retains the ability to stretch beyond its initial maximum length. PNF stretching techniques increase the ROM of the joint by using the period of time immediately following the isometric contraction to train the stretch receptors to get used to this new, increased, range of muscle length.
Comparison of Stretching Techniques

Etnyre and Lee \(^7\) studied the chronic and acute effects of three stretching techniques on hip and shoulder flexion. The three stretching techniques used in the study were static stretching (SS), contract-relax (CR), or contract-relax with agonist-contraction (CRAC). Subjects who participated in the study were assigned to either one of the three stretching groups, which exercised twice per week, or the control group, which did not engage in any stretching or warm-up prior to activity. Total ROM was compared using a goniometer to measure hip and shoulder ROM. These measurements were taken at the beginning, at the end, and every 3 weeks during the 12 week program. The results of the study showed PNF techniques to be more effective than the SS techniques. For men, the CRAC technique was the most effective of the PNF. There was no significant difference between the PNF techniques for women. The control group decreased ROM which suggests that exercise alone will not increase a person's flexibility.

A study by Sady, Wortman, and Blanke \(^6\) compared the effects of ballistic, static, and PNF stretching techniques on shoulder, trunk, and hamstring flexibility. They randomly assigned subjects into four groups: control, ballistic, static, or PNF. Each subject performed their stretching routine three times per week for 6 weeks. Flexibility measurements were taken pre- and posttesting using the Leighton flexometer. Three measurements were taken on two separate days for each muscle group. Only the PNF group had increased flexibility significantly greater than the control group.

Tanggawa \(^9\) compared the HR procedures to passive mobilization on tight hamstring muscles. The HR procedure is a PNF stretching technique that holds the muscle in an isometric contraction against maximal resistance followed by a
passive stretch into a greater ROM. Tight hamstrings were defined as having a straight leg raise of less than 70 degrees in the right lower limb. Thirty male subjects were randomly assigned to a control, PNF, and passive stretching groups. Treatment occurred 2 days per week for 4 consecutive weeks. The two treatment groups were measured prior to and after treatment on day one through day six. The control group was also measured twice a day on day one through day six. A metronome, calibrated to 1 beat per second, was used as a timing apparatus for all procedures. The HR group performed the following stretching exercises on treatment days: with the knee extended the examiner resists hip extension, abduction, and internal rotation, plantar flexion with eversion, and toe flexion. The passive stretching group exercises were described as follows: with the leg straight and the knee fully extended the examiner asked the subjects to relax their leg and foot while he raised the leg to the point where the subjects could feel a pull behind their knee. Then the examiner pushed the leg up for 2 seconds and held it for 5 second and repeated the procedure three more times. The control group did not perform any stretches. The results of the study showed the HR group consistently had the greatest gains in the range of passive straight leg raises on each treatment day. Mean daily gain for HR group was 7.6 degrees; 4.5 degrees for the passive mobilization group; and 0.7 degrees for the control group. They also found that the HR produced better results in a shorter period of time.

Starring et al.\textsuperscript{10} compared cyclic and sustained passive stretching using a mechanical device to increase resting length of the hamstrings. A total of 10 men and 33 women volunteered to participate in the study. Subjects were randomly assigned to the cyclic and passive stretching groups. The subjects sustained stretching to tolerance of their right hamstring for 15 minutes on five
consecutive days. Hamstring flexibility was measured pre and post using a standard goniometer. The cyclic group increased a mean of 15.4 ± 5.0 degrees and maintained a mean of 10.4 ± 5.5 one week later. The passive group increased a mean of 13.4 ± 4.4 degrees and maintained 7.9 ± 4.0 degrees of this increase one week later. The increases in hamstring flexibility of both groups were found to be significant (p < .001). The cyclic group improved significantly more than the passive group by 2 degrees. However, 2 degrees was not considered clinically significant in knee flexion.

Wallin et al.11 performed a 60 day training study to compare ballistic stretching to contract-relax stretching. Forty-seven subjects were randomly placed into four groups. Three groups of 10 subjects performed the CR method three times per week for the first 30 days. The last group of 17 subjects trained using the ballistic stretching method for three times per week during the same time frame and the last 30 days of the study they performed the CR method. The results of the study showed the CR method to be significantly better at improving flexibility than the ballistic stretching method. After the initial 30 days of training the first three groups trained 1, 3, and 5 times per week, respectively. The results showed that flexibility can be maintained by training one day per week, while three and five times per week improved flexibility further.

Prentice12 compared static stretching to PNF stretching for improving hip joint flexibility in 46 male and female subjects ages 18-34 years. Subjects were randomly assigned to either the static or slow-reversal-hold stretching group. At the beginning of the study baseline measurements were taken of the right and left hip using a goniometer. During the 10 week training study, each subject performed their flexibility program three times per week under direct supervision of an exercise leader. Measurements were taken again at the end of the
10 weeks. They found that both stretching techniques were effective in increasing hip joint flexion. The PNF stretching technique was significantly better than the static stretching technique.

The influence of isometric exercise and passive stretch on hip joint motion was examined by Medeiros et al.\textsuperscript{13}. Thirty male volunteers participated in the study. The subjects were randomly assigned and equally divided into a control group, a passive stretch group, and an isometric contraction group. Each subject assumed a left side lying position on the force table. The pelvis and the left lower extremity were stabilized. A cuff was applied to the right lower extremity to which the force was attached. With the cuff attached, the isometric group performed 20 isometric contractions, and the passive stretching group performed 20 passive stretches. The control group received two measurements without stretching. Measurements were taken before and after stretching on 8 consecutive treatment days. Both the passive and the isometric contraction groups improved in hamstring flexibility compared to the control group. However, they were not found to be significantly different from each other.

Special Considerations For Cardiac Patients

There is special concern for cardiac patients when performing certain types of flexibility stretching exercises. When involving cardiac patients in any type of activity it is important to assess the effect the activity will have on the function of the heart. PNF stretches involve an isometric contraction of a muscle. Isometric exercises have been shown to increase blood pressure in individuals when performed for an extended period of time.

The effect of isometric stretch on blood pressure has been studied by several authors. The effects of isometric exercise on cardiac performance was studied by Kivowitz et al.\textsuperscript{14}, who measured blood pressure responses during a
5 minute hand grip test on 22 patients with heart disease. They found that patients who had good left ventricular reserve had a rise in stroke work with little or no change in left ventricular end diastolic pressure (LVEDP). Patients with poor left ventricular reserve had a fall in stroke-work with little or no change in LVEDP. It was concluded that in patients with severe coronary disease, sustained isometric contraction could precipitate an episode of sustained chest pain or induce ischemia.

Cornellius and Craft-Hamm\textsuperscript{16} also studied the acute effects of PNF flexibility techniques on arterial blood pressure. Sixty men were assigned to one of three stretching groups: (1) hold-relax, (2) contract-relax, and (3) slow-reversal-hold-relax. All stretches lasted 6 seconds, and blood pressures were taken at rest and at the end of each stretch. They found that arterial blood pressure did not significantly increase while ROM significantly improved. The authors concluded that the benefits obtained from PNF stretching outweigh the risks of elevated blood pressure.

Cornellius, Jensen, and Odell\textsuperscript{16} also studied the effects of PNF stretching on blood pressure, but were able to measure blood pressures during the stretching phase using a Finapres finger cuff. Sixty male and female subjects were assigned to one of three stretching groups. Each group performed a different PNF stretching technique. Measurements of ROM and blood pressure were taken throughout the study. Blood pressures were obtained at rest, at baseline following passive stretching, and during the PNF stretching. The authors found that one or two trials of the PNF treatments were not found to significantly increase blood pressure, however a third trial significantly increased systolic blood pressure.
Summary

The literature reviewed provided information on the physiological effects of stretching, benefits of different types of stretches, comparison of the different stretching techniques, and special considerations for the cardiac population. The physiological characteristics of flexibility provided information on how the body reacts to muscle stretch. The muscle spindle provides the information of the length of the muscle. When a stretch occurs, the muscle spindles send information to the CNS which then causes the muscle to contract. If a muscle is stretched too quickly and with too much force, the myotatic stretch reflex causes the muscle to contract, preventing stretching of the muscle any further. Ballistic stretching initiates the myotatic stretch reflex, therefore it is considered unsafe.

It can be concluded from the related literature that flexibility is an important part of an exercise program. The static stretch was found to be safe and effective in improving flexibility. The majority of research indicates that PNF stretching provides the greatest improvements in flexibility. Information of PNF stretching and blood pressure responses indicate that PNF stretches can safely be performed if less than three trials are performed. The lack of research on flexibility in cardiac rehabilitation patients shows that there is a need for more study of this population.
REFERENCES


