

Can the Functional Movement Screen be Used as an Assessment Tool for Improving Movement Patterns in Collegiate Dancers?

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Abstract:

Introduction: The Functional Movement Screen is a common tool used to assess fundamental movement patterns. Results from the screening process can influence exercise program design. FMS screening is not as commonly used in dancers as other sports. Information regarding how dancers could benefit from a structured training program based upon FMS remains unclear.

Purpose: The purpose of this study was to utilize Functional Movement Screening (FMS) results to develop an 8-week corrective exercise program intervention to improve movement patterns in dancers.

Methods: This study followed a pretest-posttest design. Participants (n=15) were tested on the first five screens of the FMS. A progressive, eight-week corrective exercise program focusing on hip stability, ankle dorsiflexion, and thoracic mobility was implemented twice a week for 20 minutes each session. A dependent t test ($\alpha \leq 0.05$ a priori) and video recording were used for analysis of pre and posttest results.

Results: Nine dancers completed the intervention. Improvements in overall posttest scores were noted in 4 out of the 5 FMS screens with the deep squat improving significantly ($p < 0.017$).

Conclusion: Results indicate that a corrective exercise intervention can improve fundamental movement patterns which highlights the value of FMS screening in the dancing population.

Keywords: Functional Movement screen, Corrective Exercises, Dancers

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Review of Literature:

Introduction

Dance is a form of exercise which aims to combine both athleticism and aesthetical appeal. Because of the history and meaning behind dance, dance is often classified as an art instead of as a sport. However, dancers still require many of the same athletic aspects of other traditional athletes such as soccer or basketball. By better understanding the sport of dance, it is possible to provide appropriate testing measures which can then be used to create a sport specific training program. Therefore, this study aimed to implement the Functional Movement Screen (FMS) with a college dance population to assess movement imbalances and to correct movement deficiencies with an 8-week corrective exercise program.

Understanding the Physical Demands of Dancing

Dancers require stamina, power, strength, endurance, flexibility and agility to perform properly. A typical day for many professional dancers includes about 2 hours of warmup and technique work at the barre followed by 4-6 hours of rehearsal. Depending on the season, these 6- 8 hour days of dancing can also end in an actual performance (“What Is A Normal Day For A Professional Dancer?”, 2017). This routine is repeated 5- 6 days a week. As such, dancers require high levels of stamina. Dance is classified as an intermittent form of moderate- heavy exercise due to the sudden bursts of activity coupled with the extreme precision needed in certain movements (Twitchett, Koutedakis, & Wyon, 2009). Because of this, both the anaerobic and aerobic systems are used when dancing depending upon the level of intensity and duration of each piece. In terms of aerobic capacity, dancers are estimated to have an average maximum ventilatory oxygen uptake (VO₂ max) of 37 to 57 ml·kg⁻¹·min⁻¹ depending upon the type of

dance, age of dancer, gender of dancer, and level of training (Rodrigues- Krause, Krause, & Reischak-Oliveira, 2015). This is slightly higher than the average VO₂ max of 38-41 ml·kg⁻¹·min⁻¹ that is observed in normal females aged 18-25 (Bryant & Green, 2010). Having a strong aerobic and anaerobic base allows the dancers to be able to perform better overall.

Dancing requires muscular power, muscular strength, muscular endurance, flexibility, and agility (Williams, Gdovin, Allen, Wilson, Cazas-Moreno, Ossenheimer, & Garner, 2016). Having great muscular power allows for the dancers to reach the impressive heights that are expected of them in their jumps and leaps. Muscular strength is an especially important aspect, particularly in the lower body and core, due to the nature of many dance movements (Roussel et al., 2014). Nearly all actions in dance originate from the core musculature firing first in order to raise a leg, balance on one foot, or perform slow, controlled movements such as the *allongé*, for instance. Meanwhile, muscular endurance is necessary as dancers must often maintain high levels of power output in bouts of 30 – 60 seconds depending upon choreography requirements (Rodrigues- Krause, Krause, & Reischak-Oliveira, 2015).

Dancers are also known for their extreme flexibility which is exhibited in various movements such as splits, arabesques, *sissones*, and *penchés*, all of which require greater than normal flexibility through the ankle plantar flexors, hamstrings, hip adductors, hip flexors, rectus abdominis, and oblique muscles (Penrod, 2005). In addition, many forms of dance, especially ballet, require dancers to remain in an externally rotated hip position known as being turned out. For instance, all five of the standard foot positions of ballet shown in Figure 1 require dancers to stand in the turned out position (Sherman, Mayall, & Tasker, 2014).

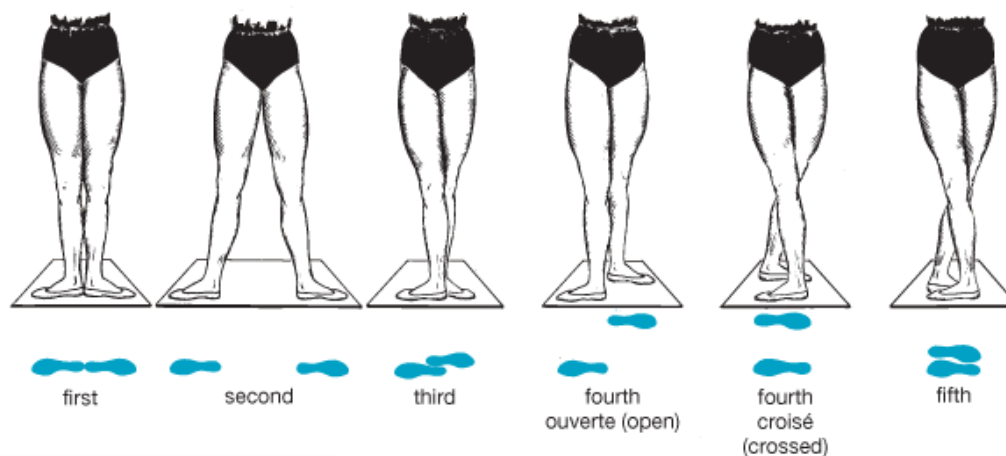


Figure 1: Five basic foot positions in ballet

This constant externally rotated position often causes imbalances between the hip external rotators and the hip internal rotators. In addition, many dancers are unable to produce the needed 140° of hip external rotation solely from the hip rotators and instead only contribute on average 50° of turnout to the hip rotators (Carter, Duncan, Weidemann, & Hopper, 2018). In order to make up for the lack of rotation in the hips, many dancers compensate by relying upon turnout from the knees and ankle pronators which leads to a higher incidence of injury in the foot, ankle, and knee.

Finally, agility is needed in different combinations as the choreography often calls for quick changes in direction on a relatively small stage. Dancers are also required to perform movements on one leg or en relevé. As such, they need to have good balance and the ability to support themselves in either a one- legged stance, a decreased foot surface area, or both (Cheng-Feng, Fong-Chin, & Hong-Weng, 2005). All of these aspects of fitness must be considered and addressed when creating an appropriate exercise plan in order to allow the dancers to perform better and reduce the likelihood of injury within this population.

Injury in Dance

Dancers are a population with high rates of injuries. It is estimated that 75% and 95% of professional dancers have suffered an injury at some point in their career (Galantino, Lim, Bahring, & Woolverton, 2017). Another study found that, in a collection of professional ballet companies, the incidence of injury was 54.8% of dancers while a collection of modern dance companies reported an overall injury prevalence of 46.3% (Jacobs et al., 2017).

The majority of injuries occur in the lower body, with the ankle being the most common site for injury. One study reported that 67.6% of injuries in women and 40.9% of injuries in men were ankle sprains (Costa, Ferreira, Orsini, Silva, & Felicio, 2016). Other common sites for injury include, in order of prevalence for the lower body: the ankle, the knee, the foot, and the hip/ thigh. Meanwhile, the thoracic spine was determined to be the most likely place for injury in the back while shoulder injuries were considered to be the most common site for upper body injury (Galantino et al., 2017).

In addition, most injuries are caused due to overuse. One study found that 64% of injuries in women and 68% of injuries in men were due to chronic overuse while only 32% of injuries in women and 40% of injuries in men were due to traumatic injury (Nevill, Brooks, Koutedakis, & Wyon, 2012). Men often experience higher rates of traumatic injury as many of their routines call for the more powerful jumps, leaps, and lifts which are more likely to create an acute injury. The high instances of injury in dance point towards the need for a structured training program in order to decrease the likelihood of such events from occurring. A proper testing protocol that assesses the athlete's individual movement patterns and athletic base is the first step in designing a relevant training program for any sport.

Functional Movement Tests

Functional movement tests assess how the participant moves in various motions such as squatting, lunging, stepping, and reaching. The overall purpose of functional movement tests include determining muscular asymmetries, assuring that the different parts of the closed kinetic chain are either stable or mobile according to their function, and detecting inefficient movement patterns. While pretesting with functional movement tests is not an assurance that the athlete will remain uninjured throughout their season, functional screens do provide valuable information about the athlete's movement patterns which can be useful in later exercise programming.

There are a few different tests which are useful in exercise testing. One of the most common is the Functional Movement Screen (FMS). The FMS is composed of seven different tests- the Deep Squat, Hurdle Step, In Line Lunge, Shoulder Mobility Test, Active Straight Leg Raise, Trunk Stability Pushup, and Rotary Stability Test- all of which dynamically assess common movement patterns. Each test of the FMS is graded on a scale of 0-3, with 0 indicating that there was pain with the movement and 3 being the best possible score. A study of 257 different Division II NCAA athletes found an average FMS score of 15 out of 21 points which is slightly higher than the general population average FMS score of 14 points (Dorrel, Long, Shaffer, & Myer, 2018). Generally, scores lower than 14 indicate that the participant might be at an increased risk of injury due to asymmetries in musculature or overcompensations throughout the kinetic chain. Athletes are still able to perform with low FMS scores; however, their movement quality might be impaired which could lead to further complications.

Many sports have started to incorporate various functional movement tests into their training in an effort to recognize faulty movement patterns which can then be addressed in a

corrective exercise program. Generally, a standard test, such as the Functional Movement Screen is first utilized and then other sport specific tests are completed in an effort to create a more well-rounded assessment of the sport. While many studies have observed the effects of functional tests in traditional sports such as football or soccer, there is currently less known relating to functional movement tests for dancers.

Functional Tests in Dancers

One study by Skotnicka, Karpowicz, Bartkowiak, and Strzelczyk used the FMS to assess the movement patterns of dancers (2017). The dancers exhibited the lowest scores in the Deep Squat and Trunk Stability Push Up and the highest scores in the Shoulder Mobility and Active Straight Leg Raise. The Deep Squat tests assesses a variety of closed kinetic chain actions such as ankle dorsiflexion, knee and hip flexion, thoracic spine extension, and shoulder flexion and abduction. Scoring a two on the Deep Squat usually indicates limited ankle dorsiflexion or reduced thoracic mobility while scoring a one often indicates other movement issues in the aforementioned areas. The Trunk Stability Push Up examines the ability of the participant to perform an upper body movement while stabilizing the trunk in the sagittal plane which is important for efficient transfer of energy from lower body to upper body movements. The low FMS scores indicate that dancers lack upper body and core strength as well as having potential dorsiflexion or thoracic spine mobility issues.

Another study reported the highest FMS scores for a group of dancers also occurring in the Shoulder Mobility Screen and the Active Straight Leg Raise (Allen, Nevill, Brooks, Koutedakis, & Wyon, 2013). Since dancers are known for their flexibility, the researchers hypothesized that the large range of motion observed in the two aforementioned tests cost them

stability in certain crucial areas such as the lumbopelvic complex as the dancers scored the lowest in the Hurdle Step, In Line Lunge, and Deep Squat screens. All of these tests require a specific amount of control in the hips and scapula in order to be performed properly which indicates that dancers might have reduced movement quality in these areas.

This concept was further observed in an additional study which found that the FMS was a useful method for indicating common muscular weaknesses. Again, the Deep Squat and Trunk Stability Push Up were the lowest scoring tests. The researchers also implemented a Dance Specific Screen (DSS) in this study which analyzed how well the dancers were able to move in dance related movements. Seven basic ballet moves- the plié, etendré, relevé, glissé, sauté, elancé and tourné- were used in order to gauge how well each dancer was able to move in their sport (Galantino, Lim, Bahring, & Woolverton, 2017). The results from the FMS and the DDS were fairly similar in total scores, with the only difference being that that the DDS typically scored a few points lower on overall scores. The DDS indicates that many dancers often participate in compensatory movements in order to perform exercises commonly found in all dance classes. Prolonged over compensation results in less effective movement patterns and can potentially lead to higher incidences of injury in this population over time. Providing a more sport specific testing protocol is necessary in furthering the knowledge available concerning the specific movement patterns of dancers. However, this screen is still relatively new and needs to be further studied before wide spread implementation.

Functional Movement Screens are also useful in indicating the potential likelihood of an injury occurring to a dancer. In a study which used the Movement Competency Screen (MCS), a set of eight different movements similar to the FMS, the results found that dancers who scored below a 23 out of the 36 possible points, were significantly more associated with an increased

prevalence of injury (Lee, Reid, Cadwell, & Palmer, 2017). While there is no method to prevent injury, it is possible to discover traits which might indicate a higher chance of injury within a certain population.

Corrective Exercise Programs Based on Functional Tests

With the data obtained from the functional movement tests, it is possible to design a corrective exercise program in order to improve movement quality which could potentially decrease the likelihood of injuries. One study exploring this concept used the FMS as a pretest; the researchers then split the group into two—one which acted as the control and the other which received a twelve week exercise program based on the corrective exercises from the FMS manual and core exercises performed with a Swiss ball (Skotnicka et al., 2017). In the exercise intervention group, over 33 exercises meant to improve deficits seen from low FMS scores were performed once a week for an hour and a half for twelve weeks with many of the corrective exercises involving variations and progressions. For instance, to address hip stability in the Hurdle Step, supine bridges were performed with the arms on the floor, with alternating knee flexion, with alternating leg extension, and finally with the foot on a sensory disc. Hip stability and core activation were also addressed in the single leg lowering exercises meant to aid in improving Active Straight Leg Raise scores. Deep Squat corrective exercises included kneeling dorsiflexion stretches to address dorsiflexion issues and wall sits with shoulder presses to address thoracic mobility. Results showed that both groups were fairly similar at the beginning; however, upon completion of the corrective exercise program, the intervention group showed significant improvements in the Deep Squat ($p = 0.000574$), Hurdle Step ($p = 0.013349$), Trunk Stability Push Up ($p = 0.023198$), and In Line Lunge tests ($p = 0.035265$). These differences created significant differences between groups in the posttest Deep Squat and Trunk Stability Push Up

tests (Skotnicka et al., 2017). Another study implemented a similar corrective exercise program using the FMS as a basis of measurement. In this three year study, it was found that dancers exhibited a significant decrease in injuries between year one and year two ($p < .001$) and between year one and year three ($p < .001$) due to the benefits of more efficient movement patterns as assessed through the FMS (Allen et al., 2013). Extending the exercise program would be likely to continue to help the dancer population. Having proper movement patterns means that movement is more efficient which leads to a decreased likelihood of injury.

Summary

Dancers require a wide range of fitness skills such as muscular strength and endurance, power, agility, flexibility, and a decent aerobic capacity. However, dance is often still viewed more as an art form rather than a sport which means that many dance programs lack the conditioning programs often found in other sports. This lack of specific programming can contribute to the high injury rates observed within this population.

Standardizing screening protocols for dancers is an important step in developing a comprehensive exercise program design. Using a screen such as the FMS which analyzes the movement patterns of a dancer may be beneficial in creating an appropriate exercise program which can help a dancer become stronger and, therefore, reduce their likelihood of injury.

Problem Statement:

Whether or not the FMS screening tool and subsequent corrective exercise program can improve movement patterns in collegiate dancers remained unclear.

Purpose statement:

The purpose of this study was to implement a corrective exercise program based upon results from a FMS prescreen to improve the movement patterns of dancers.

Research Question:

This research aimed to answer the central question:

Can a corrective exercise program based upon the FMS be a valid and efficient method for improving the movement patterns of dancers?

Null Hypothesis (H_0):

There will be no difference in movement patterns in collegiate dancers after completing a corrective exercise program based upon the FMS.

Alternate Hypothesis (H_A):

There will be a difference in movement patterns in collegiate dancers after completing a corrective exercise program based upon the FMS.

Assumptions:

It was assumed that the dancers were able to perform all exercises to the best of their ability. It was assumed that the dancers followed the instructions given by the researcher in order to ensure similar procedures. It was also assumed that the participants abided by the starting statements and continued their lifestyles without starting or stopping any exercise or diet plans throughout the length of the study. Finally, it was assumed that the data gained from this study was representative of collegiate dancers.

Definition of Terms:

Movement Patterns- the common ways in which the body moves to accomplish a certain task such as squatting, lunging, stepping, reaching, hinging, and carrying.

Muscular Imbalances- opposing muscles that vary in strength or flexibility which creates differing directions of tension, resulting in higher likelihood of injury.

Musculoskeletal Injury- disorders occurring in the musculoskeletal system (bones, muscles, tendons, ligaments, nerves, discs, and blood vessels) that often result in pain with or without movement.

Chronic Injury- an injury in which pain lasts for a few months and is often times recurrent. Commonly caused by continuous overuse of the same parts of the musculoskeletal system.

Traumatic Injury- an injury in which the onset is sudden and the resultant injury is often times more severe than in chronic injuries.

Functional Movement Screen- set of seven tests (Deep Squat, Hurdle Step, In-Line Lunge, Shoulder Mobility, Active Straight Leg Raise, Trunk Stability Push Up, and Rotary Stability Test) meant to assess movement patterns and determine muscular imbalances or compensations.

Stability- the ability to control a motion or maintain posture.

Mobility- the combination of the flexibility of a muscle, range of motion of a joint, and ability of a body segment to move.

Corrective Exercise- simple exercises or stretches meant to help fix observed muscular imbalances in order to increase movement quality.

Research Designs and Methods:**Study Type:**

The study design was a pre experimental one group pretest/ posttest. It contained a mixture of both descriptive and inferential data.

Study Population:

The study population was female collegiate level dancers from the southeast region of the United States of America.

Study Sample:

The sample was fifteen female dancers (n =15) who were enrolled in the Beginning Jazz 1 class at Florida Southern College and who wished to participate in the study. Each dancer was registered as either a dance major or dance minor. A convenience sample was used as the dancers were solicited based upon the suggestion of their instructor.

Inclusion Criteria:

In order to be included in this study, the participants had to have been females between the ages of 18 and 22. Participants had to be registered during the Fall 2017 as either a dance major or dance minor in the Florida Southern College Dance Department. The participants needed to be in good health and have no major injuries. All participants were required to have signed an informed consent form prior to participation in the study. In order to be included in data analysis, participants were required to meet a minimum of eight of the twelve corrective exercise sessions.

Exclusion Criteria:

Participants were excluded from the study if they were outside of the set age range, not a dance major or minor, exhibited major health concerns, or did not participate in the required minimum amount of sessions. Participants who were familiar with the FMS testing protocol were also excluded from this study. Any participant who no longer wished to participate or who was unable to participate due to injury was excused from the study.

Protection of Validity

Internal Validity:

Internal validity is the extent to which changes in the dependent variable can be directly attributed to the manipulation of independent variables. This study aimed to control threats to internal validity. The biggest threat to validity was the various activities that the dancers participated in besides the exercise intervention. However, as the participants were dancers, it was unrealistic to ask them to cease all activity outside of the exercise intervention. For the duration of the study, the participants were asked not to stop or start any exercise programs or diet programs that they were undergoing. A report was made of the dancers' activity levels in order to observe how the level of exercise experience potentially impacted individual results. To increase the degree of standardization throughout the study, the same researcher administered and evaluated the FMS pre and post testing. A generalized script was prepared and read during the testing to further regulate protocol (Appendix A). The same researcher was also responsible for the exercise intervention in order to allow for similar cueing between sessions.

External Validity:

External validity refers to how well the study sample represents the general population. In this study, the general population was collegiate dancers. As the sample size ($n=15$) was relatively small, the results from this study were not be easily able to be generalized to the entire population of collegiate dancers as accurately as if the sample size was larger. In addition, the chosen class was the Beginning Jazz 1 class. Different dance styles require specific training modalities which created a barrier for a producing a generic dance program. However, the dancers that were involved in this study also participated in other dance styles as part of the FSC Dance Department's curriculum, making them more likely to better represent a well-rounded dancer.

Instrumentation

The first five tests (Deep Squat, Hurdle Step, In Line Lunge, Shoulder Mobility Test, and Active Straight Leg Raise) of the Functional Movement Screen (FMS) were used for both the pretests and the posttests. Standard FMS scoring guidelines were followed (Appendix B). Both frontal and lateral angles of each test were video recorded to allow for increased observation of multiple angles. A handheld bioelectrical impedance (BIA) device manufactured (Omron) was used during testing in order to test for body fat percentages and body mass index (BMI). During the exercise intervention, the blue (heavy) and black (extra heavy) mini resistance bands (Perform Better™) were used. All exercise testing occurred in the FSC Exercise Science Lab. Half of the exercise intervention occurred in the Exercise Science Lab and the other half occurred in the Wynne Warden Dance Studio on the Florida Southern Campus.

Methodology Implemented

This research started by contacting the director the FSC Dance Department. Upon receiving her approval, the lead researcher met with the Jazz 1 Beginning class explaining the research and expectations of participants. An informed consent form (Appendix C) was administered to participants upon agreement of participation. A visual description of the research methodology is represented in Figure 2.

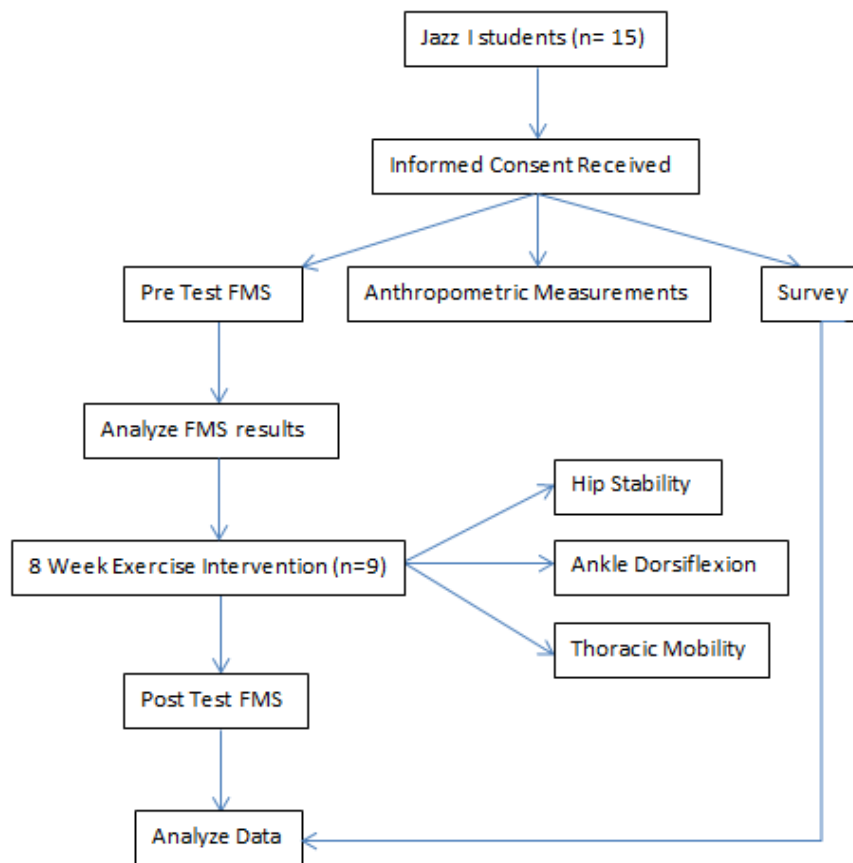


Figure 2: Visual representation of the research methodology used

Prescreening:

During the prescreening, general anthropometric data of the participants such as age, height, weight, BMI, and percent body fat was collected. Weight and height measurements were performed with the participants barefoot.

Participants performed the first five tests of the FMS. The tests, performed in the order listed, included the Deep Squat, Hurdle Step, In Line Lunge, Shoulder Mobility Test, and Active Straight Leg Raise. The tests were done according to FMS protocol (Appendix B). Participants were graded on a scale of 0, 1, 2, 3 scale with a score of 0 indicating that pain was felt with the movement and 3 indicating that the movement was performed correctly. Rankings of 2 indicated less developed movement patterns while a score of 1 indicated more severe movement pattern issues. Each screen was video recorded so that the results could be assessed afterwards to reduce researcher bias. Standard FMS scoring guidelines, as outlined in Appendix B, were followed.

Exercise Intervention:

Upon completion of the pretest, the videos were analyzed in order to determine the focus of the exercise intervention. A previous study of dancers performing the FMS indicated that, despite performing well in the Active Straight Leg Raise, dancers commonly lose stability in their hips due to the excessive flexibility needed to be successful in this sport (Allen, Nevill, Brooks, Koutedakis, & Wyon, 2013). Another study involving dancers and the FMS, concluded that the Deep Squat scored the lowest, indicating that dancers have movement pattern issues in a squatting position (Skotnicka et al., 2017). According to the FMS manual, common reasons for low scores in the Deep Squat include poor ankle dorsiflexion, lack of hip mobility, and limited thoracic mobility (Cook, 2010). Due to these issues and the results of the video analysis, the

exercise intervention focused on improving hip stability through increased core strength, thoracic mobility, and ankle dorsiflexion.

The entire study lasted eight weeks with one week dedicated for pretesting, six weeks committed for the exercise intervention, and the final week used for post testing. The exercise intervention was progressive, changing every four sessions to encourage the concept of progressive overload. The intervention occurred two times a week, in accordance to resistance training recommendations from the American College of Sports Medicine (ACSM) which state that adults should participate in resistance type training two to three times a week (“ACSM News Release”, 2018). Each session lasted twenty minutes in order to allow for appropriate learning and adjustment time.

There were five exercises in each session. The number of sets and repetitions for each exercise were determined by the ACSM standards for muscular endurance which state that exercises should be performed for 2-3 sets consisting of 12 repetitions or greater (Esco, 2013). Each set had a 20 second rest period in between exercises. Progressions for the exercises chosen included increasing the number of reps, changing resistance, or transitioning from bilateral to unilateral movements.

Exercises were chosen based upon the needs observed during pretesting as well as prior literature such as the Skoknieta et al. study and suggested FMS corrective exercises. Dorsiflexion was addressed through banded ankle work and kneeling dorsiflexion stretches. Thoracic mobility was improved through the iron cross stretch. Hip stability was improved through single leg and unilateral glute bridges as well as boat pose variations involving bent and straight leg raises. All of these exercises cumulated in either a bilateral or unilateral deadlift

depending on the progression week. The deadlift variation reinforced concepts of ankle dorsiflexion, proper shoulder retraction, and core activation previously worked on in the session. A detailed chart of the chosen exercises and their progressions are included in Appendix D while detailed pictures of each exercise are included in Appendix E.

Posttest:

Upon completion of the eight-week exercise intervention, the participants were retested using the FMS and following the same procedures as outlined in the pretest protocols. The video results were analyzed by the same researcher in accordance to the same FMS protocol.

Data Analysis

Pre and posttest data for the FMS was analyzed in order to determine if the exercise intervention improved movement patterns. A dependent t test (set a priori of α with the alpha $<.05$) was used in order to determine statistical significance. In addition, video analysis was collected and assessed to determine if dancers showed improvement between their pre and posttest results as well as to cross- validate the researcher's scores. Finally, the results of the provided survey were examined in order to gain a better understanding of the lifestyle of a collegiate dancer which may influence testing (Appendix F).

Safety, Anonymity, and Confidentiality of Human Subjects

The safety and confidentiality of the subjects was of utmost concern as this study involves an exercise intervention. Because of this, participants were required to be in good health in order to participate despite the fact that the study itself posed minimum risk to the participants. The research was first approved by an International Review Board (IRB) in order to ensure

further participant safety. Data collected from the participants was kept in a folder that was only accessible to the lead researcher and remained in a locked location when not in use. The participants were not referred to by name or identifying characteristics in any reports of this study. Participants also gave explicit consent to use their pictures in the final publications of this research.

Results:

Demographics

Of the original 15 dancers who underwent the FMS pretesting, nine dancers completed the required eight of twelve training sessions. The participants averaged 14.94 hours of dance exposure (classified as enrolled classes, individual practice, rehearsal, and dance team practices) each week. Six of the nine dancers regularly participated in structured exercise with the most common form being aerobic exercise and flexibility training. Only one dancer participated in regular resistance training. Basic demographic information is provided in Table 1.

Table 1- Basic Demographics of Participants (Weight, Age, and Anthropometric Measurements)

Participant	Weight (lbs)	Age	BMI	%BF
1	106	19	20	21.2
2	117.5	19	23.1	23.6
3	139.5	19	25.1	27.9
4	125.5	20	19.3	22.7
5	145.5	18	23.1	26.8
6	150	19	29.8	31.3
7	177	18	27.7	35.1
8	104	18	19.7	20.9
9	105	19	21.9	23.5
Average:	130.00	18.78	23.30	25.89
Standard Deviation:	24.98	0.67	3.65	4.83

Injury during Program

Two dancers reported experiencing an acute injury, classified as missing less than three days of dance practice, during the eight-week time period. One injury occurred in the shoulder/neck region while the other occurred in the lower back. Neither injury inhibited the dancers from participating in the study.

FMS Results

The FMS test is scored on a 3, 2, 1, 0 system with a 3 being the desired score. In executing 5 screens from the FMS, participants scoring a 15 achieved proficiency in all assessments. The average score for all five tests during the pretest was 12 out of a possible 15 points. The posttest average for all five tests increased to 13.22. Each individual test, except for the Active Straight Leg Raise, which was already at maximum score during pretest, also showed improvements from pre and posttest averages (Figure 3).

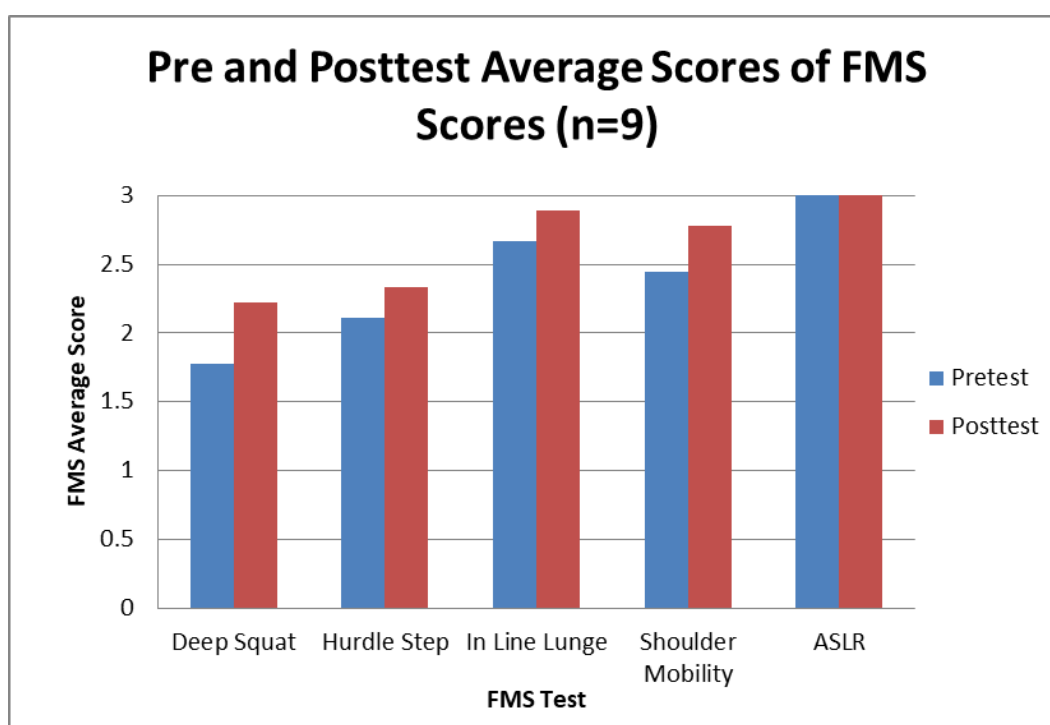


Figure 3- Pre and Posttest Averages of FMS

Despite the improvement from pretest to posttest scores in four out of the five tests, only the Deep Squat test showed significant ($p < 0.017$) improvement between pre and post testing. A breakdown of each dancer's individual score is presented in Table 2.

Table 2- Individual Pre and Posttest FMS Scores

	Deep Squat		Hurdle Step		In Line Lunge		Shoulder Mobility		ASLR	
Participant:	Pretest	Posttest	Pretest	Posttest	Pretest	Posttest	Pretest	Posttest	Pretest	Posttest
1	1	1	2	3	3	3	2	3	3	3
2	2	2	2	2	3	3	2	3	3	3
3	2	3	2	3	2	3	2	3	3	3
4	1	2	2	3	2	2	3	3	3	3
5	2	3	2	2	3	3	2	3	3	3
6	2	2	2	2	3	3	3	2	3	3
7	2	2	2	2	2	3	3	3	3	3
8	2	3	3	2	3	3	2	2	3	3
9	2	2	2	2	3	3	3	3	3	3
Average:	1.78 ± .44	2.22 ± .67	2.11 ± .33	2.33 ± .50	2.67 ± .50	2.89 ±.33	2.44 ± .53	2.78 ± .44	3.00 ± .00	3.00 ± .00
P value:	0.017		0.299		0.085		0.098		NA	
*Indicates Significance										

In the Deep Squat pretest, two participants scored a 1 and seven participants scored a 2.

Four out of nine participants (4/9) raised their score by an entire point from pretest to posttest. In the Deep Squat, lack of full range of motion, resulting in squat heights greater than parallel to the femur or reduced thoracic mobility were observed in the pretest results. In the post test, better mobility was observed in the Deep Squat with an improvement in thoracic mobility also noted in many participants (Figure 4).

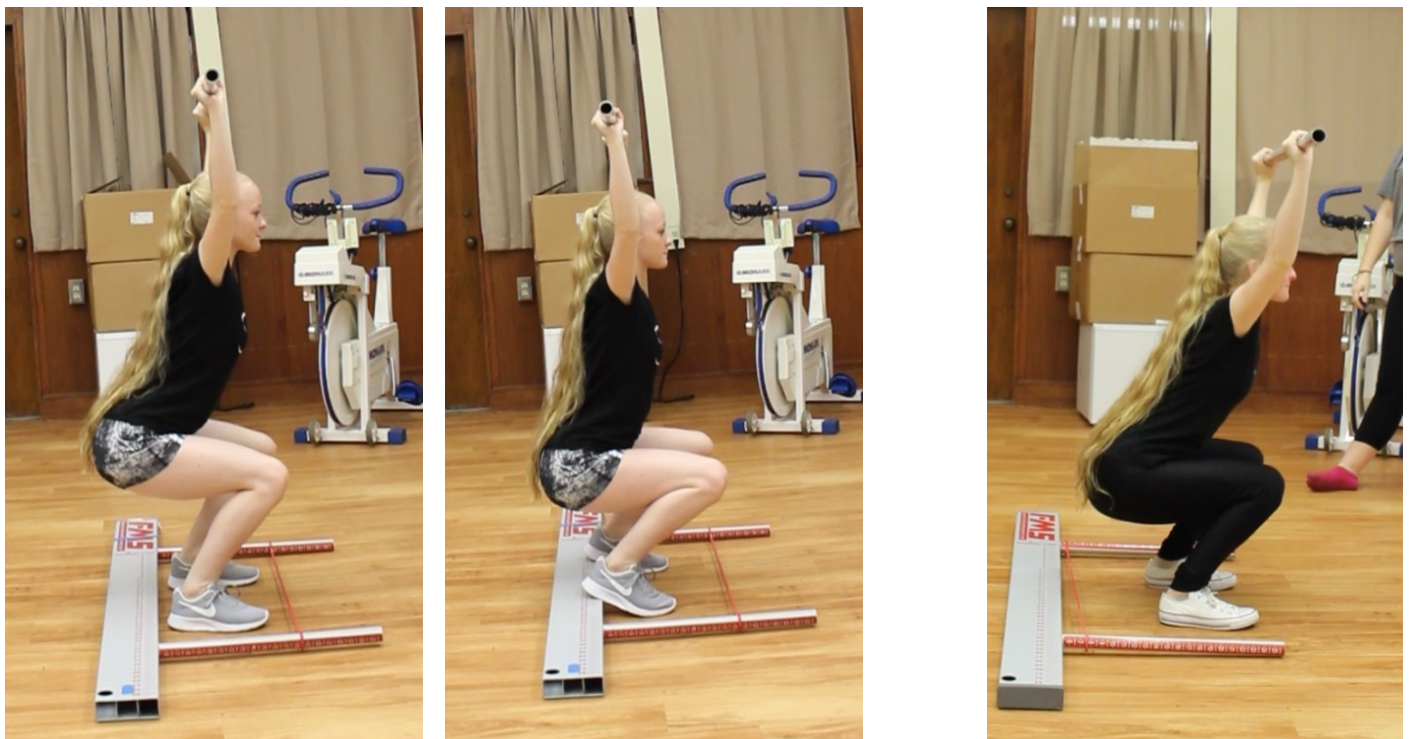


Figure 4- Participant who received a score of 2 (heels on FMS board in order to reach parallel with femur) during pretest improved to a score of 3 during post test in the Deep Squat (No FMS board, femur parallel, dowel over feet)

Every participant but one dancer scored a 2 on the pretest of the hurdle step. In the post test, three dancers increased their score to a 3; however, one dancer decreased her score by a point. Examples of one participant improving their Hurdle Step score is shown in Figure 5.



Figure 5- This dancer scored a 2 during pretest and a 3 during posttest. Reasons for the difference in scoring include the ability to keep the alignment between the hips, knees, and ankles.

The In Line Lunge had six participants score a 3 and three participants score a 2 during pretest. In the post test, two out of the three participants who scored a 2 were able to increase their score to a 3 (Figure 6).

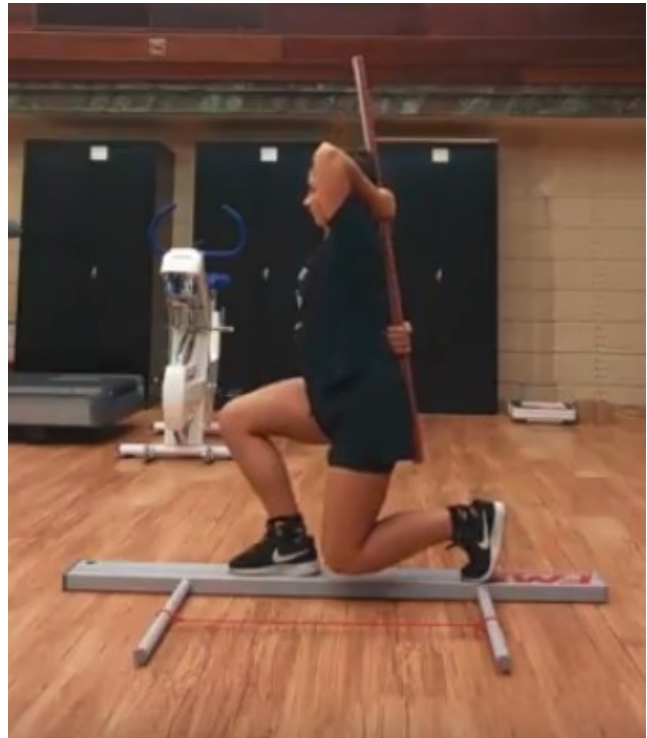


Figure 6- Comparison of pre and posttest In-Line Lunge showing increased ability to lunge deeper during lateral view analysis, indicating increased dorsiflexion.

In the Shoulder Mobility pretest, five participants scored a 2 and four participants scored a 3. Of the five participants who scored a 2, four of them were able to raise their score to a 3. Notably, two dancers received a score of a 2 in accordance to FMS protocol due to asymmetries between right and left sides during the pretest. In the post test, both dancers were able to raise their scores to a three indicating a reduction of asymmetries. However, one participant showed a decrease from a 3 during the pretest to a 2 during the post test. Figure 7 highlights the shoulder mobility screen.



Figure 7- Participant who scored a 2 during pretesting on the Shoulder Mobility Screen due to asymmetries between right and left sides. This dancer scored a 3 with the left arm raised and a 2 with the right arm raised, resulting in an overall score of a 2 due to FMS protocol of taking the lower score for the overall screen score. This participant increased her score to a 3 during post testing, however, posttest video is not available.

The Active Straight Leg Raise (ASLR) showed the same results of a 3 for all participants during both pre and posttests. Many of the dancers exhibited hyperflexibility in this test as they were able to lift their leg past the dial by a large amount (Figure 9).

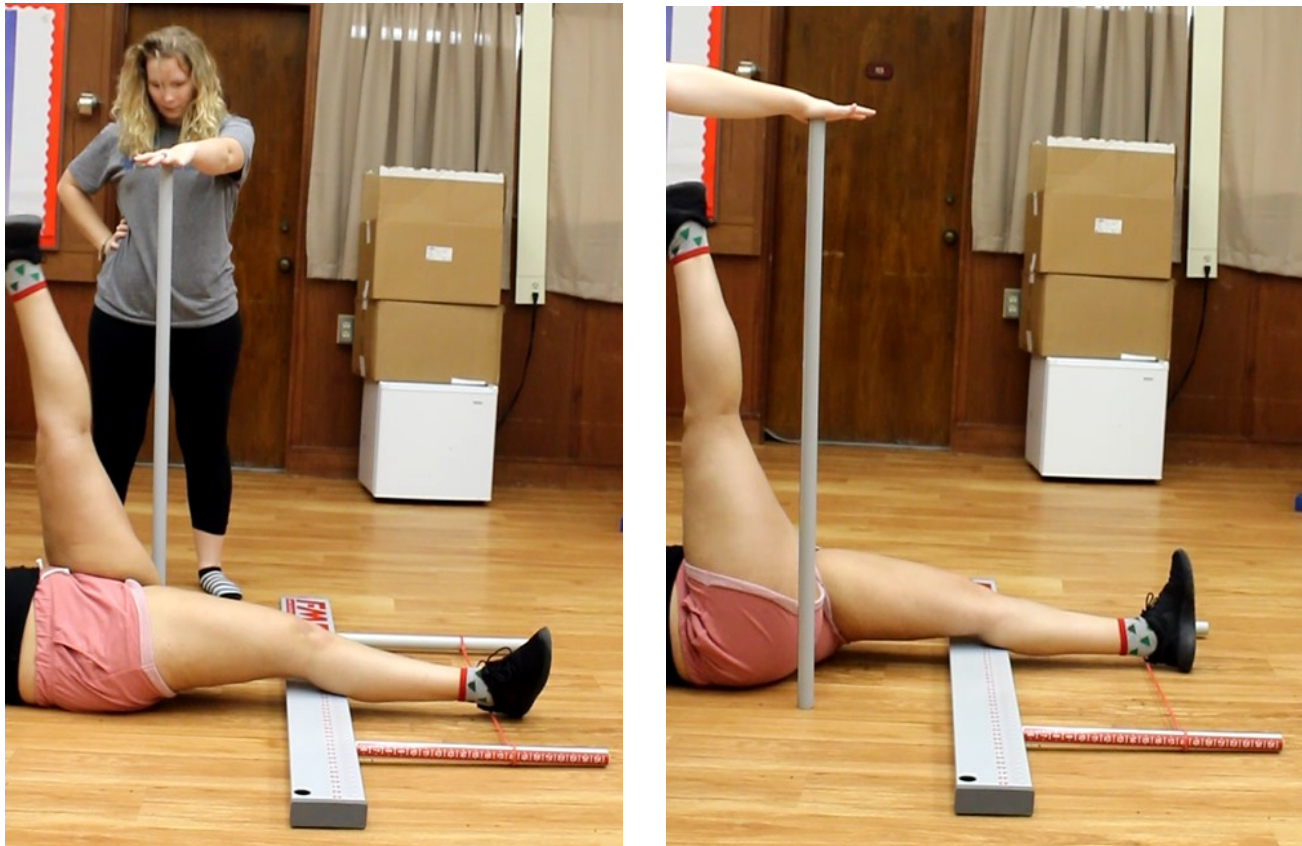


Figure 9- All dancers were able to receive a score of 3 (flexed foot passes dowel held between ASIS and mid-thigh) during both pre and posttest Active Straight Leg Raise tests.

Discussion

The main purpose of this study was to determine if a corrective exercise program could improve functional movement patterns in collegiate dancers. A limited number of studies have implemented the Functional Movement Screen as a pre assessment for the exercise programming. As such, this study aimed to examine those aspects and assist in providing further direction in exercise programming for dancers.

The eight-week exercise intervention was meant to focus primarily on ankle dorsiflexion, thoracic mobility, and hip stability as achieved through core strength. These aspects were chosen based upon the tests (Deep Squat, Hurdle Step, and Shoulder Mobility test) which scored the lowest during the pretest. The results of the corrective exercise intervention indicate that implementing these few simple exercises before each dance session could be potentially beneficial for improving the movement patterns of dancers.

The Deep Squat of the FMS is meant to assess the bilateral mobility of the ankles, knees, hips, shoulders, and thoracic spine (Cook, 2010). The average pretest score in the Deep Squat during the pretest was a 1.78 out of 3 possible points, indicating that the aforementioned areas needed to be addressed during the intervention. Common occurrences seen in the video analysis included excessive forward lean and a potential lack of ankle dorsiflexion, resulting in reduced depth of squat or the heels coming off of the ground. Other similar studies which utilized the FMS also reported the lowest overall scores in the Deep Squat test. In one study, Skotnicka et al. (2017) found that these low scores could potentially be due to lack of dorsiflexion and thoracic mobility, both issues which were addressed during the eight-week intervention. The group of dancers were divided into a control group and a group which received a corrective exercise

program after FMS pretesting. Posttest results showed a significant difference in the experimental group from pre to post testing in the Deep Squat, Hurdle Step, In Line Lunge, and Trunk Stability Pushup following the exercise intervention. The results of this study align with the Skotnicka et al. study and show that a corrective exercise program is beneficial to dancers as improvements in movement patterns was noted in both this study and the current study.

Each FMS test showed improvement after the eight-week intervention except for the Active Straight Leg Raise (ASLR). The ASLR did not show improvement since each dancer received a perfect score of a three during both pre and post testing. Dancers require greater than average levels of flexibility so these results are to be expected. During pretesting, however, many of the participants demonstrated an inability to control their pelvis while performing a peripheral movement which, in this case, was a straight single leg lift. Although according to the FMS scoring protocol, the participants received the highest score, in actuality, their performance indicated that many of the dancers lacked proper core musculature activation. Being able to control the core is a vital part of being able to balance and perform lower extremity movements which are prominent in a dancer's movement patterns (Davenport, Air, Grierson, and Krabak, 2016). A study by Watson et al. found that, after a nine-week core training intervention which included components of balance/dance posture, strength, endurance, and proprioceptive control of the core and lower extremity, dancers showed improvement in balancing positions (2017). This study used a three tier progression of static contractions in a stationary position with or without slow movements, static contractions in an unstable position or dynamic movements in a stable position, and finally dynamic movements in an unstable position in order to teach transverse abdominis activation. Following this intervention, dancers showed significant improvement in their ability to perform balances and single leg movements such a *passé relevé*.

Another study focused on how injury rates in dancers compare to their level of lumbopelvic control and the presence of hypermobility (Roussel, Nijs, Mottram, Van Moorsel, Truijen, & Stassijns, 2009). This study found that, rather than hypermobility, which occurred in 44% of the tested 32 dancers, the ability to exhibit lumbopelvic control was a better indicator for the likelihood of injury, signifying that there is a negative relationship between lumbopelvic control and injury. The high levels of flexibility often noted in dancers oftentimes decreases the stability of the lumbopelvic joint. The dancers in the current study all received a score of three on the ASLR; however, upon examination of the video analysis, a lack of lumbopelvic control, as indicated by the participant's hips rocking off of the floor, was observed, especially within the pretest videos. The isometric holds (modified boat pose) with peripheral leg movements in this study was meant to train the dancers to activate their core musculature while performing single leg movements, a common movement pattern for dancers. Posttest video analysis showed a greater level of control within the participant's lumbopelvic joint without decreasing any of the flexibility that is essential for dancers. Providing proper core training and teaching movement control can help to decrease the likelihood of injury associated with overly lax joints.

This study was limited in a few different ways. First, the sample size was small with nine people, thereby making it difficult to extrapolate this research to a wider population. The population itself was also homogenous as the sample was composed of only female dancers between the ages of 18 and 20, all of which were enrolled in a beginner jazz class, despite potential prior dance backgrounds. In addition, the amount of equipment, space, and time for a proper exercise intervention was limited. In addition, there was concern that the changes observed within this study could be resultant from additional behaviors outside of the exercise intervention. According to the Specific Adaptation to Imposed Demands (SAID) principle,

muscular adaptations are made based upon the level of stressors applied to the bodily system. Outside activities and exercise could potentially influence the demands placed upon the dancers and skew the results to show a greater adaptation than what really occurred. The survey provided to each of the dancers aimed to reduce the uncertainty of the influence of outside activities on the results of the study. However, each participant still had variability within their weekly routines which could have potentially affected the results.

Future studies should include both female and male dancers of all levels of collegiate dance. Repeating this research utilizing all seven of the FMS screens would be beneficial in observing the accuracy of the entire FMS for assessing movement quality in dancers. Also, future research should explore the next step in exercise program design which is designing a structured strength and conditioning program. Dance as a sport is still lacking a comprehensive and universal strength and conditioning program so research as to the best methods for implementing this is needed.

Conclusion:

Performing corrective exercises before each dance session can potentially help dancers improve their movement patterns by teaching proper muscular activation and alignment. Results showed an increase in FMS scores which indicates improved movement quality. A better understanding of proper movement patterns could potentially help decrease the risk of future injury, which is a common occurrence in dancers. The exercises performed in this study demonstrated the ability to improve key patterns like ankle dorsiflexion, thoracic mobility, and hip stability which are essential for creating a strong foundation of movement. This base will allow the dancers to participate in a more intense strength and conditioning program which could

help the dancers eventually perform better and in a safer manner. Implementing the Functional Movement Screen and a subsequent corrective exercise program based upon those results could be beneficial for dance training.

Appendix A- FMS Script

Deep Squat

- Stand w/ feet slightly wider than shoulder width apart with toes pointing forward
- Place dowel on back, with wrists and elbows in line (90 degree angle)
- Press dowel up so elbows are straight and dowel is overhead
- Descend into squat as low as possible while keeping dowel up and heels on ground
- Return to starting position
- *Place heels on FMS board if not 3*

Hurdle Step

- *Measure to tibial tuberosity*
- Stand with toes touching hurdle step
- Hold dowel with elbows and wrists in line (90 degree angle)
- Lower dowel onto shoulders
- While looking ahead, raise right leg over hurdle
- Touch heel down on opposite side of hurdle
- Return to starting position
- Repeat on opposite side

In Line Lunge

- Place dowel behind back so that it touches the butt, shoulder blades, and head
- Hold dowel with right hand by curve of neck and left hand by curve of lower back
- Step onto FMS board with right toes on zero mark
- Step forward so that the heel of the left foot is on the tibial tuberosity mark
- Descend into lunge so that right knee touches FMS board while maintaining 3 point contact with dowel on the back
- Return to starting position
- Repeat on opposite side

Shoulder Mobility

Impingement Test

- Place right hand on left shoulder
- Lift right elbow up towards face
- *Ask if pain is felt*

- *Measure length of palm*
- Make fists with hands
- Place right fist over the head and down the back
- Place left fist as far up the back as possible
- Don't try to wiggle hands closer
- *Measure distance*
- Repeat on opposite side

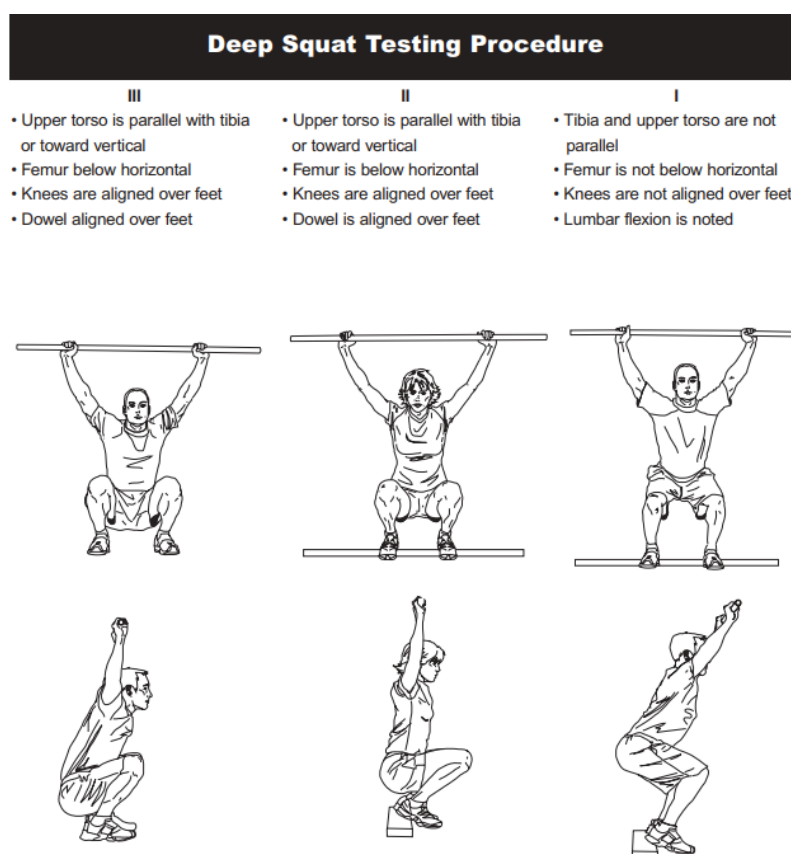
Active Straight Leg Raise

- Lay down with back of the knees over FMS board and feet together, toes pointing up
- Place hands next to your side with palms facing up
- Raise right leg as high as possible while maintaining contact with the board on with the left knee
- *Measure malleolus reach at 3 points- b/w mid-thigh and ASIS, b/w mid-thigh and patella, and below patella- depending on need*

Appendix B- FMS Scoring and Testing Procedure

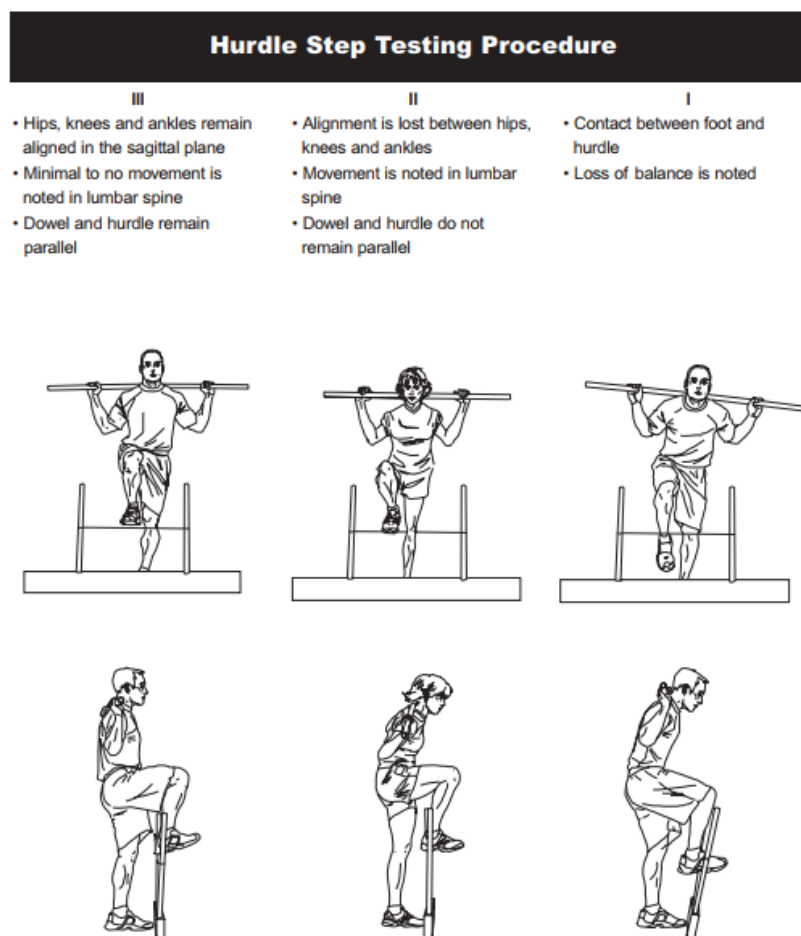
1. Deep Squat

The individual assumes the starting position by placing his/her feet approximately shoulder width apart with the feet aligned in the sagittal plane. The individual then adjusts their hands on the dowel to assume a 90- degree angle of the elbows with the dowel overhead. Next, the dowel is pressed overhead with the shoulders flexed and abducted, and the elbows extended. The individual is then instructed to descend slowly into a squat position. The squat position should be assumed with the heels on the floor, head and chest facing forward and the dowel maximally pressed overhead. The individual may repeat the movement up to three times. If the criteria for a score of III is not achieved, the athlete is then asked to perform the test with a 2 x 6 board under their heels.



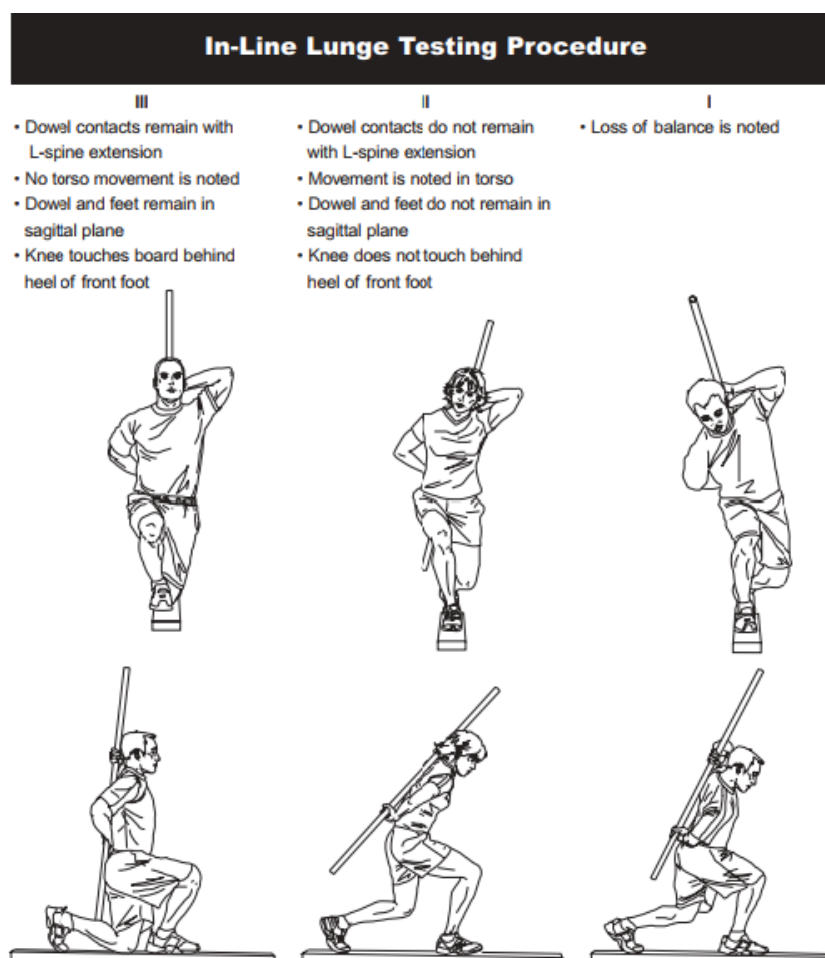
2. Hurdle Step

The individual assumes the starting position by first placing the feet together and aligning the toes touching the base of the hurdle. The hurdle is then adjusted to the height of the athlete's tibial tuberosity. The dowel is positioned across the shoulders below the neck. The individual is then asked to step over the hurdle and touch their heel to the floor while maintaining the stance leg in an extended position. The moving leg is then returned to the starting position. The hurdle Step should be performed slowly and as many as 3 times bilaterally. If one repetition is completed bilaterally meeting the criteria below a score of III is given.



3. In Line Lunge

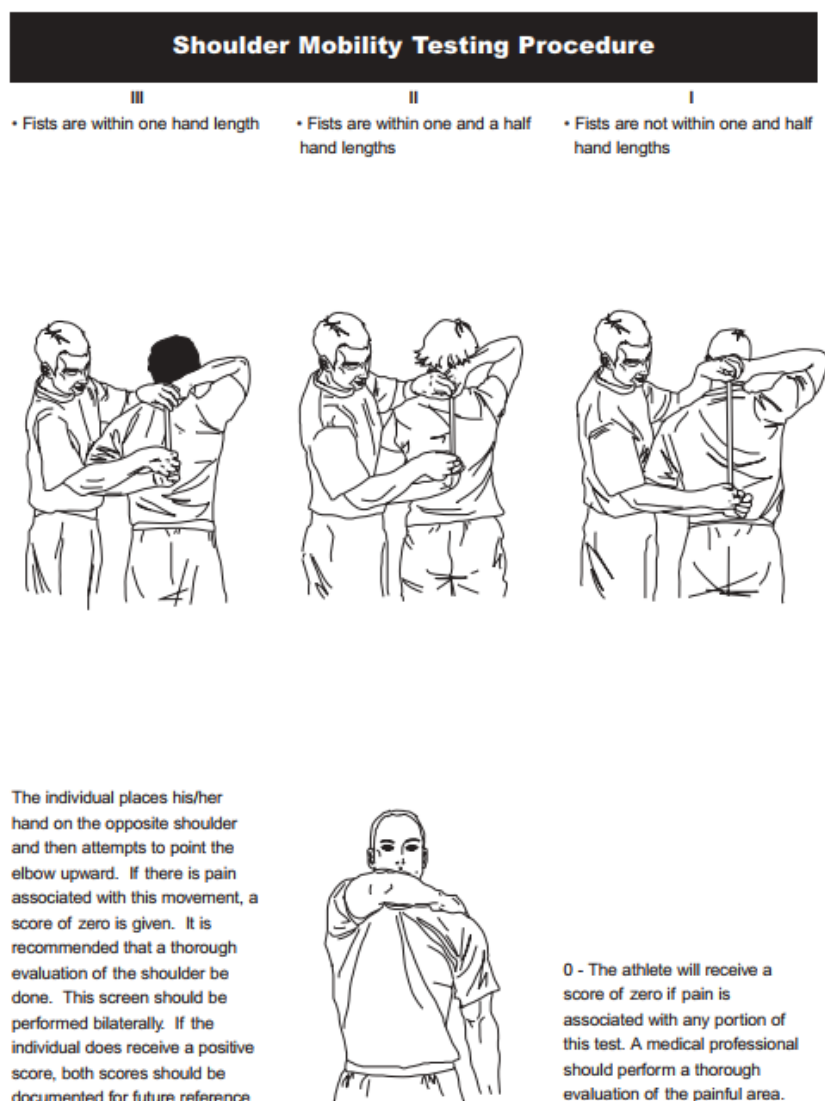
The tester attains the individual's tibia length, by either measuring it from the floor to the tibia tuberosity or acquiring it from the height of the string during the hurdle step test. The individual is then asked to place the end of their heel on the end of the board. The previous tibia measurement is then applied from the end of the toes of the foot on the board and a mark is made. The dowel is placed behind the back, touching the head, thoracic spine and sacrum. The hand opposite to the front foot should be the hand grasping the dowel at the cervical spine. The other hand grasps the dowel at the lumbar spine. The individual then steps out on the board placing the heel of the opposite foot at the indicated mark on the board. The individual then lowers the back knee enough to touch the board behind the heel of the front foot and then returns to starting position. The lunge is performed up to three times bilaterally in a slow, controlled fashion. If one repetition is completed successfully, then a three is given.



4. Shoulder Mobility

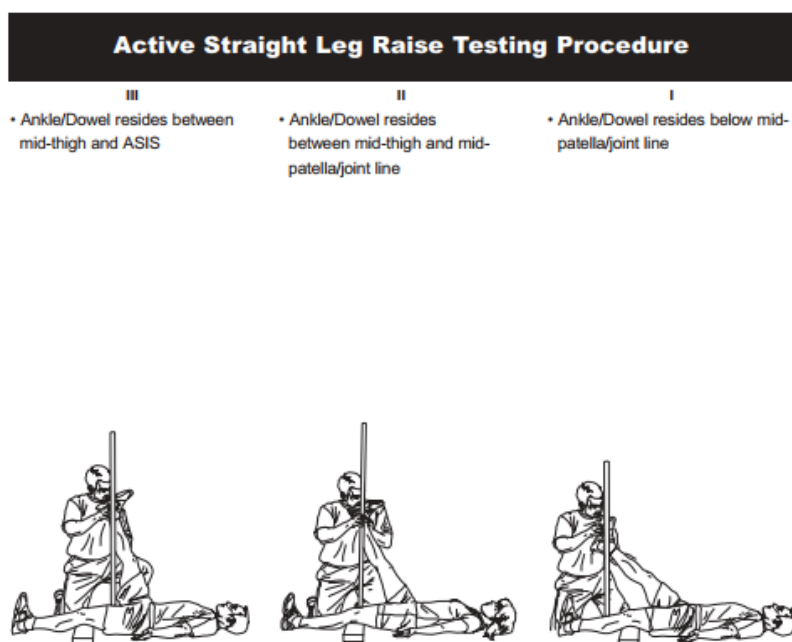
The tester first determines the hand length by measuring the distance from the distal wrist crease to the tip of the third digit. The individual begins standing with feet together, and remains in this position throughout the test. The individual is instructed to make a fist with each hand, placing the thumb inside the fist. They are then asked to assume a maximally adducted, extended and internally rotated position with one shoulder, and a maximally abducted, flexed and externally rotated position with the other. During the test the hands should remain in a fist and they should be placed on the back in one smooth motion. The tester then measures the distance between the two closest bony prominences. Perform the shoulder mobility test as many as 3 times bilaterally.

Clearing exam: There is a clearing exam at the end of the shoulder mobility test. This movement is not scored; it is simply performed to observe a pain response. If pain is produced, a positive is recorded and a score of zero is given to the entire shoulder mobility test. This clearing exam is necessary because shoulder impingement can sometimes go undetected by shoulder mobility testing alone.



5. Active Straight Leg Raise

The individual first assumes the starting position by lying supine with the arms in an anatomical position and head flat on the floor. The board is placed under the knees. The tester then identifies mid-point between the anterior superior iliac spine (ASIS) and mid-point of the patella, the dowel is then placed at this position perpendicular to the ground. Next, the individual is instructed to lift the test leg with a dorsiflexed ankle and an extended knee. During the test the opposite knee should remain in contact with the board, the toes should remain pointed upward, and the head remain flat on the floor. Once the end range position is achieved, and the malleolus is located past the dowel, then the score is recorded per the criteria. If the malleolus does not pass the dowel then the dowel, is aligned along the medial malleolus of the test leg, perpendicular to the floor and scored per the criteria. The active straight leg raise test should be performed as many as 3 times bilaterally.



Appendix C- Informed Consent

INFORMED CONSENT:

1. This is a research effort to assess the movement patterns of dancers and address any issues through the creation of a corrective exercise program.
2. Your participation in this research is voluntary.
3. Your participation will require a 10 week commitment which includes meeting twice a week for approximately 20 minutes each session.
4. Your participation will require you to work with the research team at the Florida Southern College Exercise Science department.
5. Your participation will require you to have basic anthropometric tests completed before the treatment, which include: Height, weight, body composition, and body mass index.
6. Your participation will require you to complete a pre and posttest through the seven step Functional Movement Screen (FMS) that will be videotaped.
7. Your participation will require you to receive biweekly exercise sessions aiming to correct movement discrepancies, most likely noted throughout the core and lower extremities. These exercises will gradually progress throughout the course of this exercise program.
8. You will be asked to maintain your normal eating and exercise schedule throughout the day of the experiment.
9. You may withdraw from participating in this research at any time without negative consequences or penalties; likewise, refusal to participate will not result in any penalty to you.
10. You will not receive financial compensation for your participation in this research study.
11. Participation presents minimal risks to you.
12. Public dissemination will occur in academic research journals and presentations with results of the research presented in summary form only and with no individual identification in the data analysis.
13. Your signature at the bottom of this form indicates that you have given voluntary consent to participate in this study.
14. Please contact **Dr. Mick Lynch at 863-680-6205** or at jlynch@flsouthern.edu if one or more of the following apply to you:
 - a. You have questions regarding your rights as a participant in this study.
 - b. You wish to have a copy of the results presented as a summary form.
15. You may also contact Kyle Fedler, PhD, who is the Provost and Chief Academic Officer of Florida Southern College at 863-680-4124 if you have questions about your rights as a participant.
16. This research protocol and informed consent has been reviewed and approved by the Florida Southern College Human Subjects Review Committee (HSRC) for use from (9/28/17) to (9/28/18).

☐ ***By checking this box, you acknowledge that you have read and understand the above material and that you understand what this research involves.***

By signing below, you are agreeing and consenting to participate in the research.

Participant PRINTED Name

Participant Signature

Date

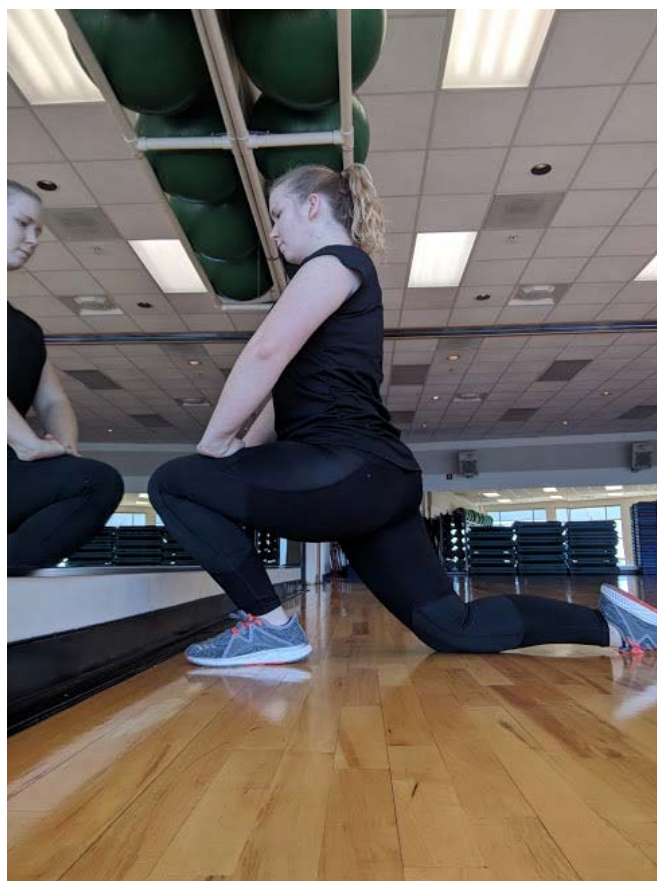
Appendix D- Chosen Exercises and Progressions

	Sessions 1-3				Sessions 4-6			
Focus:	Exercise	Reps 1	Reps 2	Sets	Exercise	Reps 3	Reps 4	Sets
Ankle Dorsiflexion	Dorsiflexion w/ Band (F, B, L)	12	14	2	Dorsiflexion w/ Band (ABCs)	1	2	2
Thoracic Mobility	Wall Slides	12	14	2	Wall Slides	12	14	2
Hip Stability/ Core Activation	Bent Knee Raises (Low V Position)	12	14	2	Bent Knee Raises (High V Position)	12	14	2
	Bilateral Glut Bridge	12	14	2	Bilateral Glut Bridge	12	14	2
	Bilateral Deadlift	12	14	2	Bilateral Deadlift	12	14	2
	Sessions 7-9				Sessions 9-12			
Focus:	Exercise	Reps 5	Reps 6	Sets	Exercise	Reps 5	Reps 6	Sets
Ankle Dorsiflexion	Kneeling Dorsiflexion Stretch	10	12	2	Kneeling Dorsiflexion Stretch	14	16	2
Thoracic Mobility	T Spine Rotation Stretch	15s	25s	4	T Spine Rotation Stretch	35s	45s	4
Hip Stability/ Core Activation	Straight Leg Raises (Low V Position)	12	14	2	Straight Leg Raises (High V Position)	12	14	2
	Unilateral Glut Bridge	12	14	2	Unilateral Glut Bridge	12	14	2
	Unilateral Deadlift	12	14	2	Unilateral Deadlift	12	14	2

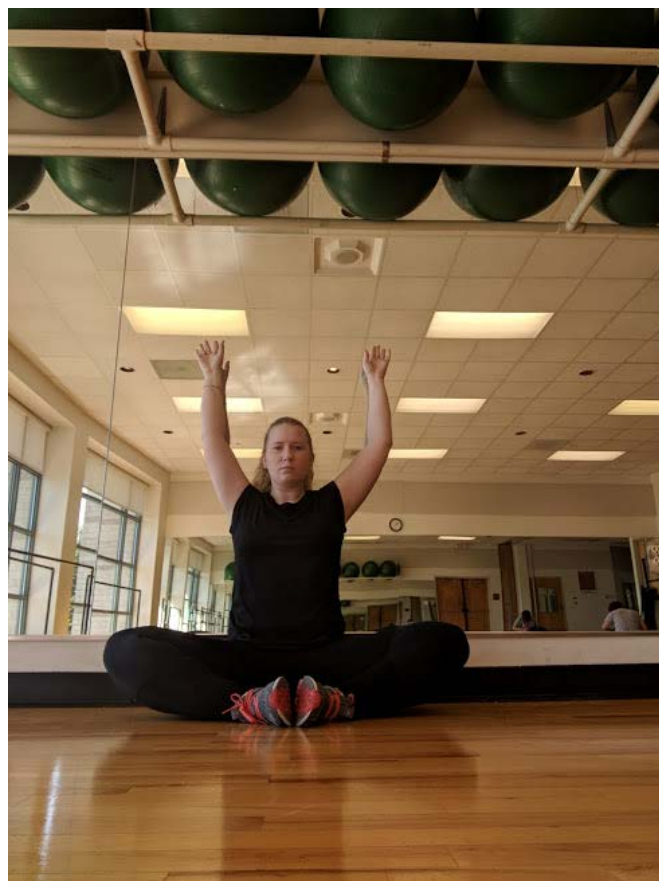
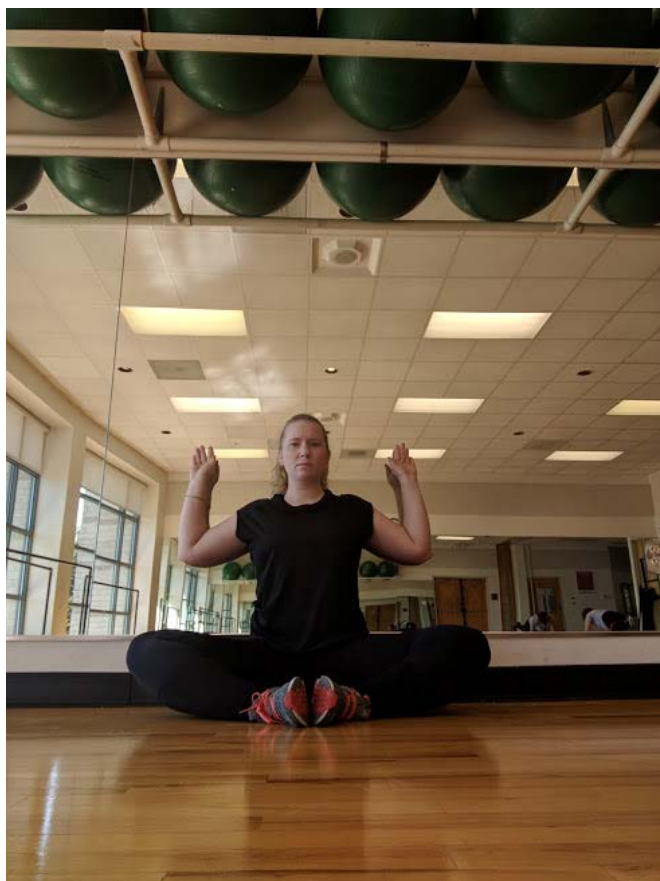
Appendix E- Visuals of Performed Exercises



Ankle Dorsiflexion exercise variations performed during the first half of the exercise intervention



Kneeling Dorsiflexion stretch performed during the last half of the intervention



Wall Slide meant to improve thoracic mobility during first half of intervention. Iron Cross stretch performed during last half of the intervention is not pictured.

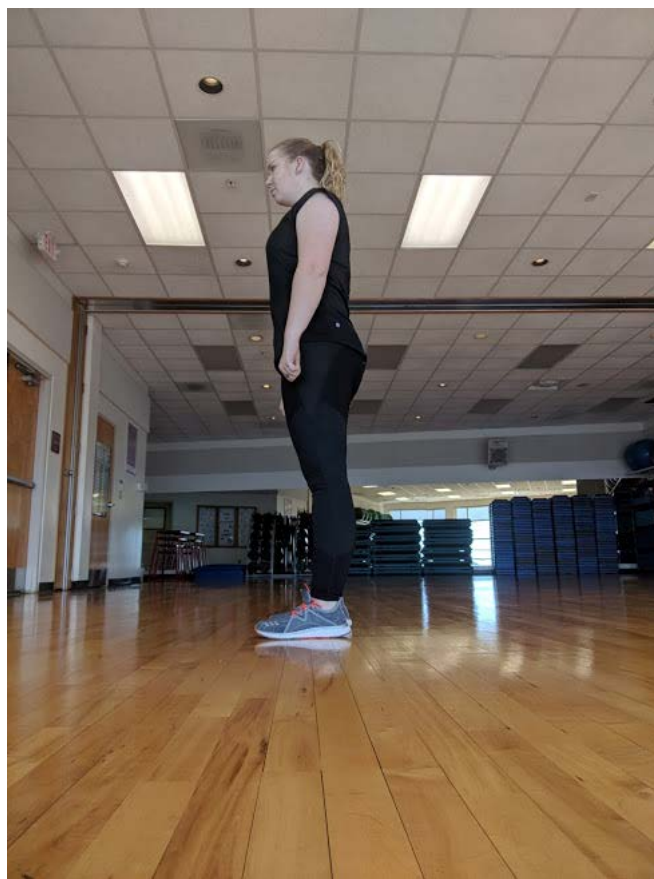


Boat Pose variations. The first four sessions (top row) involved bent knee raises while the next four sessions (second row) involved straight leg raises. The final 8 sessions progressed to a high boat position and followed the same bent knee, straight leg progressions as previously shown.

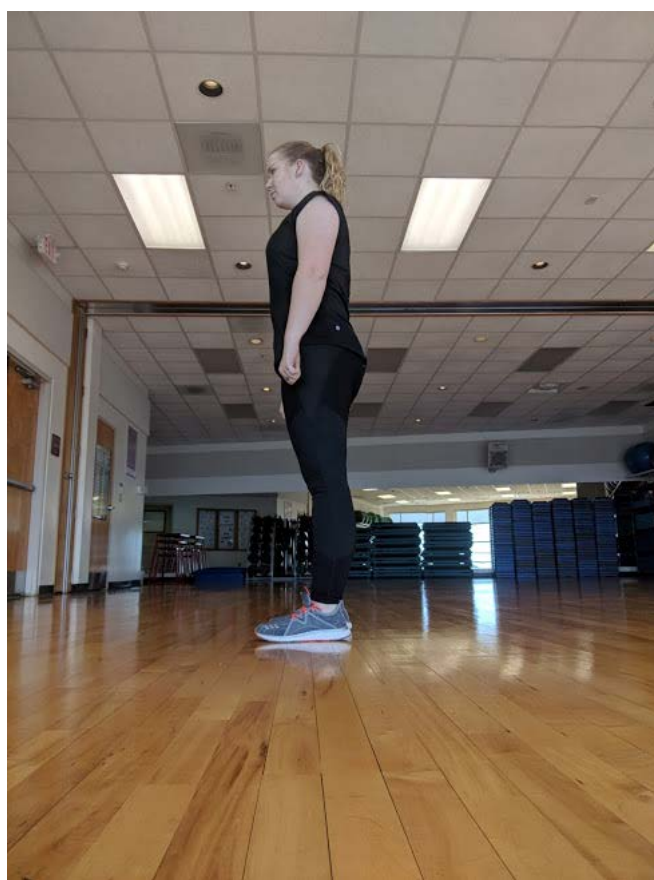


The first half of the exercise intervention involved performing a bilateral glute bridge (top) while the second half involved a unilateral glute bridge (bottom).





The exercise intervention cumulated in a deadlift variation each session. The participants first performed a bilateral deadlift (above) before progressing to unilateral deadlifts (below) in the second half of the program.



Appendix F- Survey

1. How many dance classes are you currently enrolled in?

- | | |
|------|-------|
| a. 1 | d. 4 |
| b. 2 | e. 5+ |
| c. 3 | |

2. How many days a week do you participate in dance outside of your enrolled classes (i.e. personal practice, rehearsal, dance team, etc.)

- | | |
|------|------|
| a. 1 | e. 5 |
| b. 2 | f. 6 |
| c. 3 | g. 7 |
| d. 4 | |

3. On average, for how many hours do you participate in dance each week (i.e. time in enrolled classes + time in outside dance activities)?

- | | | |
|-----------------------|----------------|--------------------------|
| a. 4 hours of
less | e. 11-12 hours | i. 19- 20
hours |
| b. 5-6 ours | f. 13-14 hours | j. More than
20 hours |
| c. 7-8 hours | g. 15-16 hours | |
| d. 9-10 hours | h. 17-18 hours | |

4. Have you ever experienced an injury from dance during the current semester which caused you to miss practice or limited your ability to perform?

- a. Yes
- b. No

5. If so, how long were you unable to perform normally?

- a. Less than 3 days
- b. 4-7 days
- c. More than a week

6. If so, which area of the body was affected? (Select all that apply)

- a. Hand/ Wrist
- b. Shoulder/ Neck/ Upper Back
- c. Lower Back
- d. Hip
- e. Knee
- f. Ankle
- g. Foot
- h. Not Applicable

7. Do you regularly participate in structured exercise other than dance?

- a. Yes
- b. No

8. If so, how many days a week do you participate in exercise?

- a. 1-2 days
- b. 3-4 days
- c. 5+ days
- d. Not applicable

9. If so, what form of exercise do you participate in? (Select all that apply)

- a. Cardio (Biking, Running, Elliptical, etc.)
- b. Resistance Training (Weightlifting, Bodybuilding, Powerlifting, etc.)
- c. Flexibility Training (Yoga, PNF Stretching, etc.)
- d. Circuit or Interval Training
- e. Group Exercise Classes
- f. Not Applicable

10. If so, how long is each exercise bout?

- a. Less than 30 minutes
- b. 30 minutes- 1 hour
- c. More than 1 hour
- d. Not Applicable

Works Cited

- Allen, N., Nevill, A. M., Brooks, J. H., Koutedakis, Y., and Wyon, M. A., 2012. Ballet Injuries: Injury Incidence and Severity Over 1 Year. *Journal of Orthopaedic & Sports Physical Therapy*, (42)9, 781-789.
- Allen, N., Nevill, A. M., Brooks, J. H. M., Koutedakis, Y., & Wyon, M. A., 2013. The Effect of a Comprehensive Injury Audit Program on Injury Incidence in Ballet: A Three Year Prospective Study. *Clinical Journal of Sports Medicine*, 23(5), 373- 378.
- Bryant, C. X., & Green, D. J. (2010). *ACE personal trainer manual: the ultimate resource for fitness professionals*. San Diego, CA: American Council on Exercise.
- Carter, S. L., Duncan, R., Widemann, A. L., & Hopper, L.S., 2018. Lower leg and foot contributions to turnout in female pre-professional dancers: A 3D kinematic analysis. *Journal of Sports Science*.
- Cheng-Feng, L., Fong-Chin, S., & Hong-Wen, W. (2005). Ankle biomechanics of ballet Dancers in relevé en pointé dance. *Research in Sports Medicine*, 13(1), 23-35.
- Cook, G., 2010. *Movement: Functional Movement Systems—Screening, Assessment, Corrective Strategies*. Santa Cruz, CA. On Target Publications.
- Costa, M. S. S., Ferreira, A. S., Orsini, M., Silva, E. B., & Felicio, L. R., 2016. Characteristics and prevalence of musculoskeletal injury in professional and non-professional ballet dancers. *Brazilian Journal of Physical Therapy*, 20(2), 166–175.

- Davenport, K. L., Air, M., Grierson, M. J., & Krabak, B. J. (2016). Examination of Static and Dynamic Core Strength and Rates of Reported Dance Related Injury in Collegiate Dancers. *Journal Of Dance Medicine & Science*, 20(4), 151-161.
- Dorrel, B., Long, T., Shaffer, S., & Myer, G. D. (2018). The Functional Movement Screen as a Predictor of Injury in National Collegiate Athletic Association Division II Athletes. *Journal Of Athletic Training (Allen Press)*, 53(1), 29-34. doi:10.4085/1062-6050-528-15
- Esco, M. R., 2013. ACSM Information for Resistance Training and Fitness. American College of Sports Medicine Consumer Information Committee.
- Galantino, M. L., Lim, J. H., Bahring, S., & Woolverton, K. (2017). Outcome Measures for Dance Injury: A Pilot Study Exploring Functional Movement Screen and a Novel Screening Tool. *Orthopaedic Physical Therapy Practice*, 29(3), 168-173.
- Jacobs, C. L., Cassidy, J. D., Schwartz, I., Côté, P., Boyle, E., Hartvigsen, J., Ramel, E., & Ammendolia, C. (2017). Musculoskeletal Injury in Professional Dancers: Prevalence and Associated Factors: An International Cross-Sectional Study. *Clinical Journal Of Sport Medicine*, 27(2), 153-160.
- Lee, L., Reid, D., Cadwell, J., & Palmer, P. (2017). Injury Incidence, Dance Exposure and the Use of the Movement Competency Screen (MCS) to Identify Variables Associated with Injury in Full- Time Pre-Professional Dancers. *International Journal Of Sports Physical Therapy*, 12(3), 352-370.

Penrod, J. W. (2005). Dancers at Risk: Who's in Charge?. *JOPERD: The Journal Of Physical Education, Recreation & Dance*, 76(9), 3-5.

Rodrigues-Krause, J., Krause, M., & Reischak-Oliveira, Á. (2015). Cardiorespiratory Considerations in Dance From Classes to Performances. *Journal Of Dance Medicine & Science*, 19(3), 91-102.

Roussel, N. A., Nijs, J., Mottram, S., Van Moorsel, A., Truijen, S., & Stassijns, G. (2009). Altered lumbopelvic movement control but not generalized joint hypermobility is associated with increased injury in dancers. A prospective study. *Manual Therapy*, 14(6), 630-635.

Roussel, N. A., Vissers, D., Kuppens, K., Fransen, E., Truijen, S., Nijs, J., & De Backer, W. (2014). Effect of a physical conditioning versus health promotion intervention in dancers: A randomized controlled trial. *Manual Therapy*, 19(6), 562-568.

Sherman, A. J., Mayall, E., & Tasker, S. L. (2014). Can a Prescribed Turnout Conditioning Program Reduce the Differential Between Passive and Active Turnout in Pre-professional Dancers?. *Journal Of Dance Medicine & Science*, 18(4), 159-168.

Skotnicka M., Karpowicz, K., Bartkowiak, S., & Strzelczyk, R. (2017). The impact of the corrective and stability exercises program on the quality of basic movement patterns among dance students. *Trends In Sport Sciences*, 24(1), 31-38.

Twitchett, E., Koutedakis, Y., Wyon, M., 2009. Physiological Fitness and Professional Classical Ballet Performance: A Brief Review. *Journal of Strength and Conditioning Research*, (23)9, 2732- 2740.

Watson, T., Graning, J., McPherson, S., Carter, E., Edwards, J., Melcher, I., & Burgess, T.

(2017). Dance, balance, and core muscle performance measures are improved following a 9-week core stabilization training program among competitive collegiate dancers. *International Journal Of Sports Physical Therapy*, 12(1), 25-41.

Williams, C. C., Gdovin, J. R., Allen, C. R., Wilson, S. J., Cazas-Moreno, V. L., Ossenheimer, C., Garner, J. C., 2016. Strength and Conditioning Considerations for Collegiate Dance. *Strength and Conditioning Journal*, (38)2, 88- 95.

“ACSM News Releases”, 2018. *American College of Sports Medicine*.

“What Is A Normal Day For A Professional Dancer?”, 2017. *Career Ignitor*.