EFFECTS OF NEURAL TENSION ON HAMSTRING FLEXIBILITY IN COLLEGIATE DANCERS: NEURAL GLIDING VS. DYNAMIC STRETCHING

An Undergraduate Research Scholars Thesis

by

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RESEARCH COMPLIANCE CERTIFICATION

Research activities involving the use of human subjects, vertebrate animals, and/or biohazards must be reviewed and approved by the appropriate Texas A&M University regulatory research committee (i.e., IRB, IACUC, IBC) before the activity can commence. This requirement applies to activities conducted at Texas A&M and to activities conducted at non-Texas A&M facilities or institutions. In both cases, students are responsible for working with the relevant Texas A&M research compliance program to ensure and document that all Texas A&M compliance obligations are met before the study begins.

We, Julianna Barraza[1], Ella Cox[2], and Kailyn Williams[3], certify that all research compliance requirements related to this Undergraduate Research Scholars thesis have been addressed with my Research Faculty Advisor prior to the collection of any data used in this final thesis submission.

This project required approval from the Texas A&M University Research Compliance & Biosafety office.

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TABLE OF CONTENTS

Page

ABSTRACT

Effects of Neural Tension on Hamstring Flexibility on Collegiate Dancers: Neural Gliding vs. Dynamic Stretching

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Dancers are required to have extraordinary hamstring flexibility to conform to the demanding physical standards of many dance genres. Neural Gliding is a technique used to increase mobility in the nervous system itself or surrounding muscular structures. Dynamic stretching is an active form of stretching, used to strengthen and increase the range of motion within the muscles and joints. The purpose of the study was to compare and contrast the effects of integrating Dynamic stretching or Neural Gliding techniques into a dancer's training regimen to improve overall hamstring flexibility. Twenty-one female collegiate dancers, ages 18-22, participated in the study. The participants were randomly divided into three groups: Dynamic stretching group (DS), Neural Gliding group (NG), and control group (CG). DS had seven participants, the NG had eight participants and the CG had six participants. All groups completed a pre, mid and post-test looking at hamstring flexibility. Participants in the DS and NG completed 8 weeks of intervention training including: a general warm-up, a stretching routine specific to their group, and a general cool-down. There were no statistically significant

differences between groups. Although, it was observed that the DG had the largest improvement on the right side in hamstring flexibility compared to the NG and CG. The left side measurements yielded no real improvement in hamstring flexibility for any group. Not all participants tested positive for neural tension during the pre-test. This inconsistency may have contributed to the lack of improvement in hamstring flexibility for the NG. Further research is needed to see if Neural Gliding can lead to improved hamstring flexibility for individuals who present with neural tension.

DEDICATION

To our family, friends, professors, and TAMU dance department for supporting us throughout this research process.

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NOMENCLATURE

Battement	Beating. A beating action of the extended or bent leg.
Grand Battement	An exercise in which the working leg is raised from the hip into the air and brought down again, the accent being on the downward movement, both knees straight.
Penché	Leaning, inclining.
Grand jeté	Large jeté. Throwing step. A jump from one foot to the other in which the working leg is brushed into the air and appears to have been thrown.
Développé	Developing movement. A développé is a movement in which the working leg is drawn up to the knee of the supporting leg and slowly extended to an open position in the air and held with perfect control.

1. INTRODUCTION

Dance Science is still an emerging field and has limited published research due to the small population sample in most areas. Stretching is one area that has been addressed by several dance-specific intervention projects. Dancers are known for their extreme flexibility and athletic ability. Classical dance training and performance requires dancers to engage in extreme hip flexion with knee extension, as in grand battement, grand jeté, and développé. The hamstrings must have enough extension to accommodate these movements without putting the dancer at risk of injury. Static stretching before activity was the traditional approach in dance training. Since the emergence of new research, dancers have begun practicing different forms of stretching, to fully lengthen muscles and acquire a full range of motion in the joints.

There are multitudes of different types of stretching that are commonly practiced. These include Ballistic, Static, Dynamic, Neural Gliding, and Prolonged stretching. The effectiveness of increasing hamstring flexibility is discussed in the following sections. Different methods of stretching have various benefits and are unique in their methodology to increase flexibility.

Static stretching is a method of stretching where the individual holds a position for an allotted amount of time (typically 15-45 seconds), to lengthen the muscle fibers. Static stretching is used to increase muscle fiber length and should be performed in a cool-down routine following physical activity. This allows the muscle fibers to relax after strenuous activity, thus preventing soreness and fatigue. According to Bandy et al. (1998), which compared the effects of Static stretching versus Dynamic stretching on a general population of men and women ages 21-41, a 30-second Static stretch performed “one time per day over 6 weeks resulted in more than twice the gains in hamstring flexibility than performing [dynamic stretching] at the same frequency and duration". A study completed at Brigham Young University in 2013 was also interested in the effects that Static stretching has on hamstring flexibility. This study followed an intervention approach, including a control group, and 2 different stretching groups to see if there was a significant change in hamstring flexibility measured by knee ROM at a 90-degree angle. Researchers found that "stretching for 6 weeks for a total of 90 s [seconds] showed increased joint ROM regardless of the number of repetitions or the duration of each stretch" (Johnson et al., 2013). This conclusion added to the research previously completed that Static stretching is effective in increasing flexibility no matter how long the Static stretch is held for.

On the contrary, Lima et al. (2018) used ballet dancers and resistance-trained women to compare the effects of Dynamic stretching and Static stretching. Dynamic stretching is a continuous repetitive movement where the muscles are lengthened to their maximum potential. Lima et al. (2018) found no significant difference in the decreased hamstring to quadriceps length ratio between the Dynamic and Static stretching groups.

An article published in The Journal of Sports Medicine, on a population of male and female modern dancers, reported that Static stretching may not "be suitable for use prior to maximal strength exercises" (Agopyan et al., 2013). This observation is important since traditionally dance classes begin with Static stretching to prepare the body. Rather than using Static stretching as a preparatory exercise, it ideally should be used as a cool down to "maintain joint range of motion and current flexibility" Critchfield (2011). Further research found that static stretching is detrimental to muscular endurance and power. This idea is supported by Ikeda & Ryushi (2021) in a study evaluating flexibility and muscular performance in young men. This showed that using static stretching increases ROM in knee extensors but decreased muscular endurance, supporting that static stretching should be reserved for post activity. The effects of

Static stretching amongst the mentioned studies above concurs with the findings of Ikeda & Ryushi (2021).

In comparison to Static stretching, it has been shown that Dynamic stretching may increase the range of motion and strength since the joint is being actively moved rather than held in one position. Dynamic stretching, "begins from a neutral position, followed by a slow movement (4-5 seconds) of the limb to end range, a brief hold at end range (4-5 seconds), and, finally, slowly (4-5 seconds) moving the limb back to the original neutral position using an eccentric contraction" (Bandy et. al, 1998). During dynamic stretching, the antagonist muscle (the muscle that opposes the action) is contracting while the muscle being lengthened is allowed to relax, thus increasing flexibility (Bandy et. al, 1998).

Since Dynamic stretching is one of the more common stretching methods used today, there have been studies investigating the effects of stretching on injury, as well as the effects of Dynamic stretching on passive stiffness of the hamstring muscles. A study completed in Japan in 2019 added to this area of research. They found that increased passive stiffness of the hamstrings and decreased knee ROM are both risk factors for hamstring injury during sports (Iwata et al., 2019). They state that Dynamic stretching performed during a warm-up is beneficial for the hamstring muscles by increasing flexibility and reducing stiffness. This type of dynamic warm-up concluded a significantly higher ROM (range, 7.4%–10%), and passive stiffness was significantly lower (range, 5.4%–14.9%) in the experimental group. (Iwata et al., 2019) This research connected the dots between passive stiffness in the hamstrings, Dynamic stretching as a warm-up, and how this may affect injury prevention. This study was not designed or interested in the injury prevention aspect of Dynamic stretching, as much as the focus being on the increase of flexibility that Dynamic stretching may produce.

In opposition to the previously mentioned research, a study conducted by Bandy et al. (1998) divided participants into three groups where they were asked to perform a set of exercises five times a week for six weeks. The results of this study found that Dynamic stretching was not as effective in increasing the range of motion as Static stretching. It was inconclusive in determining whether or not hamstring flexibility would increase from the implementation of Dynamic stretching. In summation, Dynamic stretching is most effective as a warm-up prior to exercise to reduce stiffness and is not as effective in increasing range of motion.

Ballistic stretching is commonly used in jazz techniques to warm up the body and prepare for high-intensity movements such as battement and leaps. Ballistic stretching requires the body to be warm to prevent soft tissue injury since the muscle is extended beyond natural extensibility (Critchfield, 2011). Ballistic stretching causes the sensory fibers to react quickly to prevent injury therefore, "...more of the stretch energy to be absorbed by the muscle at the end of the motion" (Critchfield, 2011). Compared to Dynamic stretching, ballistic stretching is less controlled and not as safe to perform over an extended period. According to prior research, it can be concluded that Dynamic stretching is a more effective form of stretching compared to Ballistic stretching.

PNF is a stretching technique implemented in both therapeutic and athletic settings to increase the range of motion and rehabilitate invasive tissue injuries. Hindle et al. (2012) review the possible theories and physiological changes that can occur due to implementing PNF stretching. If done consistently, post-exercise, PNF is shown to increase athletic performance and range of motion. PNF is fairly similar to Neural Gliding in that it focuses on increasing muscle elasticity.

An article published in the International Journal of Sports Physical Therapy discusses the current concepts of stretching in sports rehabilitation. In addition to the discussion on the wide range of types of stretches, Page (2012) categorizes Proprioceptive Neuromuscular Facilitation stretching as the most common type of "pre-contraction stretching." PNF is divided into Contract Relax, Hold Relax and Contract-Relax Agonist Contract. These are all generally performed by having the subject contract the muscle 75% to 100% of their maximal contraction, hold for 10 seconds, then relax. PNF stretching, as well as Static stretching, is considered effective in increasing hamstring flexibility by researchers alike. In 2016, Lobel found that using the PNF contract/release stretching method provided greater results in standing hip range of motion than an active stretch method. With a population of university female dancers, Lobel (2016) used two stretching techniques: active stretch (Bartenieff Fundamentals™ thigh lift) and passive stretching (PNF contract release form). Though both groups showed improvement, the greatest increase came from the passive stretching group.

As of recent discovery, neural tension is a lurking variable of hamstring tightness and inflexibility. Neural Gliding is a method of tension relief used by physical therapists, chiropractors, and athletic trainers with patients with numerous symptoms. A study published in 2019 in South Africa used a novel approach to looking at hamstring flexibility, this study looked at the effects of postural alignment and hamstring tightness in a general population of men and women ages 18-24. The main goal was to look at different approaches to increase hamstring flexibility to try to decrease musculoskeletal pain from poor posture. They stated that passive stretching of hamstring muscles improves flexibility. However, the use of nerve gliding in addition to passive stretching of hamstrings could result in more flexibility. They state that hamstring flexibility may reduce the risk of musculoskeletal pain (Alshammari et al., 2019).

They followed an intervention approach and had 3 different groups. All groups included a passive hamstring stretch. One group used the “Tibial nerve neurodynamic technique” and the other group used “Quadriceps activation.” This study found that there was a significant improvement in hamstring flexibility in the group that used the quadricep activation as well as passive stretching, compared to the groups that only received passive hamstring stretching.

According to Bonser (2017) in Changes in Hamstring Range of Motion After Neurodynamic Sciatic Sliders, typical treatments for muscle stiffness are treated with Static stretching. Bonser’s research poses the question that is similar to this current study: what alternative methods are there to decrease muscle stiffness, specifically hamstring stiffness and inflexibility, other than Static stretching? Is there one more effective than the other? This review narrows the scope down to neurodynamic sliders and Static stretching. Bonser reviewed a total of four studies: 2 well-designed and 2 less-well-designed studies, including a variety of populations with different inclusion criteria. In the 2 well-designed studies, the results concluded that neurodynamic sliders were most effective and the 2 less-well-designed studies resulted inconclusive in revealing one more effective than the other. Bonser concludes that there is significant evidence that Neural Gliding increases the hamstring range of motion when hamstring stiffness is present. However, in comparison to other methods of stretching, results are not as statistically significant, formulating inconclusive results.

Furthering the discovery of which methods of stretching increase hamstring flexibility most effectively, a European study completed in 2020 investigated the direct and immediate effects of Neural Gliding versus Static stretching (Satkunskiene, et., al 2020). The primary investigators had a group of 22 men that were 18-26 years old and categorized themselves as highly active. From there they were divided into two groups, a neural dynamic group, and a

Static stretching group. The intervention completed was only done on each participant's right leg and was manually performed by the research team themselves. Their results concluded that neural gliding techniques showed an “extent greater acute increase in hamstring extensibility and passive stiffness at the maximum ROM” (Satkunskiene, et., al 2020). While the effects were minimal, there was an increase in hamstring flexibility over the Static stretching groups. Similarly, the hamstring flexibility results were inconclusive in Waldhelm et al. (2019), in that the addition of Neural Gliding protocols did not negatively affect athletic performance. Waldhelm et al. (2019) investigated the acute effects of sciatic nerve gliding versus lower extremity Dynamic stretching on hamstring flexibility and athletic performance.

The area of Sports Science research is advanced in comparison to the research on dancer-specific hamstring flexibility. The previously mentioned studies provided a foundation for the design and purpose of this study. The TAMU Dance Program students were split into three groups: Neural Gliding, Dynamic stretching, and control. Flexibility was measured in pre, mid, and post-testing using the Slump Test to indicate nerve tension and measuring straight leg hip flexion with a goniometer to assess hamstring length. The Neurodynamic Assessment, or the Neural Tension Slump Test, is a manual therapy test used to “[evaluate] the length and mobility of various components of the nervous system” (Neurodynamic Assessment, n.d.). Neural tension can range anywhere from the cervical spine, the brachioradialis nerve, and the sciatic nerve. Due to the nature of the study, sciatic neural tension is assessed. Neural tension can be identified by the verbal response of the patient claiming a “deep ache or stretch” and “definite tingling sensation” (Neurodynamic Assessment, n.d.), in the lower back and the hamstring. This study focused on lower extremity neural gliding at the hip joint. It was theorized that greater hamstring flexibility would be seen in the Neural Gliding group thus proving that neural tension can be a contributing factor in hamstring tightness.

2. METHODS

2.1 Participants

All 21 participants were collegiate dancers, ranging from ages 18-22 years old with an average weight of 140.19 lbs (SD of ± 21.346239) and an average height of 65.5 inches (SD of ± 2.731649). It was required that participants be enrolled in the TAMU Dance Science Program and be free of lower extremity injuries at the time of the study. All the participants were female, though the study was open to male participants, there is only one male enrolled in the TAMU Dance Science Program at this time and he did not participate in this study. Participants were recruited through several methods including a mass email (sent to the entire TAMU dance program), flyers in the dance studios on the TAMU campus, live announcements made in TAMU dance program technique classes, and social media postings to the Dance Program Facebook group. All participants completed a medical history questionnaire and an informed consent form before the start of the study. The participants were randomly divided into three groups: dynamic stretching group (DS), neural gliding group (NG), and control group (CG).

2.2 COVID-19 Protocols

This research was conducted during the COVID-19 pandemic, therefore, extra protocols were developed by the research team and approved by the TAMU Division of Research. For the pre, mid, and post-tests, participants scheduled individual times to allow for them to complete the warm-up and testing before the next participant arrived. Space and the equipment were disinfected between each participant, researchers and participants wore a mask the entire time and hand sanitizer was used before and after any contact. During all intervention sessions, participants were allowed to attend in person on campus or virtually via Zoom. The studio on campus where all the training sessions were held was marked by 7 foot by 7-foot boxes taped on the floor. Participants were required to stay in one of these squares or at least 6 feet apart during all training sessions. All researchers and participants were required to wear a mask at all times. Hand sanitizer was used before and after any contact and space had been sprayed with a 45-day anti-microbial shield product (this was applied once a month for the entire semester).

2.3 Pre, Mid, Post-Test

The pre, mid, and post-test all began with a 5-minute warm-up, a hamstring flexibility test measured by a Goniometer, a Neural Tension Slump Test, and a questionnaire to evaluate their relative hamstring flexibility and any indication of neural tension. The participants were not instructed to complete a cool-down at the end of the pre, mid, and post-testing. The warm-up consisted of 20 alternating stationary lunges, 20 alternating stationary side lunges, 15 parallel squats, 15 jumping jacks, a 30-second plank timed with a stopwatch application, and 10 leg swings in attitude from first position on each leg (20 total).

To administer the Hamstring Flexibility Test, based on the directions provided by Trinity Laban Conservatoire of Music and Dance, the participant begins the test by lying supine on a firm surface, arms by their sides with palms facing downwards. The participant should be instructed to lie symmetrically with both heels, buttocks, and shoulders in contact with the surface. The participant is instructed to raise one leg by flexing the hip. The knee must remain fully extended during this movement (even small amounts of knee flexion would affect the validity of the score). The goniometer is used to measure the angle between a line drawn from the greater trochanter to the proximal head of the fibula and the horizontal. Repeat three times on the right and then three times on the left. An average should be provided for the right and left sides. The degree on the goniometer that indicates a tight hamstring length in a dancer ranges from 0 degrees to 110 degrees. Borderline tight hamstrings for a dancer population is 111 to 119 degrees. 120 to 180 degrees on the goniometer is considered “within normal limits” expected of a dancer.

To perform the Neural Tension Slump Test, instruct the participant to sit on the edge of a PT table or chair, legs relaxed, and to sit up tall. Tell the participant to slump down in their lower back, as if relaxing on a couch. Then, instruct them to extend their right leg with a flexed foot. Lastly, ask the participant to tuck their chin to their chest. The participant would then indicate if they had pain or discomfort down their right leg or lower back. Repeat on the left side. A Slump Test can result in one of two ways: positive or negative. A positive Slump Test result occurs when the participant verbally indicates they have pain or discomfort in the leg that is raised. A negative slump test result occurs when the participant does not indicate pain or discomfort in the leg that is raised.

The participants were asked to complete a questionnaire at the end of the pretesting and post-testing. Each questionnaire included 6 questions. The pretest included questions about which technique level they are enrolled in, if any, and if they have had previous injuries. There were questions asking participants to say what they hope to gain from being in this study, as well as a question asking the participants if they believe this training would improve their hamstring flexibility. They were also asked to rate from 1-5 their overall hamstring flexibility, with 5 being most flexible and 1 being least flexible, as well as rate the severity of pain or discomfort in the hamstrings, from 1-5, with 5 being very severe pain and 1 being no pain at all. The post-test survey included questions regarding which intervention group they were assigned to, which technique class they are enrolled in currently, if any, as well as an open-ended question if the participant had comments on their improvement or lack thereof with the training that they participated in. The participants also rated their overall hamstring flexibility from 1-5, as well as rating the severity of their pain or discomfort in the hamstrings also from 1-5. The scale was the same as the survey given during the pretesting.

2.4 Training Sessions

The DS and NG went through 8 weeks of intervention training between the pretest and the post-test, while the CG was instructed not to alter their normal routine. During the 8-week intervention, the DS & NG trained 3 days a week and started every intervention with the same 5-minute warm-up from the pre, mid, post-tests. The training sessions were offered at two separate times each intervention day to allow for ease in scheduling the participants. There was more than one participant per training session. Participant's numbers were used during the training sessions to maintain confidentiality. After each training session, both groups completed a 5-minute cool-down with the following stretches: figure 4 stretch lying supine, low lunge with a knee off the ground, psoas stretch is done with one knee on the ground, seated adductor stretch with legs in a V position, legs crossed, seated lateral spine stretch and spiral spine stretch. Each stretch was held for 20 seconds on both the right and left sides of the body. This was timed with a stopwatch app.

Participants in the dynamic stretching group and the neural gliding group were required to warm up in the same manner to begin intervention each day. Before pre-testing, mid-testing, and post-testing, participants in all three groups were asked to perform this warm-up to ensure safe and adequate measurements of the hamstrings.

2.5 Dynamic Stretching Trainings

After the group warm-up, the dynamic stretching group began with supine lying battements in both plantar flexion and dorsiflexion. Battements, or kicks, are defined in this experiment as extreme hip flexion with knee extension and plantar flexion at the ankle. This is done while maintaining a neutral pelvis and keeping a straight standing leg. The participants completed 8 battements (kicks) on each leg in plantar flexion, then completed 8 kicks on each side in dorsiflexion. The group would then stand up to complete 16 total walking battements across the floor by alternating the right and left leg while in plantar flexion, proceeded by 16 alternating battements across the floor while the ankle is in dorsiflexion. Upon completion of the supine and walking battements, the participants completed 10 penches on each side. In this intervention, the participants performed a variation on a classical penche. In this version, the torso was allowed to be relaxed forward, with the hands placed on the floor. The goal was to dynamically battement the leg in the posterior so that the toe reaches for the ceiling. This may be more commonly called a forward bend battement derriere. This completed the intervention protocol that the dynamic group underwent throughout the study. The participants were instructed to count each exercise set on their own time.

2.6 Neural Gliding Training

Following the group warm-up, the neural gliding participants began with supine neural glides, completing 2 sets of 10 on both legs. Next, the NG would sit upright and would begin seated with one leg extended neural glides, performing 2 sets of 10 with both legs alternating being extended. Then the participants would extend both legs in front of them, while seated, and complete 2 sets of 10 seated pike neural glides. Finally, the NG would lay prone and perform prone neural glides with 2 sets of 10 alternating legs with each set. This completed the intervention protocol that the neural gliding group underwent throughout the study. Participants were under the supervision of one of three research team members and were instructed to count and complete their exercises on their own time.

3. RESULTS

3.1 Statistical Analysis

Once all data was collected from each of the testing periods, one-way ANOVA was used to determine whether any statistically significant improvements were seen. Using the pre-test and the post-test measurements for hamstring flexibility, the differences were calculated for each participant on both legs. There were no statistically significant differences between group means (Left Side - ($F(2, 18)=.0058$, $p=0.99$)) (Right Side - ($F(2,18)=2.07$, $p=0.155$)). Though there were no statistically significant results found, it was observed that the DG had the largest improvement on the right side in hamstring flexibility ($M = 17$, $SD = 11.3$) compared to the NG ($M = 9.5$, $SD = 10.88$) and the CG ($M = 5.33$, $SD = 9$). The left side measurements yielded no real improvement in hamstring flexibility for any group: DG ($M = 8.14$, $SD = 9.44$), NG ($M = 7.88$, $SD = 6.5$) and CG ($M = 8.14$, $SD = 8.02$).

3.2 Dynamic Stretching Group Results

When observing the data collected from the neural Slump Test, all of the participants in the DS group except for one, were negative for tension in the pre-test. The participant who was positive for tension on both legs during the pre-test was later determined to be negative in the post-test. Two participants that started off the study as negative later developed signs of positive tension. This is likely due to starting the semester with very little consistent dance training during the summer months then immediately returning to high-intensity training regimes. According to Figure 3.1, overall hamstring flexibility improvement on the right side was greatest in the DS group. When looking at the data collected from the Hamstring Flexibility Test, all participants showed improvement $\geq 2°$ on the right hamstring. Two of the seven participants lost approximately three degrees of flexibility on the left leg. The remaining five participants showed improvement ≥7° on the left leg. For many dancers, the right side of the body is more dominant than the left side of the body. Therefore, the right side of the body tends to be more flexible, and stronger than the left side of the body. This could be the possible reasoning behind the stark contrast of improvement in the right hamstring versus the left hamstring.

3.3 Neural Gliding Group Results

Upon further investigation of the NG group Slump Test data, six of the eight participants were negative for tension during the pre-test and remained negative through the post-test. The other two participants started the intervention period as negative and developed positive tension by the post-testing period. There was not a significant difference noted between the right and left sides for the Slump Test. As stated previously, this could be due to an imbalance in training before pre-testing up until post-testing. According to Figure 3.2, the NG group had a larger improvement of ~7.9° on the left leg, which is greater than the ~5.25° improvement on the left leg in the DS group as seen in Figure 3.3. This could reveal potential that NG is more unilateral that DS. When considering the Hamstring Flexibility Test results for the NG group, five of the eight participants showed signs of developed flexibility ≥10° on the right leg. Two participants did not show any advancement between the pre-test and post-test. The final participant lost approximately six degrees of flexibility over the intervention period. The left leg showed much more considerable improvements than the right leg. Seven of the eight participants displayed increased flexibility on the left leg of ≥4°. Only one participant declined in flexibility of approximately 2 degrees on the left leg. Unlike the DS group, there was a more significant improvement on the left hamstring than the right hamstring for the NG group.

3.4 Control Group Results

The control group did not participate in the intervention process. The neural Slump Test was consistently negative for all of the participants on both legs except for one. The participant in question started negative during the pre-test but developed positive signs in the mid and post-test. Since the majority of the participants were negative from the start of the intervention it is difficult to tell whether or not the Slump Test was advantageous to the study. When observing the CG results for the Hamstring Flexibility Test, all participants showed improvement on the left leg of at least 3 degrees between the pre-test and post-test. Of the six participants in the CG, two declined in flexibility by approximately four degrees. According to Figure 3.4, the CG had a greater increase in left hamstring flexibility than both the NG and DS groups.

3.5 Survey Results

As previously mentioned, the participants were required to complete a questionnaire at the end of the pre-testing at the beginning of the intervention, as well as a similar questionnaire at the end of the intervention period. This survey was completely self-reporting. In this survey, 100% of participants stated that they had little to no pain or discomfort in hamstring flexibility in both the pre-test and the post-test surveys. Participants were asked an open-ended question at the end of the post-test survey asking if they thought they improved their hamstring flexibility throughout the study. Of the 57% of participants that responded to this question, 91.7% of those stated that they believed they have improved in hamstring flexibility overall throughout the study. The questionnaire was based on a scale of 1-5. An average of 2.90/5 was self-reported for hamstring flexibility in the pre-test questionnaire, the average then increased to 3.41/5 on the post-test questionnaire. The reported average of hamstring pain or discomfort present was 1.29/5 in the present, with no significant change in the post-test average of 1.27/5.

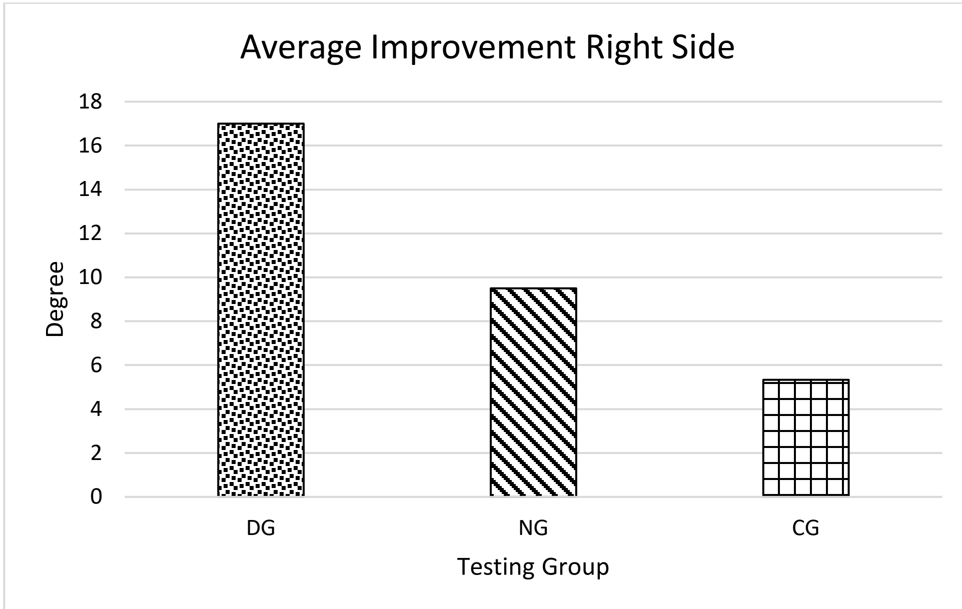

Figure 3.1: Average Improvement Right Side

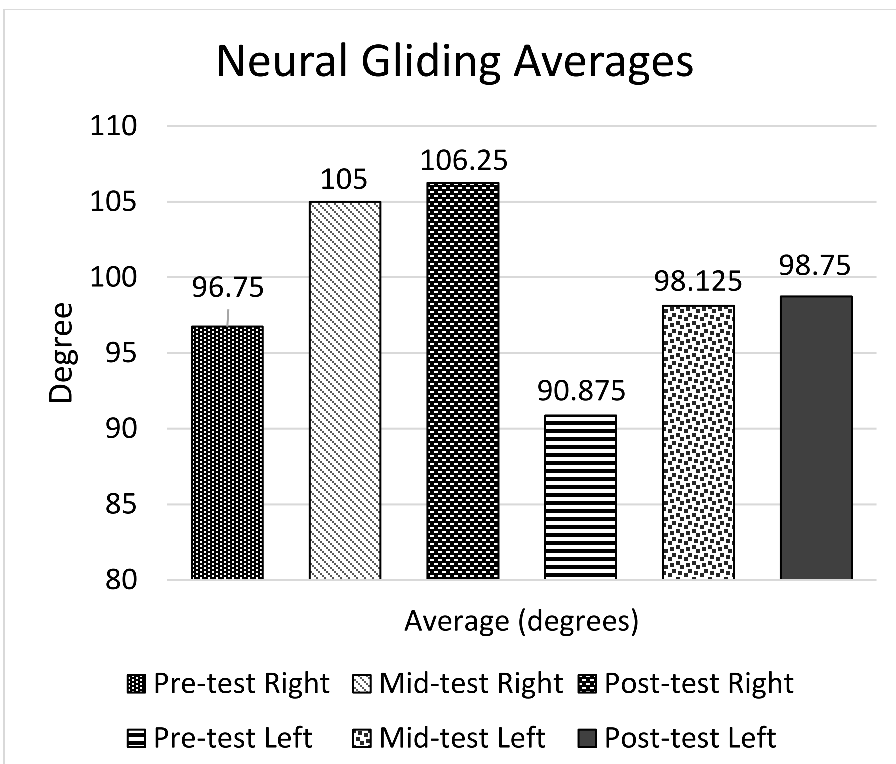

Figure 3.2: Neural Gliding Group Hamstring Degree Average

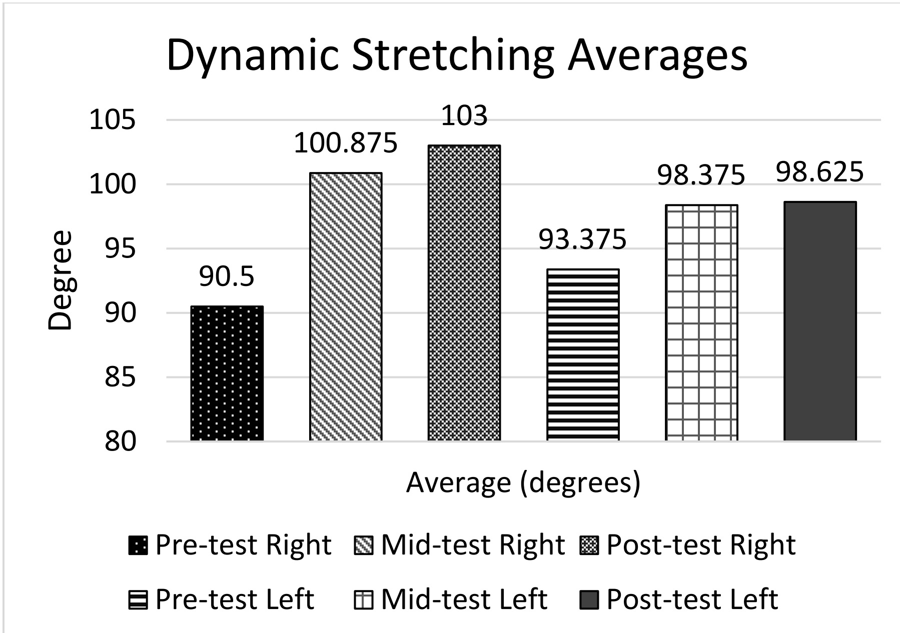

Figure 3.3: Dynamic Stretching Group Hamstring Degree Average

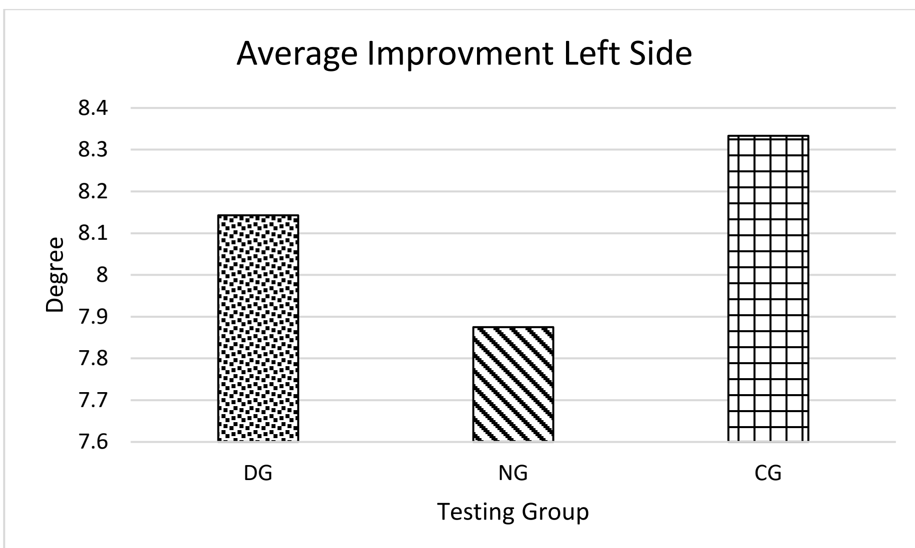

Figure 3.4: Average Improvement Left Side

4. CONCLUSION

After analyzing the results and research completed over the previous 9 months, there have been a multitude of questions, ideas, and discussion points that arose. It has been concluded that even though the specific study results are vague and insignificant, the results are now contributions to the furtherment of dance science research.

Through the progression of intervention, many limitations were discovered that could have been lurking variables in the collected data. The research process began alongside the start of the 2020 COVID-19 pandemic. Thus, forced many changes to be made and elicited creativity to continue the study in the face of CDC guidelines and the health of the participants. Once IRB approval was secured, permission was granted to facilitate a virtual intervention option for those who were forced to quarantine amid the 8 weeks via Zoom. This produced a potential limitation to the quality of the participants' intervention sessions. With at least one participant on Zoom each session, it increased the difficulty to supervise all participants equally. Additionally, participating in intervention online could have hindered the quality of the participant's intervention session as well due to limited space. However, Zoom was advantageous in increasing total participant numbers. In the past, participant recruitment in the TAMU Dance program has been scarce. Only one participant had to be removed from the analysis because they were unable to complete the post-test measurements due to COVID-19.

Another limitation that became apparent was the accuracy of the neural tension Slump Test. According to Neurodynamic Assessment, the Slump Test is a measurement tool to assess the level of pain or discomfort a patient is experiencing in areas of neural tension (elbow, neck, lower back, legs, etc.). The Slump Test presented discrepancies because the assessment is based on what the patient expresses to the assessor. In the approved testing protocol, each participant was asked when executing the Slump Test if they felt any pain or discomfort in their lower back and or lower leg. This test is subjective and self-reporting; therefore, the assessor cannot physically measure or prove the presence of tension or discomfort. This verbal test presents concerns for both the participant and the assessor. Depending on the cues given to the participant, their answer could vary depending on which researcher was collecting their data. This arose as a concern since there was an increase in positive neural tension results in the mid-test data. The cueing given by the research team may have been inadequate during the pre-test, thus could have resulted in inaccurate reports of neural tension. As of current knowledge, there is no mechanism or tool to measure neural tension more accurately. If there were to be a medical tool to assess the presence of neural tension, professionals such as doctors and therapists would be able to diagnose and record the progress of their patients more accurately. Such a measuring tool could advance rehabilitation to be more effective and precise so that those experiencing debilitating neural tension can recover.

With the primary population being collegiate dancers, other confounding variables could have caused the data to result inconclusive because of the population. For example, out of the 21 participants, 4 were not enrolled in a dance technique class in the TAMU Dance Program during the Fall 2020 semester. While this was only approximately 20%, all four were in either the NG or DG. Their data is weighted more heavily because they are in the experimental groups. The concern would not be as great if the participants were assigned to the control group. Ideally, all participants would be enrolled in a technique class to keep the testing conditions nearly identical for each participant. This could be a lurking variable to the measurements taken of hamstring flexibility. Generally, if a dancer is in continual training, their hamstring flexibility is regularly recruited because of the demands required in class. It was discovered that the most increase in hamstring flexibility in this study was found in the right hamstrings of the dynamic group. Interestingly enough, there was a slight increase in the left hamstring in the control group and the neural gliding groups. Another factor that could contribute to the high variation of data is the condition of the individual's body. One could have been experiencing muscular soreness from exercise or dance training, thus on testing days, their range of motion or physical state could have been different from their normal measurements.

According to the Dancer Wellness Project, they define a dancer's hamstring to be 120 to 180 degrees to be within normal limits. If a dancer is 0 degrees to 110 degrees their hamstrings are considered to be tight, and then "borderline tight" if they are between 111 to 119 degrees. The majority of the dancer population at A&M is not "within normal limits" rather, they are borderline or tight. Even though the TAMU dancers involved in the study are considered to have tight hamstrings, they are still hypermobile compared to the average population. Since dancers are constantly training their hypermobility, the degree of flexibility increase may not be as observably significant as it would on a non-hypermobile person.

Another variable that could be considered is the study design. Originally, the intent for the intervention was to serve as a cool-down for dancers in the TAMU Dance Program to complete after technique classes. Following the proper progression of a workout, a cool-down is necessary for muscles to recover and for the heart rate to return to resting rate. However, the majority of participants completed the weekly intervention before the technique class. Thus, serving as a warm-up, rather than a cool-down. Similarly, some participants completed intervention in between two classes. While a warm-up is just as crucial as a cool-down, the focus of the study was to see the effects of stretching methods, which should be done after class when muscles are warm and ready to be stretched. This could have caused the insignificance of the results due to the inconsistency of the intervention sessions. As previously mentioned, having the participants in near-identical environments would have protected the data from becoming misconstrued.

As the data, progress, and results are evaluated, there are many areas in which future investigators can improve and increase accuracy and significance. These areas include, but are not limited to, the Neural Slump Test and improving its accuracy in testing for neural tension, having a population that previously tested positive for neural tension, and finding more effective and definitive exercises that can better distinguish which technique is most effective in increasing hamstring flexibility. While it is recognized that both resources and participants were limited, this preliminary research has the potential to be replicated again in the future.

The research completed on the effects of Neural Gliding versus Dynamic stretching on hamstring flexibility is still in the beginning stages of acquiring data that is significant. With discoveries about potential lurking variables and how to design a more effective study, the path to unveiling the most effective and healthy way to increase hamstring flexibility for not only the dancer population but all who require hamstring flexibility.

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