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Flexibility: The Forgotten Component of Fitness: Eccentric Exercise vs. Static Stretching to Improve Flexibility

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ABSTRACT

The purpose of this research is to assess the effects of eccentric exercise as well as static stretching on flexibility following a six-week training intervention. It also compared the effects to those of a static stretching program. The hypothesis is that eccentric training will show larger enhancements in flexibility in sagittal plane movements of the hips and knees in comparison to a static stretching program. Training sessions were done three days per week and had a 24-hour rest period minimum between them. The exercises for the eccentric group were as follows: standing hip extension, standing split, straight leg lowering, and lying leg curl. The stretches for the static stretching group included a standing leg hamstring stretch, piriformis stretch, standing quadricep stretch, and a seated forward fold. Significant changes were noted with eccentric exercise as well as static stretching. No significant differences were noted between training groups. Therefore, it was concluded that eccentric exercise does improve flexibility but has no significant difference compared to static stretching.

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DEDICATION

A special thank you to my friends and family who have constantly provided encouragement and support throughout the process of my thesis and my degree. I am very grateful for the support system that has helped me along this amazing journey.

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CHAPTER I

INTRODUCTION

Flexibility is defined as the ability of a muscle to lengthen, allowing one joint (or more than one joint in a series) to move through a range of motion (Bandy et al., 1997). There are a multitude of negative side effects accompanied with inflexibility on untrained individuals. For example, in order to maintain adequate and healthy cartilage, joints must move through a full range of motion. If a person does not move their joints in such a manner, that person risks not supplying the joint with adequate amounts of synovial fluid and blood supply. Boone and Azen (1979) found that, on average, the hip has 113 degrees of flexion and 28 degrees of extension and an average flexion in the knee was approximately 134 degrees. Having limited flexibility can lead to higher risk of injury (Gleim & McHugh, 1997). Static stretching programs are often utilized to help enhance range of motion/flexibility, reduce risk of injury, and increase performance/power. However, one mode of exercise not commonly utilized for increasing flexibility is eccentric training. Eccentric exercise focuses on time under tension, slowing down the negative portion of an exercise to increase the amount of time the muscle is elongating. "Eccentric training could result from a lengthening of the respective muscle groups, which in turn may result in an increase in range of movement" (Muhamad & Afiq, 2018, p. 193).

There are studies that have investigated the effects of static stretching as well as eccentric training on strength gains, but very few have compared the two to see which is more effective at increasing flexibility. Muhamad and Afiq (2018) found that after eight weeks of intervention, flexibility increased in healthy, overweight, and obese women.

The intervention consisted of a simulated version of leg press using resistance bands and slowly lowering a fully extended leg for a total of ten repetitions for three sets with thirty seconds of rest in between. Similar to Muhamad and Afiq (2018), Bandy et al. (1997) examined flexibility and found that when participants utilized static stretching their range of motion was increased as opposed to the control group in the study.

Experimental Purpose

There is very little research examining the effects of eccentric training on flexibility. Accordingly, the purpose of this research is to assess the effects of eccentric exercise as well as static stretching on flexibility following a six-week training intervention. The focus of the study was to note the changes in flexibility of the knees and hips after undergoing an eccentrics program. It also compared the effects to those of a static stretching program.

Hypothesis

The hypothesis is that eccentric training will show larger enhancements in flexibility in sagittal plane movements of the hips and knees in comparison to a static stretching program.

CHAPTER II

LITERATURE REVIEW

This review of literature examines research that relates to the assessment of flexibility through field tests and manual goniometers, the methodology of exercise selection for eccentrics as well as static stretching and their effects on flexibility. There have been studies assessing the best methods to improve flexibility but few have examined eccentric exercise as a method of improvement.

Field Tests

The Fingertip-to-Floor Test is one method to assess flexibility where the subject is directed to bend forward as far as possible with his/her arms extended. Perret et al. (2001) assessed the validity of the Fingertip-to-Floor Test with 32 subjects to determine the reliability of the test and measured the validity with 10 subjects. A total of three procedures were performed to assess validity and four assessments were done to determine reliability and all were done within one hour of each other. For the test itself, participants stood on a platform that was raised 20 cm and were barefoot. Participants were instructed to bend forward as far as they could to try to touch the floor while maintaining proper positioning. Proper positioning included knees, arms, and fingers all being fully extended. The measurement taken was the distance between the participant's middle finger and the base of the box. After conducting the tests, the authors found a mean standard deviation of -0.6 ± 2.8cm. The results also showed an intraclass correlation coefficient (ICC) of 0.99 which demonstrates that the Fingertip-to-Floor test was extremely reliable. Results from the Fingertip-to-Floor Test were compared with the radiographic measures of the movement to determine validity. From these results, Perret et al. (2001) determined that the correlation between the two was -0.96, indicating that the test was extremely valid for measuring flexibility.

Another test commonly used to assess flexibility is the modified Sit-and-Reach test. This test assesses the flexibility of the hamstrings, hips, and low back. Muyor et al. (2014) investigated the validity of the modified Sit-and-Reach test, by comparing results between the modified Sit-and-Reach, the Toe Touch, and the Passive-Straight-Leg-Raise test. The study included 141 young male athletes with a mean age of 16.03 ± 1.00 years. Participants were instructed to abstain from vigorous activity for 24 hours prior to testing . Proper positioning was maintained for all three of the tests being performed. The modified Sit-and-Reach protocol included keeping the knees straight with legs together, and the soles of the feet kept flat on the testing box. The protocol for the Toe Touch included standing on the modified Sit-and-Reach box, having the knees fixed at full extension by the tester, feet at hip width. Once in position subjects were instructed to bend forward as far as possible and hold for five seconds. For the Passive-Straight-Leg-Raise, to assess hamstring flexibility using a Uni-Level inclinometer, the subjects were lying supine and the tester lifted the leg until the participant reported pain or the pelvis started to rotate**.** Muyor et al. (2014) found that the modified Sit-and-Reach test had a positive correlation (r=0.65) with the Passive Straight Leg Raise and the Toe Touch had a positive correlation (r=0.69) with the Passive Straight Leg Raise.

Goniometers

A third common form of assessing flexibility and range of motion is with a goniometer. Watkins et al. (1991) examined the reliability of goniometer measurements in their study with a subject pool of 43 participants. Of these participants there were 29 males and 14 females with an age range of 18-80 years and a median age of 39 years. The study consisted of two sessions to test the intratester and intertester reliability of goniometer measurements in comparison to visual assessments of range of motion. The ICC for knee flexion was 0.99 and the ICC for knee extension was 0.98 with intratester, and the ICC for flexion and extension were 0.90 and 0.86, respectively, for intertester reliability. These results indicate that "Goniometric passive range of motion (PROM) measurements of knee flexion and extension are highly reliable when taken by the same physical therapist" (Watkins et al., 1991, p. 95). The study demonstrated that when using goniometers as a measurement tool, it is highly reliable, with an intratester reliability coefficient of .99. Having a high reliability when used by the same tester helps support the use of this device in other studies when assessing range of motion about a joint as opposed to using a visual estimate.

Eccentrics Selection and Effects

There are a multitude of studies that have examined the effects of eccentric exercise on strength and hypertrophy and how these exercises, while not commonly considered when attempting to enhance flexibility, can in fact be shown to elicit positive changes in flexibility over time. McAllister et al. (2014) examined the amount of hamstring activation during various exercises. Twelve men with resistance training experience and an average age of 27.1 ± 7.7 years were selected to note the activation of the hamstrings when performing the glute-ham raise, the good morning, the Romanian deadlift (RDL), and the prone leg curl. Subjects underwent four testing sessions where surface electromyography was used to record muscle activity during the lifts. The authors found that the glute-ham raise and the RDL exercises had a significantly higher activation than the good morning and prone leg curl (McAllister et al., 2014). This indicates that those specific movements can elicit greater effects on strength and range of motion in comparison to others. While the study did find that eccentric contraction elicited a higher amount of muscle activation in the glute-ham raise in comparison to the good morning and RDL, it did have limitations. One of the limitations was that the subjects were all healthy younger males. With that demographic as their subject pool, the question remains whether or not this is true in untrained individuals, older individuals, or those of special populations.

Orishimo and McHugh (2015) also studied eccentric exercises, but unlike McAllister and colleagues (2014), they focused on exercises done at home without external resistance being added to the movement. They included 12 healthy subjects who were injury free and no injuries to the lower extremities within the previous six months or any knee injuries within the previous year. Their training protocol included four exercises, three as described by Askling et al. (2013), the standing hip extension, standing trunk flexion (diver), and the standing split (glider). The fourth exercise was a sliding supine eccentric bridge (slider). Proper technique for the first three were defined by Askling et al. (2013), the diver was to be done from a standing position, similar to a single RDL where subjects were to stand on one leg while stretching the arms forward and hinging at the hips. The glider is another standing position where one hand holds on to a support and the legs are slightly split. Once in position the subject is to glide one leg backward while putting his/her bodyweight on to the front leg. Once the subject feels a stretch in the hamstring the subjects was instructed to come back up. The slider, clarified by Orishimo and McHugh (2015), is done on the floor. First the subject performs a single leg bridge, then by extending his/her knee and sliding a foot forward lowering the subject's torso to the ground. Once down the subject returns to the starting position. This protocol was utilized to ensure that subjects were going through a full range of motion during the eccentric phase of the movement. The training volume progressed over the course of the four-week study beginning with three sets of 10 repetitions with each leg.

To assess hamstring activation the authors used an electromyography (EMG) test during movements to note activity throughout the exercise. The results indicated that the exercises did show substantial hamstring activation and significantly improved strength when associated with eccentric exercises. The results from this study can be combined with those from the study above to demonstrate that selecting exercises that elicit substantial hamstring activation can, over time, increase strength as well as flexibility. While the studies did show similarities in hamstring activation, they differed in their overall purposes.

Static Stretching Selection and Effects

Static stretching has been used to enhance flexibility for many years. It is often found that when examining the effects of static stretching most compare the results to a second form of either stretching or training. One example of this is from Morton et al. (2011). These authors conducted a five-week study in which they compared the effects of static stretching to the effects of resistance training on flexibility. The subject pool of 42 participants, with an average age of 21.92 ± 3.64 years, was split into three groups, a static stretching group, a resistance training group, and a control group. The pre- and post-testing for each participant was performed by the same tester to help limit intertester error. Both interventions were designed by a certified strength and conditioning specialist. The stretches used in the study were selected to mimic the same range of motion used in the resistance training group and the sessions lasted 25 to 35 minutes. During the five weeks of the study, participants were told to refrain from any extra resistance training or physical activity until the end of the study. In order to test flexibility a universal goniometer was used to assess degrees of range of motion. Following the intervention, post-testing showed that the results from the two intervention groups were significantly greater than the control, indicating that both methods improved flexibility. The results showed a positive difference between both interventions and controls, but no significant difference between the training programs. An important limitation of the study is the short duration. The study was only five weeks long. In most cases it is difficult to determine long-term effects of interventions with a shorter period however the authors stated, “because of calendar and facility constraints, it was only possible to continuously run the interventions for a 5-week period” (Morton et al., 2011, p. 3397). Another limitation for the study is that even with a large subject pool the age range examined is a younger population. Having a wider age range helps generalize the effects of the intervention for a larger group of people which may be determined by further investigation. Even with the limitations of the study in mind it is still important to note the findings that static stretching did in fact increase flexibility over a five-week period, which provides insight to the overall purpose of the review in supporting that static stretching will increase flexibility in a short period of time. While this study did focus on the differences or similarities between static stretching and resistance training it was not eccentric training. However as previously stated, both resistance training and static stretching were suggested to increase flexibility.

Similarly, the authors of the next study decided to examine the effects of different types of stretching on range of motion. Siebert and colleagues (2020) investigated the effects of static stretching, dynamic stretching, and foam rolling on range of motion. The subjects consisted of 14 male students with a mean age of 23 years. For the intervention protocols to be completed, three separate sessions consisting of foam rolling, static stretching, and dynamic stretching sessions were to be 48 hours apart from each other. During each session participants completed a warmup, a pre-test measurement of range of motion, intervention, followed by post-test measurements. The results showed that following the static stretching protocol, range of motion was increased by 3.8 ± 1.1° and following the dynamic stretching protocol, range of motion was increased by 3.7 ± 1.8°. Siebert and colleagues (2020) noted that no significant differences were found between groups. The authors also noted that the stretch loading was longitudinal, meaning "in the line of action between muscle origin and muscle insertion." (Siebert et al., 2020, p. 4). The results of this study demonstrated multiple effects of static stretching. First, static stretching does in fact increase range of motion over a period of time. Second, prolonged static stretching can, without a dynamic warm-up, have an adverse effect and decrease performance in athletes. The results of this study coincide with the previous study in that static stretching does show improvements, when applied appropriately. While the study did support that static stretching had a positive effect on range of motion, there are some limitations that must be discussed. The population being studied was fairly limited, only 14 subjects all of which were males. Being able to apply the results to a more diverse range of people can be difficult if the study limits its view to only look at young healthy males. The study also did not introduce their methods over a long duration, so the results may only be accurate during a short time span. This study, similar to the last, did note changes in flexibility due to static stretching, however their methods varied. Morton and colleagues (2011) had their participants stretch statically for three sessions per week for a period of five weeks, where Siebert and colleagues (2020) had only three sessions total to examine the acute effects of static stretching. The study done by Seibert and colleagues (2020) also only had a total duration of 30 seconds per stretch for their sessions. This is not consistent with previous studies done when speaking to total stretching time. The American College of Sport Medicine (ACSM) for example recommends stretching for bouts of 10 to 30 seconds accumulating a minimum of 60 seconds of static holding for each stretch (Reibe et al., 2018).

Static Stretching Duration

The studies in the previous section have shown that static stretching produces improvements in flexibility and range of motion at four and six weeks but have not examined how long these effects last. Depino et al. (2000) examined the duration that range of motion was maintained after a short-term static stretching intervention. Thirty males with a mean age of 19.8 ± 5.1 years volunteered to participate in this study. For the intervention, subjects performed four static stretches lasting 30 seconds each with a 15-second break between sets. After stretching, post-test measurements were taken every three minutes for 15 minutes and again after 30 minutes. Post-test measurements displayed increases in range of motion of 6.8 and 5.6° at one- and three-minutes , respectively, post cessation of intervention. After three minutes there were noted decreases in gains and at six minutes subjects were back to baseline. The results of this study provide beneficial information to many in the exercise science realm. By knowing how long the effects of stretches last one can appropriately time the implementation of static stretches to utilize the benefits associated with static stretching. One limitation that should be noted is similar to the previous study by Siebert and colleagues (2020) in that it had a limited subject pool. The study had 30 subjects but all of which were males, and because of that more research is needed to note any differences between men and women across age groups to be able to generalize the findings to a more diverse population.

Current Research on Eccentric Exercise

There are many studies currently being done on eccentric exercise focusing on pain management and strength gains, but none that focus on flexibility. One study currently being done in the field of eccentrics is by Vidmar and colleagues (2020). In their study the focus was on comparing the effects between different eccentric training methods, constant load and isokinetic eccentrics. With a subject pool of 30 males with an average age of 25 years, their study, similar to previously reviewed studies, lasted six-weeks. Having two training sessions per week for the duration of the study, Vidmar and colleagues (2020) found that after their intervention, isokinetic eccentric training had significantly higher improvements in strength and performance compared to traditional eccentric training under constant load.

While there are very few studies comparing eccentric exercise and static stretching there is one by Gillani and colleagues (2020). In their study the purpose was to compare the effects of eccentric exercise versus static stretching to help with pain management in patients with upper cross syndrome. The authors had a total of 40 subjects, with a median age of 42.75 ± 11.13 years in one group and a median age of 40.50 ± 9.14 years in the second. Their study, similar to Vidmar and colleagues (2020), consisted of two training sessions per week and, unlike the previous study, had a duration of three weeks. Similar to this study, another study looking at eccentrics while using the same cadence, Gillani and colleagues (2020) used a five-second count for their eccentric exercise group and their results suggested that eccentric exercise did help with pain management. Their results also suggested that there was no significant difference between groups and both were effective in decreasing pain and reducing neck disability.

One study currently being done that did not follow the same cadence as Vidmar and colleagues (2020) and Gillani and colleagues (2020) is Sarto and colleagues (2020). In their study they examined muscle activation during eccentric exercise. In their study the eccentric exercise had a three-second negative cadence, two-seconds shorter than previous studies. Their study suggested that to elicit changes within the muscle using eccentric exercise and a three-second negative an overload of 150 percent of a one-rep max was needed. For that reason, the cadence selected in this study was a five-second negative.

Summary

The research above provided adequate information to support conducting a study with a short-term eccentric exercise program to note its effects on flexibility. Orishimo and McHugh (2015) provided exercises that elicit changes without additional external forces such as weights or bands. McAllister et al. (2014) supported that short duration static stretches could still provide enough stimulus to elicit changes in subjects. Morton et al. (2011) and Siebert et al. (2020) helped determine the stretches and stretching duration for the static stretching group. Orishimo and McHugh (2015) and McAllister et al. (2014) helped determine eccentric cadence as well. One limitation seen throughout the research is that most studies were completed with young and healthy individuals. For that reason, the mean age of the participants in this study will be slightly over that of the previous research. The research above also suggests that while current research is being done utilizing eccentric exercise, the objectives are not focused on its effects on flexibility, which is one reason this study focused on that aspect.

CHAPTER III

METHODOLOGY

Experimental Approach to the Problem

This study used eccentric training methods to examine the changes in flexibility over a six-week period. These changes were then compared to the effects of a static stretching program in order to address the following research questions, does the implementation of an eccentric training program affect flexibility? If so, how do the changes in flexibility compare between a static stretching program and an eccentric training program.

Requirements for Inclusion

Eligible participants needed to be 18 years and older, who were not currently participating in a static stretching or an eccentric training program and who had no current musculoskeletal injuries to the lower back, hamstrings, hips, or any other areas that would prevent them from performing the movements without pain. For recruiting purposes, a flyer addressing the focus of the study was posted outside the Student Recreation Center at a local Midwest University and at a local gym. Upon receiving approval for study by the Institutional Revenue Board (IRB) and consenting to participate in this study, subjects were assigned a subject number to be used on all data recording records. The only place their names and subject numbers were listed together was on a master subject list that was kept separate from all other data on a password protected computer. During testing sessions, data were recorded on a form with only the subject ID used for identification. Results and information from pre- and post-testing were recorded in writing and transferred to an electronic spreadsheet. Only the primary investigator and the faculty committee have access to subject data and information.

Precautions

There were precautions that were taken due to the COVID-19 pandemic. For the pre-testing measurements, the modified Sit-and-Reach, Finger-to-Floor test, and Active Lying Hamstring Raise as well as the manual muscle tests that were done, the Standing Knee Curl and the goniometer measurements, masks were worn. In addition, the testing was done in under fifteen minutes to limit time of exposure per the guidelines of the Center for Disease Control and Prevention (CDC) (McFee, 2020). All testing equipment was cleaned before and after testing was done using a disinfectant spray and disposable towels supplied by the university as an approved method of sanitizing. To keep exposure time minimal, any additional information needed was delivered via email. The workout logs were sent via email as well. The short demonstration session for the eccentric training group as well as the static stretching group was done via video recorded on an iPhone and send to participants via email, so that they could refer to them, if they needed a reminder on how to perform the exercises, when necessary. Any additional information was delivered via email.

Procedures / Familiarization

During the pre-screening session, both the eccentric training group and the static stretching group went through a 15-minute session, on how to properly perform eccentric training, led by the primary researcher. The control group was given a pamphlet during their pre-testing session, stating the effects of both static stretching as well as eccentric training, but were told not to change their means of training and not to implement either of the programs being used in the study.

Measurements

Participants completed a health history questionnaire (Appendix A), as well as a PAR-Q (Appendix B) to help assess their level of fitness and identify any criteria that would exclude them from participating in the study. An informed consent was completed to ensure that participants fully understood the risks of participation (Appendix C). Pre-intervention measurements of flexibility were taken as well as height (InBody n.d.), weight (InBody n.d.), and age. Measurements of active range of motion were taken to assess flexibility. For active range of motion, the modified Sit-and-Reach test, an Active Lying Hamstring Raise, the Finger-to-Floor test, and a Standing Knee Curl measurement were used to assess flexibility. Protocols of ACSM Guidelines (Reibe et al., 2018) were followed to ensure proper measurement. Subjects were instructed to sit on the floor with their hips against the wall, knees straight, and feet flat on the box. Next they were instructed overlap their middle fingers, and exhale while extending their arms forward as far as possible without bending their knees and push the marker on the modified Sit-and-Reach box (Vital Signs n.d.). For the Active Lying Hamstring Raise subjects were lying supine and were instructed to raise one leg as high as possible while keeping their knee straight and opposite leg on the ground and a goniometer (Oiiki n.d.) was used to measure the degrees of motion. The standing Finger-to-Floor test was performed by standing on a homemade plyometric box, with the feet together and toes on the edge of the box. They were then instructed to fold forward as far as possible without bending their knees.

Then, participants were randomly assigned to groups using Microsoft Excel. Each participant received an email of a template for a workout log with the intention of promoting program adherence and increasing accountability. The subjects were directed submit workout logs weekly to “Check In” with the author via email so that adherence could be monitored throughout the study.

Training Protocols

The intervention was six weeks long in order to evaluate the short-term effects of eccentric exercise versus static stretching on flexibility. The sessions were executed three days per week and had a 24-hour rest period minimum between them. The exercises were performed in the homes of the participants and were therefore unsupervised. McAllister et al. (2014) supported that two of the exercises selected for the eccentrics group excel at eliciting the activation of the hamstrings. The exercises for the eccentric group were as follows: standing hip extension, standing split, straight leg lowering, and lying leg curl (Appendix D). They performed three sets of 10 repetitions for each movement with a five-second negative one-second positive tempo cadence. After each exercise the subject had 30 seconds of rest between the sets and they were to complete all sets of one exercise before continuing to the next. The cadence of the exercises performed had the negative, or eccentric, portion of the movement had a duration of five seconds, then the positive, or concentric, portion of the movement lasted one second. All exercises were done with only bodyweight. The static stretching group participated in static stretching focused on sagittal plane knee and hip flexibility three days per week for a period of six weeks. The stretches selected were selected due to results seen by Morton et al. (2011), which suggested said stretches to improve hamstring flexibility The stretches included a standing leg hamstring stretch, piriformis stretch, standing quadriceps stretch, and a seated forward fold (Appendix E). They held each stretch for two sets of 30 seconds with 10 seconds of rest in between. They finished one stretch before moving on to the next. All participants were given a workout log (Appendix F) template to monitor the frequency and duration of exercise sessions.

Data Analysis

Descriptive statistics (mean ± SD) for all demographic variables were calculated using IBM SPSS Statistics for Windows, Version 21.0. A single sample t-test was executed for each assessment of flexibility, the modified Sit-and-Reach (S/R), the Fingertip-to-Floor (FTF), the Standing Knee Curl (SKC), and the Active Hamstring Raise (AHR), to note the changes between pre- and post-testing with a significance of a $p \leq 0.05$. An ANOVA was conducted for each individual flexibility test (S/R, FTF, SKC, AHR) to compare results across the eccentric exercise group (ECC), the static stretching group (STAT), and the control group (CNTRL). The significance of effects was based on a $p \leq 0.05$ level. Upon completion of the intervention for six-weeks, post-testing was conducted in the same location as pre-testing, with the same equipment, and by the same assessor within five days of completing exercise protocols. Workout logs, if not already, were submitted to the author via email.

CHAPTER IV

RESULTS

The purpose of this research was to assess the effects of eccentric exercise as well as static stretching on flexibility following a six-week training intervention. The study recruited 21 participants (8 male, 13 female), data from six participants was excluded due to a failure to participate. Those subjects did not perform the necessary exercises three nonconsecutive days per week for the duration of the study. The remaining 15 subjects (4 males, 11 females) had an average age of 38.87 ± 14.10 years. Average ages for each group can be seen in Table 1. Subjects were then randomly divided into three groups, a control group (CRTL; n = 4), a static stretching group (STAT; n = 6), and an eccentric training group (ECC; n = 5). Subjects whose data were analyzed completed “check-ins” as requested. Of those subjects the average number of sessions completed was 17.27 ± 0.79 sessions, which is an adherence rate of 95.9 percent. The subjects who did not participate failed to submit their workout logs. Table 1 displays the descriptive statistics (mean ± SD) for all demographic variables, there were no significant differences between the three groups for age, height, or mass.

Table 1

Subject Demographics

Group	Age (years)	Height (in)	Mass (lbs)
STAT (n=6)	35.5 ± 13.99	65.33 ± 2.88	165.5 ± 27.81
ECC (n=5)	51.17 ± 32.95	74.17 ± 20.15	173.33 ± 45.55
CNTRL (n=4)	44.5 ± 18.88	65 ± 3.46	137 ± 8.29

Note: Static Stretching Group (STAT), Eccentric Exercise Group (ECC), Control Group (CNTRL), no significance found

Research Question 1

The first research question was: what are the effects of eccentric exercise and static stretching on flexibility following a six-week training intervention? A single sample t-test was conducted to explore the differences in pre- and post-testing amongst the eccentrics group in all of the flexibility measurements. Table 2 shows the results of the t-tests. Significant changes were noted in five of the six flexibility measurements in the eccentric exercise group as well as the static stretching group. For the control group significant changes were noted in four of the six measurements.

Table 2

Eccentrics Pre/Post Data

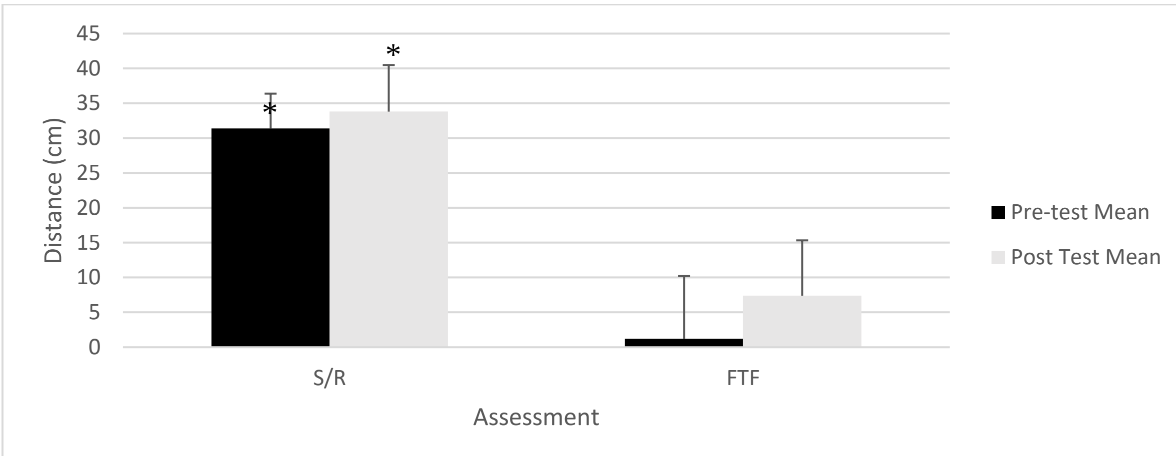
Assessment	Pre-Test Mean (± SD)	Post-Test Mean (± SD)	*p*-value
Modified Sit and Reach	31.4 cm ± 4.98*	33.80 cm ± 6.69*	0.001
Finger to Floor	1.20 cm ± 9.01	7.40 cm ± 7.93	0.105
Standing Knee Curl (Left Leg)	109.20° ± 7.60*	119.0 ° ± 5.48*	0.001
Standing Knee Curl (Right Leg)	108.40° ± 5.32*	121.80° ± 10.64*	0.001
Active Lying Hamstring Raise (Left Leg)	85.00° ± 12.02*	94.20° ± 15.24*	0.001
Active Lying Hamstring Raise (Right Leg)	79.40° ± 12.72*	87.40° ± 8.53*	0.001

Note: significance $*p \leq 0.05$

Figures 1 and 2 also show the results from the t-tests for the Eccentric Exercise group. Assessments that were significant are the modified Sit-and-Reach, the Standing Knee Curl, and the Active Lying Hamstring Raise.

Figure 1

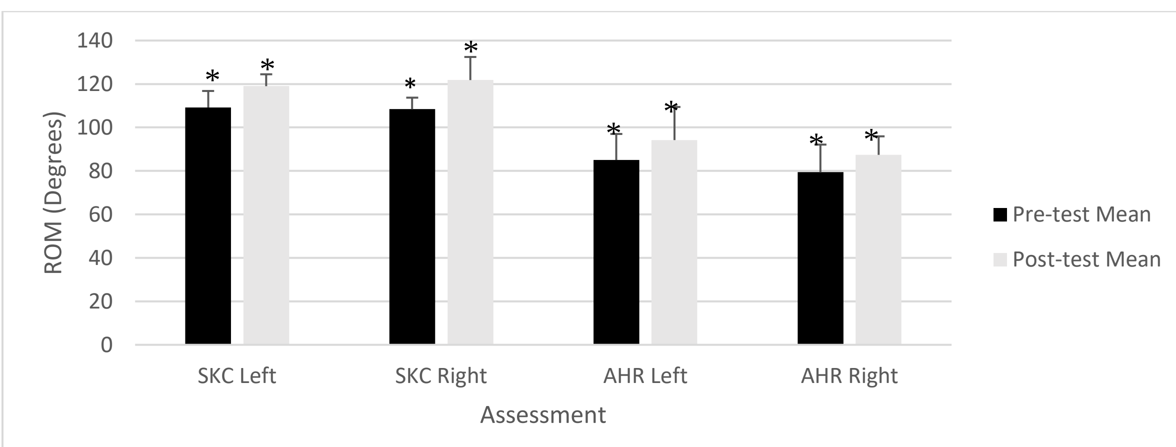
Eccentrics Sit and Reach / Fingertip to Floor



Note: Modified Sit-and-Reach (S/R), Fingertip-to-Floor (FTF)

Figure 2

Eccentrics Standing Knee Curl / Active Lying Hamstring Raise



Note: Standing Knee Curl (SKC), Active Lying Hamstring Raise (AHR)

For the modified Sit-and-Reach there was a significant difference in the measurements prior to and following the exercise intervention measurements t(4) = 14.099, $p = 0.001$. For the Standing Knee Curl on the left leg significant differences of t(4) = 32.145, $p = 0.001$. As for the Standing Knee Curl on the right leg differences of t(4) = 45.564, $p = 0.001$ were noted as significant. The results from Active Lying Hamstring Raise left leg and right leg were found to be significant with t(4) = 15.811, $p = 0.001$ and t(4) = 13.958, $p = 0.001$. Table 1 shows significant differences in the modified Sit-and-Reach, Standing Knee Curl, and Active Lying Hamstring Raise following a six-week training intervention.Table 3 shows results of the t-tests from the static stretching group showing the changes prior to and following intervention.

Table 3

Static Stretching Pre/Post Data

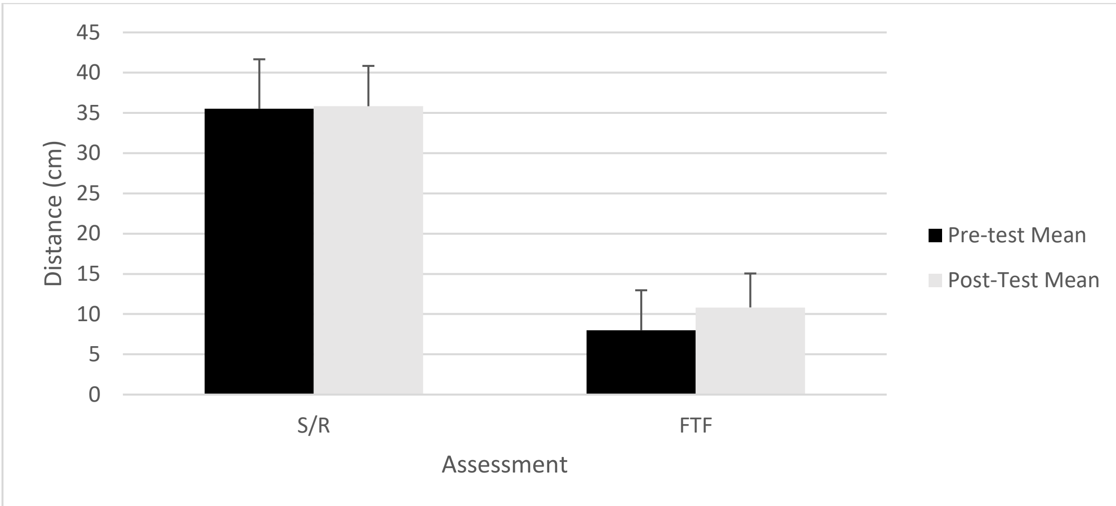
Assessment	Pre-test Mean (± SD)	Post-test Mean (± SD)	*p*-value
Modified Sit and Reach	35.5 cm ± 6.16	35.83 cm ± 4.96	0.103
Fingertip to Floor	8.00 cm ± 5.01	10.83 cm ± 4.22	0.120
Standing Knee Curl (Left Leg)*	110.67º ± 13.46	117.33º ± 5.96	0.001
Standing Knee Curl (Right Leg)*	108.33º ± 15.42	117.67º ± 16.37	0.001
Active Lying Hamstring Raise (Left Leg)*	86.33º ± 18.09	98.50º ± 15.43	0.001
Active Lying Hamstring Raise (Right Leg)*	86.00º ± 22.30	95.67º ± 7.71	0.001

Note: significance $*p \leq 0.05$.

Figures 3 and 4 depict a bar graph showing the changes prior to and following intervention.

Figure 3

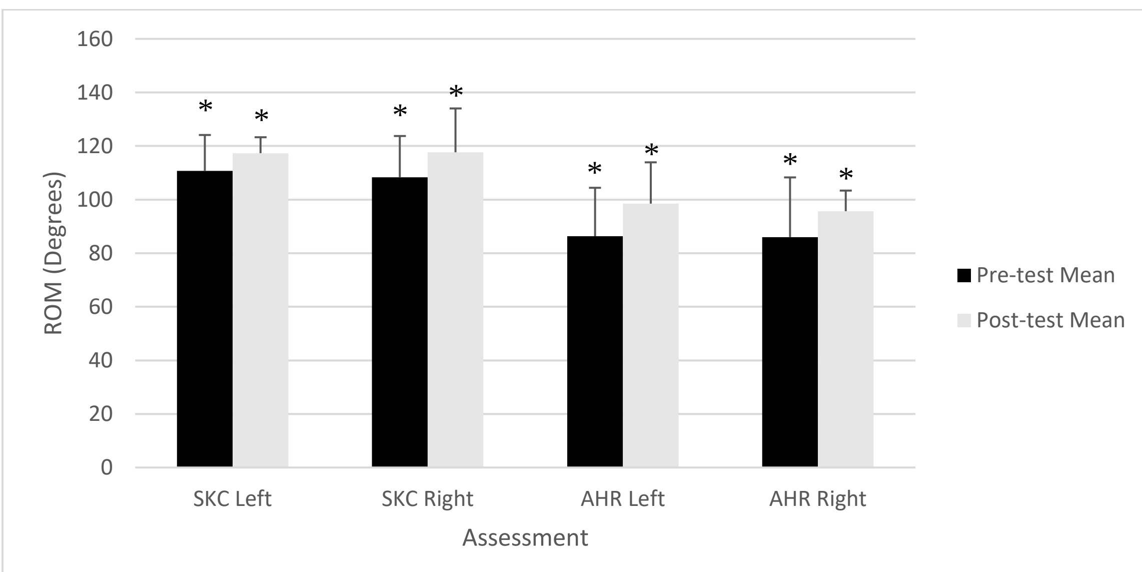
Statics Sit and Reach / Fingertip to Floor



Note: Modified Sit-and-Reach (S/R), Fingertip-to-Floor (FTF)

Figure 4

Statics Standing Knee Curl / Active Lying Hamstring Raise



Note: Standing Knee Curl (SKC), Active Lying Hamstring Raise (AHR)

For the Fingertip-to-Floor Test there was a significant difference in the measurements prior to and following the exercise intervention measurements t(5) = 3.843, p = 0.001. For the Standing Knee Curl on the left leg significant differences of t(5) = 20.145, p = 0.001. As for the Standing Knee Curl on the right leg differences of t(5) = 17.206, p = 0.001 were noted as significant. The results from Active Lying Hamstring Raise left leg and right leg were found to be significant with t(5) = 11.693, p = 0.001 and t(5) = 9.447, p = 0.001.

Table 4

Control Pre/Post Data

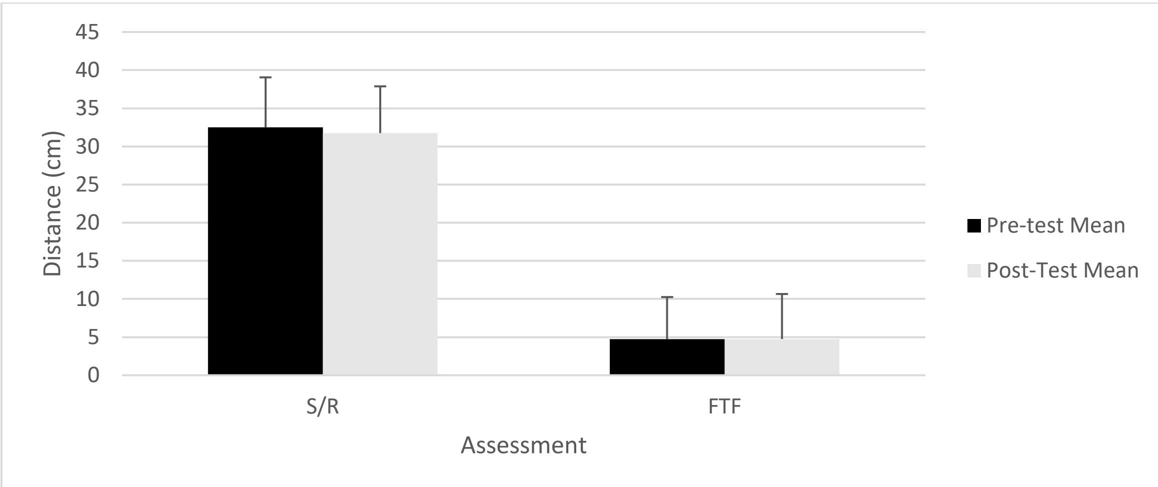
Assessment	Pre-test Mean (± SD)	Post-test Mean (± SD)	*p*-value
Modified Sit and Reach	32.50 cm ± 6.56	31.75 cm ± 6.13	0.102
Finger to Floor	4.75 cm ± 5.5	4.75 cm ± 5.90	0.120
Standing Knee Curl (Left Leg)*	97.50° ± 14.73	105.50° ± 20.27	0.001
Standing Knee Curl (Right Leg)*	103.50° ± 16.22	115.25° ± 13.23	0.001
Active Lying Hamstring Raise (Left Leg)*	80.25° ± 3.69	86.25° ± 8.96	0.001
Active Lying Hamstring Raise (Right Leg)*	79.00° ± 9.93	91.00° ± 18.46	0.001

Note: significance *$p \leq 0.05$.

Below Figure 5 and Figure 6 show the results from the t-tests for the control group prior to and following the six-week intervention.

Figure 5

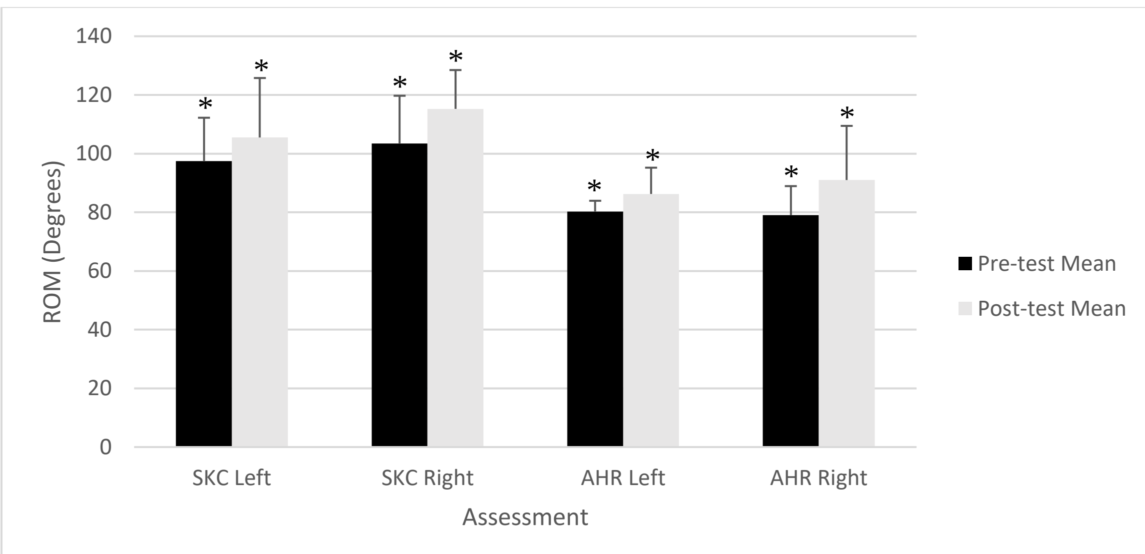
Control Sit and Reach / Fingertip to Floor



Note: Modified Sit-and-Reach (S/R), Fingertip-to-Floor (FTF)

Figure 6

Control Standing Knee Curl / Active Hamstring Raise



Note: Standing Knee Curl (SKC), Active Lying Hamstring Raise (AHR)

For the control group, significant differences were only seen in the Standing Knee Curl and the Active Lying Hamstring Raise. For the modified Sit-and-Reach there was no significant difference in the measurements prior to and following the exercise intervention measurements $t(3) = 9.912$, $p = 0.206$. Results from the Fingertip-to-Floor Test were nonsignificant with $t(3) = 1.727$, $p = 0.183$. For the Standing Knee Curl on the left leg significant differences of $t(3) = 13.237$, $p = 0.001$. As for the Standing Knee Curl on the right leg differences of $t(3) = 12.764$, $p = 0.001$ were noted as significant. The results from Active Lying Hamstring Raise left leg and right leg were found to be significant with $t(3) = 43.548$, $p = 0.001$ and $t(3) = 15.906$, $p = 0.001$.

Research Question 2

The second research question was: how did the effects of an eccentric exercise program compare to the effects of a static stretching program? An ANOVA was conducted for each individual flexibility test (S/R, FTF, SKC, AHR) to compare results across the three groups (ECC, STAT, CNTRL). The significance of effects was based on a $p \leq 0.05$ level. Pre- and post-test ANOVA results for all three groups can be seen in Table 5 below.

Results showed no significant difference in results between groups. The modified Sit-and-Reach showed $F(2, 12) = 0.713$, $p = 0.510$. For the Fingertip-to-Floor Test the results showed $F(2, 12) = 1.388$, $p = 0.287$. The Standing Knee Curl results for left and right leg are as follows, $F(2, 12) = 1.558$, $p = 0.250$ and $F(2, 12) = 0.199$, $p = 0.822$. The active hamstrings raise results for left leg and right leg are as follows, $F(2, 12) = 0.247$, $p = 0.785$ and $F(2, 12) = 0.290$, $p = 0.753$.

Table 5

ANOVA Results

Assessment	d*f*		F		Sum of Squares		*p*	
	Pre-Test	Post-Test	Pre-Test	Post-Test	Pre-Test	Post-Test	Pre-Test	Post-Test
Modified Sit and Reach	14	14	0.713	0.587	467.333	454.933	0.510	0.571
Finger to Floor	14	14	1.388	1.243	671.733	536.933	0.287	0.323
Standing Knee Curl (Left Leg)	14	14	1.558	1.158	2251.333	3176.400	0.250	0.347
Standing Knee Curl (Right Leg)	14	14	0.199	0.261	2160.933	2416.600	0.822	0.775
Active Lying Hamstring Raise (Left Leg)	14	14	0.247	0.918	2346.933	2722.400	0.785	0.426
Active Lying Hamstring Raise (Right Leg)	14	14	0.256	0.923	2443.933	2714.600	0.753	0.443

Note: No significance between groups

Results showed no significant difference in results between groups. The modified Sit-and-Reach showed $F(2, 12) = 0.713$, $p = 0.510$. For the Fingertip-to-Floor Test the results showed $F(2, 12) = 1.388$, $p = 0.287$. The Standing Knee Curl results for left and right leg are as follows, $F(2, 12) = 1.558$, $p = 0.250$ and $F(2, 12) = 0.199$, $p = 0.822$. The active hamstrings raise results for left leg and right leg are as follows, $F(2, 12) = 0.247$, $p = 0.785$ and $F(2, 12) = 0.290$, $p = 0.753$.

CHAPTER V

DISCUSSION

The purpose of this research was to assess the effects of eccentric exercise as well as static stretching on flexibility following a six-week training intervention. The focus of the study was to examine the changes in flexibility of the knees and hips after undergoing an eccentrics program and compare those effects to those of a static stretching program.

Effects of Eccentric Exercise

In the study, all eccentric exercises were completed with no additional resistance other than bodyweight. It was found that significant differences in flexibility were noted after undergoing the eccentric exercise protocols. Orishimo and McHugh (2015) conducted a four-week long study where the participants participated in eccentric exercises three days per week and found that flexibility gains were noted. Like the methods of Orishimo and McHugh (2015) participants in this study underwent training sessions three days per week but for a slightly longer duration. The results of this study showed that the eccentric exercise home program did, in fact, increase flexibility in the hamstrings. Muhammad and Afiq (2018) also evaluated eccentric exercise for short duration as their subjects underwent eccentric exercise training three days per week for eight weeks. The results of their study found that with the exercise group, hamstring tightness was significantly reduced. The study done by Muhammad and Afiq (2018) differed from the current study in that the participants used resistance bands to add tension to eccentric movements whereas the participants in the current study used bodyweight exercises to elicit changes.

In the current study, training variables chosen were based on previous research to stimulate changes in flexibility. Muhammad and Afiq (2018) suggested that increases can be seen with three training sessions per week. Orishimo and McHugh (2015) suggested that a four-week study may note short duration changes in flexibility. The current study combined the lengths of the two studies and was six weeks long. Orishimo and McHugh (2015) also demonstrated that bodyweight eccentric exercises such as the ones chosen for the current study. While deviating from the normal approach of having a given additional resistance or load, could elicit changes in flexibility. Static stretching durations were selected based off research conducted by Depino et al. (2000) who suggested that shorter static stretching durations, such as 30 seconds with short rest between bouts, demonstrated changes in flexibility as well.

Eccentric Exercise Compared to Static Stretching

The results of this study suggest that there were no significant differences between groups. There are multiple reasons that could account for the lack of significance between groups, the first being the total volume of exercise. The eccentric exercise group followed protocols suggested by Orishimo and McHugh (2015) as well as Muhammad and Afiq (2018). Mike and colleagues (2017) suggested that by having longer eccentric portions of movements they saw significant increases in power production and for that reason the time of eccentric contraction chosen for the study was five seconds. However, for the static stretching group the total time was only one minute per limb per stretch. Depino and colleagues (2000) suggested 30 second bouts of exercise to elicit increases in flexibility and Takeuchi and Nakamura (2020) suggested 20 second bouts of a high intensity static stretch would also elicit changes in flexibility. Because of that the 30 second duration was chosen for each bout, with a 60 second total duration being suggested to enhance hamstring flexibility according to Cini and colleagues (2017). Another reason that shorter bouts of stretching were selected came from suggested findings of Siebert and colleagues (2020). Those authors found that, prolonged static stretching can, without a dynamic warm-up, have an adverse effect and decrease performance in athletes.

Limitations

The current study had multiple limitations. While the aim of the study was to determine if eccentric exercise could improve flexibility, it also compared of effects of eccentric to those of static stretching. One of the limitations of this study is that all exercise sessions were unsupervised. While Orishimo and McHugh (2010) support this method, supervised sessions would ensure proper movement was maintained throughout the sessions. While most of the participants were diligent in their attempts, there were six sets of data that were excluded due to a lack of adherence to protocols. Those subjects did not perform the necessary exercises three nonconsecutive days per week for the duration of the study.

Another limitation of the study was the short time frame. While research from Orishimo and McHugh (2015) as well as Morton et al. (2011) suggested that eccentric exercise as well as static stretching worked well in noting changes in flexibility over a short period of time, a longer study may provide more information and possibly show significant differences between training groups.

A final limitation to the study is the time between the subjects last training session and the post-test screening. Depino and colleagues (2000) suggested that effects of static stretching were no longer seen six-minutes after intervention and Iwata and colleagues (2019) suggest that after 15 minutes effects of static stretching were no longer apparent. However due to conveniency to the participants the post-test screening was unable to happen directly after the subject's last session.

Recommendations

Future research in this area could include a much larger population of subjects ranging from younger individuals to older individuals. It is also important for the investigator(s) of the study to be present during training sessions to ensure proper movement mechanics and execution. Additionally, varying the participant population with groups of individuals who are highly trained and compare the results to untrained individuals may be beneficial. There is limited research currently on the topic of eccentric exercise in noting its ability to enhance flexibility. It could also be beneficial to compare eccentric exercise under load and static stretching according to ACSM guidelines. For eccentric training under load using protocols similar to Marušič and colleagues (2020) which consisted of a six-week period, participants underwent eccentric training for two sessions weekly. For static stretching as ACSM recommends (Reibe et al., 2018), stretching for seven days per week for a total of 60 seconds per stretch per limb, and then noting the differences over a six-week period. Another aspect to consider for future study is supervised sessions. The current study selected a 90 percent adherence rate as suggested by Mikesky and colleagues (1994). With a supervised training session, it can be ensured the entire eccentric portion of movement is being maintained for the proper amount of time, or possibly using a timer or stopwatch to ensure proper time under tension.

Conclusions

The purpose of this research was to assess the effects of eccentric exercise as well as static stretching on flexibility following a six-week training intervention. Post intervention the results showed significant changes in both the eccentric exercise and the static stretching group. With the results and limitations in mind it can be concluded that eccentric exercise significantly increased flexibility in the modified Sit-and-Reach, Standing Knee Curl, and active hamstring raise tests. It can also be concluded that there was no significant difference between eccentric exercise and static stretching in improving flexibility. Future research in this area could include a much larger population of subjects ranging from younger individuals to older individuals, supervised sessions, and possibly less frequent sessions to determine if less eccentric work can still elicit significant changes in flexibility.

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APPENDIX A

HEALTH HISTORY QUESTIONNAIRE

All questions contained in this questionnaire are strictly confidential and will become part of your medical record.

Name (Last, First, M.I.):	☐ M ☐ F	DOB:
Marital status: ☐ Single ☐ Partnered ☐ Married ☐ Separated ☐ Divorced ☐ Widowed		
Previous or referring doctor:	Date of last physical exam:	

PERSONAL HEALTH HISTORY

Childhood illness: ☐ Measles ☐ Mumps ☐ Rubella ☐ Chickenpox ☐ Rheumatic Fever ☐ Polio		
List any medical problems that other doctors have diagnosed		
Surgeries		
Year	Reason	Hospital
Other hospitalizations		
Year	Reason	Hospital

List your prescribed drugs and over-the-counter drugs, such as vitamins and inhalers		
Name the Drug	Strength	Frequency Taken
Allergies to medications		
Name the Drug	Reaction You Had	

HEALTH HABITS

All questions contained in this questionnaire will be kept strictly confidential.				
Exercise	☐ Sedentary (No exercise)			
	☐ Mild exercise (i.e., climb stairs, walk 3 blocks, golf)			
	☐ Occasional vigorous exercise (i.e., work or recreation, less than 4x/week for 30 min.)			
	☐ Regular vigorous exercise (i.e., work or recreation 4x/week for 30 minutes)			
	Do you know what eccentrics are?		☐ Yes	☐ No
	If yes, have you ever done an eccentrics program?		☐ Yes	☐ No
	Do you currently stretch?	☐ Yes	☐ No	
	If yes, is it dynamic or static?	☐ Dynamic	☐ Static	
Caffeine	☐ None	☐ Coffee	☐ Tea	
	# of cups/cans per day?			

FAMILY HEALTH HISTORY

	Age	Significant Health Problems		Age	Significant Health Problems
Father			Children	☐ M ☐ F	
Mother				☐ M ☐ F	
Sibling	☐ M ☐ F			☐ M ☐ F	
	☐ M ☐ F			☐ M ☐ F	

APPENDIX B

2020 PAR-Q+

The Physical Activity Readiness Questionnaire for Everyone

The health benefits of regular physical activity are clear; more people should engage in physical activity every day of the week. Participating in physical activity is very safe for MOST people. This questionnaire will tell you whether it is necessary for you to seek further advice from your doctor OR a qualified exercise professional before becoming more physically active.

GENERAL HEALTH QUESTIONS

Please read the 7 questions below carefully and answer each one honestly: check YES or **NO**.	**YES**	**NO**
1) Has your doctor ever said that you have a heart condition **OR** high blood pressure ?		
2) Do you feel pain in your chest at rest, during your daily activities of living, **OR** when you do physical activity?		
3) Do you lose balance because of dizziness **OR** have you lost consciousness in the last 12 months? Please answer **NO** if your dizziness was associated with over-breathing (including during vigorous exercise).		
4) Have you ever been diagnosed with another chronic medical condition (other than heart disease or high blood pressure)? **PLEASE LIST CONDITION(S) HERE:**		
5) Are you currently taking prescribed medications for a chronic medical condition? **PLEASE LIST CONDITION(S) AND MEDICATIONS HERE:**		
6) Do you currently have (or have had within the past 12 months) a bone, joint, or soft tissue (muscle, ligament, or tendon) problem that could be made worse by becoming more physically active? Please answer **NO** if you had a problem in the past, but it **does not limit your current ability** to be physically active. **PLEASE LIST CONDITION(S) HERE:**		
7) Has your doctor ever said that you should only do medically supervised physical activity?		

APPENDIX C

VOLUNTARY AGREEMENT CONSENT

Assessment, Testing, and Prescription Lab
Kinesiology, Sport & Recreation Department
Eastern Illinois University

PATCITIPATION NAME___________________________ DATE_________________

I hereby consent to voluntarily to participate in the study investigating the acute effects of eccentrics/static stretching on flexibility. I will engage in one specific type of exercise to determine the effects of that method of exercise on flexibility. I have been informed that my time commitment is about 30 minutes in person and three sessions per week for the next six weeks at home and that I should wear clothes that allow for free movement during testing sessions.

It is my understanding that I will complete a questionnaire about my health history regarding any current conditions or symptoms that might be contradictory for exercise.

I have been informed that the purpose of this test is to determine the relationship between eccentrics/static stretching and flexibility. Pre-intervention testing will be done in the Assessment, Testing and Prescription Lab at EIU. During this testing I understand that I must wear a mask the entire time.

There exists the possibility that certain abnormalities may occur while exercising such as, muscle soreness or tightness. Every effort will be made to minimize these risks by providing a briefing session as well as exercise videos to ensure proper form is maintained through the duration of the exercise sessions done at home.

I understand that I have the responsibility to be honest and forthcoming in providing information about my medical history and any untoward symptoms that I experience before, during or after the test. I have read the foregoing information and understand it. Questions concerning this study have been answered to my satisfaction. I have also been informed that the information derived from this test is confidential and will not be disclosed to anyone other than those that are involved in my care or exercise prescription without my expressed written consent. I also understand that I will be able to terminate my participation in the study anytime without penalty.

Participant Signature________________________________ Date________________

Witness________________________________

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APPENDIX D

Eccentric Exercises

Standing Hip Extension

Standing Split

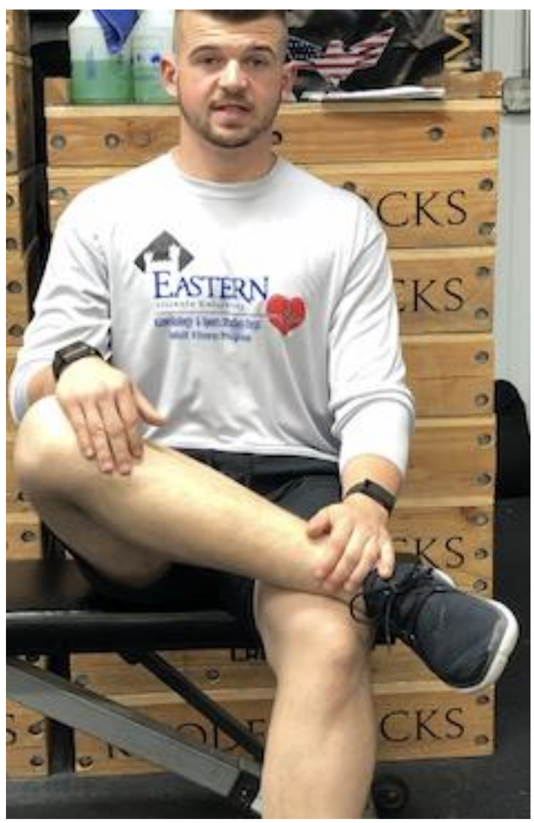
Straight Leg Lowering

Lying Leg Curl

APPENDIX E

Static Stretches

Standing Leg Hamstring Stretch



Piriformis Stretch

Standing Quad Stretch

Seated Forward Fold

APPENDIX F

Workout Logs

Workout Log – Eccentrics Group Member							
Exercise Performed	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Standing Hip Extension							
Standing Split							
Straight Leg Lowering							
Leg Curl							

Workout Log – Static Stretching Group Member							
Exercise Performed	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Standing Leg Hamstring Stretch							
Standing Quad Stretch							
Seated Forward Fold							