IMPROVING KNEE ALIGNMENT IN DANCERS WITH HYPEREXTENSION: QUADRICEP STRENGTHENING VS. PRACTICING AND CUEING

An Undergraduate Research Scholars Thesis

by

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ABSTRACT

Improving Knee Alignment in Dancers with Hyperextension: Quadricep Strengthening vs. Practicing and Cueing

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The purpose of this study is to identify the most effective method to correct a dancer's hyperextension at the knee joint. Many dancers are hyperextended at the knee joint, which is defined as the ability for their knee to extend past 180°. This causes the knee joint to become unstable as dancers' reliable functionality decreases the further past 180° the knee can extend. This instability can cause a range of ligament injuries as well as provide a base for many alignment issues. The majority of dancers are not aware of their hyperextension until they enter a collegiate level dance training program. After years of training in hyperextension, it is difficult for the dancer identify the neutral position of the knee.

Collegiate level dancers were split into a control group, a strength training group, and a cueing group. The control group participated in pre and post testing and continued regular activity throughout the study. The strength training group performed exercises 3 times a week for 6 weeks targeting the quadriceps, hamstrings, and rotator muscles. The cueing group performed ballet combinations 3 times a week for 6 weeks that are centered around controlling instability of the standing leg while being provided internal and external based verbal cues to correct their

knee hyperextension. Both intervention groups were monitored during the training to evaluate proper alignment and engagement. The pre and post-tests measured passive and active knee hyperextension, video analysis of dance movements focusing on the standing leg, and a survey allowing the participant to self-report the perceived level of success in correcting hyperextension at the knee. The expectation is that the cueing group will have a greater level of success in correcting hyperextension in technique, thus lowering the probability that a dancer will sustain an injury to the ligaments of the knee.

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NOMENCLATURE

Plié	French: to bend; a bending of the knees to render joints and muscles soft and pliable.
Tendu	French: to stretch; a dancer pointing the foot and extending the leg while connected to the floor.
Dégagé	French: to disengage; pointing of the foot in an open position with fully arched instep.
Battement	French: beating; beating action of an extended or bent leg.
Promenade	French: turn in a walk; dancer slowly turns in place on one foot with a series of slight movements in the heel.
Attitude	A particular pose in dancing on one leg, with the other lifted in the back, with the knee bent at 90 degrees and lifted higher than the foot.
Adagio	French: ease or leisure; a series of exercises, consisting of a succession of slow, graceful movements, performed with fluidity and ease.
Devant	French: in front; refers to placing a limb in front of the body.
à la seconde	French: to the second; meaning the foot is to be placed in second position (the side of the body).
Derrière	French: behind, back; refers to a limb being placed behind the body.
Developpé	French: time developed; working leg drawn up the knee of the supporting leg and slowly extended to an open position
Détourné	French: turned aside; a pivot turn toward the back foot, reverses the position of the feet.
Arabesque	Profile position of the body with one leg extended behind the body at a right angle.

(Grant, G., 2018)

CHAPTER I

INTRODUCTION

Hyperextension of a joint is defined as "an increased flexibility of joints beyond the range of motion that is considered normal for an individual, taking into consideration age, sex, and ethnic background" (F. Desfor, 2003). Hyperextension is commonly found in the knee and elbow joints and is considered to be common in regular populations, but has been found to be more prevalent in dance populations. Research performed by Learmonth Klemp found a hypermobility rate of 9.5% among 377 ballet dancers, which can be compared to 4%-7% in the general population (M. Deighan, 2005). Those who are considered to be active and engaged in weight bearing exercise (jumping, lifting, running, etc.) are at a greater risk of injuring the ligaments in these hyperextended joints, due to the role they play in establishing knee stability (Lin, H. C., et al., 2009). Dancers have been markedly susceptible to these injuries, specifically in the knee, as aesthetics play a large role in the training of dancers. A common example of injury in dancers due to hyperextension in the knee joint is tearing of the anterior cruciate ligament (C. Teitz, 2000). Dancers with hyperextended knee joints are also more susceptible to Achilles tendinitis, an injury in the Achilles tendon attributed to overuse (Somoygi, D. M., 2001).

In the past, dancers, specifically those involved in ballet, have been encouraged to make use of their hyperextension during weight bearing actions. They had been encouraged to make accommodations in their movement for the extra room their knee joints needed, such as standing with the heels apart in ballet's traditional first position of the feet. While the ideal aesthetic of long, extended legs was being reached, the dancers were more vulnerable to injury. In fact, 70% of injuries in dance occur in the lower extremity (Ambegaonkar 2016) (C. Teitz, 2000). With the

rise of dance science as a respected discipline, the new ideas that encourage long lasting and safe dance careers have permeated collegiate dance programs. This has led to a new concept in the treatment of hyperextended knees: making the legs appear straight, meaning parallel to someone with a normal 180-degree range of motion, during weight bearing movement. However, this causes dancers with hyperextension to feel as if they are bending their legs, because kinesthetically moving into knee extension past 180 degrees feels like a neutral knee position, or straight leg, to them. Although the scientific way of training dancers is healthier and encourages longer careers, it is difficult for dancers with hyperextension to keep the joint in a neutral position. It can take years for a dancer to gain control over knee alignment, which is an unsatisfactory time frame for dancers who are pursuing a professional career, and would like to extend their career as long as possible.

Most dancers begin training at a young age and there is a lack of scientific based information used in this early training. Dancers are commonly in college or beginning their professional career before they encounter the idea of dance science or dance specific kinesiology. By the time dancers engage in dance science based technical training they have already formed habitual movements that are challenging to reverse. As dancers encounter science based technical training, they are commonly instructed through a few different methods on how to avoid hyperextension. Strengthening the quadriceps and abdominal muscles, using a mirror to build proprioception of knee alignment, or cueing of pulling the knee cap up are all common methods used by dance instructors to alleviate hyperextension at the knee. Treatments found for extreme hyperextension, other than surgery within the knee, include hamstring strengthening, extension block bracing, and gait retraining (H. Bourke et al., 2010). Lack of a focused training program targeting the correction of knee hyperextension has frustrated dancers and caused them

to return to their natural hyperextended stance when they are unable to quickly improve their knee alignment. Instructors also find it difficult to spend time teaching dancers to correct their hyperextension when they believe the problem should have already been addressed by former teachers, and as they strive to progress dancers' training and technique. The miscommunication in the dance environment and absence of concrete research regarding the correction of knee hyperextension causes stress to the dancer and the instructor. Without having a clear understanding of how to correct knee hyperextension, and without instructors and dancers having that information, the amount of injuries dancers has relating to knee hyperextension is not progressing with the growing realm of dance science.

This research is aimed at discovering an effective way for dancers to be able to self-correct knee hyperextension. The researchers determined common ways dancers were previously encouraged to self-correct: quadricep strengthening and cueing to "pull up" their patella. After this determination, the researchers designed a study including three groups: a control group, quadricep strengthening intervention group, and ballet cueing intervention group. The researchers designed training programs for both intervention groups and a survey to assess dancers comfortability and confidence in their knee alignment. The expected results were the most improvement to be made from the ballet cueing intervention, because the dancers involved exclusively in strengthening would not have the kinesthetic awareness to correct their knee hyperextension in the post test.

CHAPTER II

METHODS

The researchers were able to recruit 11 participants from the Texas A&M Dance Science Program through social media posts, emails, and posters throughout facilities. To be a participant, dancers were required to be between 18 and 24 years of age, be involved in at least one technique class, be free of lower extremity injuries for the past 6 months, and prove to have hyperextension in the knee joint. Participants in the research study signed a consent form and were separated into three groups: the control group, the quadricep strengthening intervention group, and the ballet practice and cueing intervention group. They were randomly split into the described groups using a random assignment coding system. There were four participants in each intervention group and three participants in the control group.

Pre-testing

Participants were asked to attend pre-testing where they were asked to complete a written survey assessing their perceived confidence in hyperextension control and any problems it has caused. This data was to be compared with a post-test survey to measure intrapersonal improvement. Participants were then asked to begin a short warm up routine consisting of: walking for one minute to music (120 beats per minute) jumping rope for one minute to the same music, 30 alternating lunges moving across the floor and ten leg swings front to back and side to side on each leg. The purpose of this warm up was to mobilize the hip joint and activate the muscles involved in knee stability. Researchers then began testing participants for knee stability, quadricep control, and quadricep strength. One researcher ran the video station where dancers were asked to complete a series of tendu, battement, and promenade in attitude on each leg.

These videos were later analyzed by researchers to determine whether or not each dancer was working with a hyperextended knee joint or a stable knee joint on their supporting leg. One researcher administered the Quadricep Strength test, giving participants a score of 1 (for weak quadricep strength) to 5 (for strong quadriceps) using the Medical Research Council Scale (MRC scale) for muscle power. Dancers were asked to sit on an elevated surface with their legs hanging over the edge while the researcher placed their hand below their knee on the proximal area of the tibia. The participant was then instructed to push against the instructor's hand, basing their score off how hard they pushed the researcher's hand away, and whether or not the researchers hand moved at all. Two researchers were in charge of measuring knee hyperextension in multiple positions using an athletic trainer table and a goniometer. Goniometers are common instruments used to measure angles, benefiting research in hyperextension because angles of hyperextension in the body can be easily measured (P. Teran-Yengle et al., 2016). The Involuntary Knee Hyperextension test was performed by having one researcher hold the ankle of the participant's completely relaxed leg up off the table. The second researcher then measured the degree of hyperextension in the relaxed knee joint as it was suspended in the air. A second method for testing involuntary knee hyperextension was conducted in the Arabesque test. Participants were asked to stand in parallel with their hands on the table for balance stability and one leg extended back into arabesque. Researchers then encouraged them to use their hyperextension and measured the degree seen at the knee joint. This measurement was taken on both legs. Tests for voluntary knee hyperextension were completed using the Voluntary Supine test and Voluntary Parallel test. In the Voluntary Supine test, the participant lay on the athletic training table with one leg suspended above the table and held by a researcher, while the other researcher asked the participant to "show a straight leg" (i.e. not hyperextend the knee) and measured the angle at

participants knee. In the Voluntary Parallel test, the participant was asked to stand with their feet in a parallel position and show the researchers a “straight leg”. The angle at the knee was measured on both legs and recorded. These values were considered to be an indicator of what dancers believed to be correct knee alignment and how well they were able to correct knee alignment using only proprioception. Hamstring flexibility was tested using the straight-leg raise test (Harley, Y. X. R., et al., 2002). For this test, researchers manually lifted and stretched the leg of a participant as close to their chest as possible, without an involuntary bend in the knee, a shift in pelvic alignment, or excessive resistance from the leg. The degree of flexion at the hip joint was measured and recorded. All of these tests were repeated in the post test to observe any change achieved by intervention.

Strengthening Intervention

The goal of the strengthening intervention was to increase not only quadricep strength, but also the strength of all the muscles involved in knee joint stability. All intervention sessions were completed using music at 128 beats per minute, taking either two or four musical counts to complete each repetition (rep) in each exercise. Researchers counted reps for the participants, while participants focused on the mechanics of the exercises and proper body alignment. The participants began with 15 bridges, lying in a supine position with the knees bent then raising the hips toward the ceiling. They then progressed to step-ups, stepping with one leg at a time up on to a bench at a height of 18 ¼ inches and then back down to the ground one leg at a time, 15 times on each leg. This was followed by 15 lunges on each leg and 15 squats, keeping the knees in proper alignment over the second metatarsal bone in the foot. Next, resistance band abduction was completed using a red, medium-resistance, looped TheraBand around their lower thigh. Participants were told to stand in a slight squat and side step to the right for 15 steps, then back

to the left for 15 steps. Participants then completed 15 reps of one-leg assisted squats on each leg by extending one leg while bending the weight-bearing leg to squat down onto a bench that was 20 ½ inches tall. The last exercise completed was quad sets, done by resting the back of the knee on a foam roller of 6 inches in diameter and engaging the quads to extend the leg. This exercise was completed 5 times on each leg, taking two counts to extend the leg, four counts to hold the leg in the extended position, two counts to relax the leg, and two counts to rest. After three weeks of intervention in the previously described manner, intensity was added to all the exercises. For bridges, participants held a 20-pound weight over the anterior superior iliac spine of the pelvis and continued the exercise as normal. For step-ups and lunges, the participants were instructed to hold a 15-pound weight and continue the exercises as normal. A 20-pound weight was held at the chest to add intensity to the squat exercise. For band abduction, a second band was added to the exercise. The bench was lowered to 18 ¼ inches tall for the one-leg assisted squats, and for quad sets, participants were required to complete 10 reps on each leg instead of 5. After completing each intervention session throughout the six weeks, participants were led in a small stretch, with each stretch held for 30 seconds. The first stretch was completed in a seated position with one leg bent and one leg straight, stretching over the straight leg toward the toes. The next stretch was a seated quad stretch, completed by tucking one leg under the pelvis and bending one leg out in front of the body, then extending at the hip joint to stretch the front of the quad. Participants then stood up and stretched the upper body towards the floor over their straight legs for 30 seconds and then bending one leg for 15 seconds and then switching legs. The stretching pattern never changed throughout the six weeks of intervention.

Cueing Intervention

The goal of the cueing intervention was to have dancers' practice not hyperextending their knee joint(s) during regular dance movements that they would encounter in class. The ballet genre of dance demonstrates the largest range of hyperextension issues due to the structure of a traditional ballet class, body positions, the high impact or weighted movements involved, and the misinformation handed down through the generations. For this reason, ballet was used as the training method for the cueing intervention group. Combinations created by the researchers were kept basic so the dancer could focus on the cues rather than remembering the combination. Each combination was a minute long, done with the left hand on the barre then with the right hand on the barre, and was performed at 120 beats per minute using a metronome. Researchers were consistently giving participants verbal cues on how to keep the knee in a neutral position, such as: "pull the knee cap up," "feel like there is a wall behind your leg," and "keep your quadriceps engaged." Participants began with plié (French: to bend), used in ballet to warm up lower extremity muscle groups. When returning from plié to neutral position, participants were reminded to not hyperextend their knees and to keep their heels connected to the ground. Tendu (French: to stretch) was the second exercise, which is meant to warm up the ankle joint and prepare dancers for more complicated movements later in class. This exercise focused on dancers keeping their standing leg in a neutral position while using the working leg gesturally, so the dancers were reminded to not hyperextend the standing leg's knee joint. The next exercise completed was dégagé (French: to disengage), it is to tendu and was used to reinforce the ideas established for the dancers in the tendu combinations. Dancers finished with battement (French: to beat), the most difficult exercise for dancers to control their hyperextension because of the pressure put on dancers to get the gesture leg as high as possible. Dancers were closely

monitored during this combination to ensure that they were not hyperextending the knee joint and that their knees were kept in a stable position throughout the combination. This was especially important in battement derrière, where dancers typically let their shift of body weight affect the engagement of the standing leg, pulling their knee back into hyperextension. After the first three weeks, the combinations were adjusted to increase the amount of dancers' effort to remember not to hyperextend their knees. The barre combinations remained the same but were completed at twice the speed and were repeated twice, so they were still one minute in length. Also, in an effort to increase difficulty in the second half of intervention, a center adagio combination (without the support of the barre) was added to the practicing and cueing intervention methods. The center adagio combination consisted of a series of développés, a promenade in attitude, and a détourné turn, and, like the other ballet intervention combinations, was a minute in length and completed at 120 beats per minute using a metronome. Dancers were again encouraged to keep a neutral knee position and were cautioned when their supporting leg's knee pushed back into hyperextension.

Post-testing

Post-testing followed the same procedures as pre-testing. The researchers were looking for the most improved change during the barre evaluations, the muscle power test using the Medical Research Council Scale, and voluntary hyperextension. All post-test findings were recorded and compared with pre-test evaluations for statistical analysis of the results.

CHAPTER III

RESULTS

The only test that showed a statistical significance was the Arabesque test. In the recorded Arabesque Test, there was a statistically significant difference between groups as determined by one-way ANOVA (Left Side - ($F(2,8) = 5.056$, $p = 0.038$)) (Right Side - ($F(2,8) = 13.414$, $p = 0.003$)). Post hoc tests using the Bonferroni correction revealed that there is a significant difference between the Ballet group and the Strength group on the Right Side. None of the other post hoc comparisons showed a significant variance.

The Voluntary Parallel test and the Voluntary Supine test did not show any statistical Significance. In the Voluntary Parallel Test, there were no statistically significant differences between group means as determined by one-way ANOVA (Left Side - ($F(2, 8) = 2.75$, $p = 0.123$)) (Right Side - ($F(2,8) = 1.790$, $p = 0.228$)).

In the Voluntary Supine Test, there were no statistically significant differences between group means as determined by one-way ANOVA (Left Side - ($F(2, 8) = 1.541$, $p = 0.271$)) (Right Side - ($F(2,8) = 2.075$, $p = 0.188$)).

Statistical analysis was not performed on the Involuntary Knee Hyperextension test or the Hamstring Flexibility test due to a majority of the participants receiving a worse score in the post test. In the Involuntary Knee Hyperextension Test, there were no statistically significant differences between groups. Results demonstrated that participants in all groups, with the exception of one participant in the strength group, increased their degree of involuntary knee hyperextension on both sides.

In the Hamstring Flexibility Test, there were no statistically significant differences between groups. Results demonstrated that on average participants in all groups decreased in their degree of hamstring flexibility.

In the Quadricep Strength Test, there were no statistically significant differences between groups. Results demonstrated that all participants either had the same score in the post test as they did in the pre-test or decreased by one margin in strength.

In the recorded Tendu Test, there were no statistically significant differences between groups. Results demonstrated that on average the ballet cueing intervention group participants improved in their knee hyperextension control. On average the control group and strength intervention group results demonstrated no change.

In the recorded Battement Test, there were no statistically significant differences between groups. Results demonstrated that three of the four participants in the ballet cueing intervention group improved in controlling their hyperextension on the left side. There was no change in other groups.

In the recorded Promenade Test, there were no statistically significant differences between groups. Results demonstrated that three of the four participants in the ballet cueing intervention group improved their knee hyperextension control on both sides. There was no change in other groups.

CHAPTER IV

DISCUSSION

Throughout the course of this study, dancers from the Texas A&M University Dance Program were continuing to participate in regular program activities, including varying levels of class, rehearsal, and performance participation. As the semester progresses in the program, dance activities become more intense and time consuming, leading to more focus from dancers on work and performance readiness versus rest and recovery. This needs to be noted to understand the varying results that were gathered from certain tests. It should also be noted that participants of different ages and classifications participated in this research, and, as this collegiate program is dance science based, some participants had more experience learning about and correcting knee hyperextension prior to this study.

The involuntary knee hyperextension test was found to be statistically significant and showed increased involuntary knee hyperextension in all participants. This is likely due to the increase in dance activities toward the end of the semester and lack of concentrated focus on control of hyperextension outside of the study. The decrease in hamstring flexibility can also be attributed to the increased intensity of dance throughout the semester. As the difficulty of their dance schedule develops, dancers spend less time focusing on stretching their heavily used muscles, leading to tightening and shortening of those muscles.

Neither the voluntary supine or voluntary parallel test produced a statistically significant P value. However, looking at the individual participant data, the researchers were able to notice a small change in hyperextension control. In the voluntary supine test most participants were able to show improvement in proprioceptive hyperextension control on at least one leg. This is also

true of the control group which would lead the researcher to believe that the dancers' proprioceptive skills were being challenged outside of the study.

The MRC test for muscle strength showed a decrease in strength of the quadriceps in the ballet intervention group and maintenance of muscle strength in the strengthening intervention group. This was to be expected as the strengthening group worked for 6 weeks exclusively on the strength of their quadriceps, while the ballet group did not apply any focus to their quadricep muscles. The ballet group was more susceptible to the negative effects of dance exclusive training while the strengthening group inadvertently cross trained and was able to avoid the loss of muscle strength throughout the second half of the semester.

The barre tests were evaluated by researchers and given a positive or negative score based on whether they were positive or negative for hyperextension on their standing leg. In the tendu barre recording at the pretest, the entire ballet intervention tested positive for knee hyperextension. At the post-test there was only one participant that was unable to correct their hyperextension, and that was only on their right leg in tendu. One control participant also showed improvement in tendu; this is likely due to outside training and a personal understanding of what the researchers were evaluating for. In battement, only ballet participants saw improvement of their standing leg hyperextension. However, there were fewer ballet intervention participants that were able to improve hyperextension in battement than in tendu. One ballet participant made no improvement in battement on either leg, and three out of four participants could only show improvement on one leg. This is likely because of the pressure dancers face to produce leg height in battement. It is common for dancers to lose control in other regions of the body during battement in sacrifice for gaining leg height. In promenade, the only improvement shown was in the ballet group, and again one ballet intervention participant did not make any

improvement at all. The ballet intervention participants were able to experience exclusively performing promenade during the course of their intervention, so it is expected that they would show improvement while other groups would not. Overall, the ballet intervention showed the most improvement in the barre evaluations, which was expected due to the nature of their intervention procedure.

Although the strengthening intervention was shown to maintain quadricep strength and have small improvements in hyperextension control, the ballet group showed more promise for actually decreasing the impact of their hyperextension during dance movements. However, with the variable level of outside training dancers were receiving and their varying level of proprioceptive understanding of knee hyperextension, participants in each group showed different levels of improvement.

Due to the unforeseen events surrounding the COVID-19 virus in spring 2020, complete data was unavailable at the time of publication for this URS thesis. This effected the surveys given in the study, and they were unable to be evaluated due to the Coronavirus outbreak.

CHAPTER V

CONCLUSION

The researchers recommend that further research be performed on the subject of proprioceptive improvement of knee hyperextension in dancers. This research should be performed with a larger number of dancers with more specific criteria, such as prior knowledge of hyperextension and amount of dance participation outside of the study. These were the largest two confounding variables in the research and should be minimized as much as possible.

Assuming the ballet group made the most improvement in this study, specifically regarding the control of knee hyperextension, further research should be done to look at the impact of quadricep strengthening on cueing methodology. Is it only useful to train dancers to not hyperextend their knees using cueing methods, or does quadricep strengthening impact the dancer's proprioceptive abilities?

Research could also be conducted to determine at what age hyperextension control training should begin. It should be explored at what age dancers are able to understand proprioceptive hyperextension training and at what age the information and training will provide the greatest impact to future dance careers.

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