# CORE STABILITY OF UNDERGRADUATE COLLEGIATE DANCERS: AN INVESTIGATION OF PILATES ON CORE STABILITY AND DANCE PERFORMANCE

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## ABSTRACT

Core stability is crucial for dancers, who must execute complex movements while maintaining proper alignment. However, there is limited research on suitable core stability tests for dancers. This thesis aimed to: (a) develop a reliable, dance-specific abdominal test, scoring tool, and protocol for assessing the effects of Pilates training in intervention studies, and (b) contribute to understanding the impact of Pilates on dance performance, including both mat and apparatus work.

The literature review highlighted the lack of research on Pilates' impact on dance training, with mixed results. Study 1 compared a traditional abdominal endurance test, FITNESSGRAM curl test (FGCT), with Pilates-based exercises (e.g., Legs Up, Legs on Diagonal) and found no significant differences in lower rectus abdominis engagement. However, pelvic alignment issues in the FGCT may have influenced results, as it does not consider dance-specific alignment.

Study 2 explored the effects of a Pilates Mat routine on modern dance performance and core stability. Although statistical data was limited, participants showed a mean of 75% improvement in plank tests, improving on the plank scoring test with participants reaching the average rating. The movement phrase, scored by three independent evaluators with 67% inter-reliability, showed that dancers improved in the dance movements from pre to post testing, with the largest improvement seen in handstand performance. Using Braun and Clarke's (2006) thematic analysis three themes were developed: (1) Core Strength and Control, (2) Body Awareness, (3) Support for Dance Practice. Participant responses supported perceived impact of Pilates on core control, body awareness and improved dance training.

Study 3 investigated the effects of a Pilates wall unit on dancers, focusing on pelvic alignment and core stability. The intervention group showed a significant improvement in the lower abdominal test (+12.3%), with moderate improvements in other tests for pelvic alignment and core strength. The intervention groups improved consistently in the active neutral test with a mean improvement of 40%. Both groups showed improvements in leg angle performance during the lower abdominal test, however, the intervention group demonstrated more consistent gains, potentially attributable to the structured Pilates-based core training. Qualitative data assessed dancer perception of the impact of Pilates on core stability and dance training. Through the coding process and theme development, two key themes emerged: (1) Strength and Progression, (2) Awareness and Control. Dancers perceived improvement in core strength and stability, body awareness and more control in dance movements.

The findings suggest that current abdominal tests are not fully applicable to dancers, as they do not account for alignment. While this thesis did not develop a new test, it provides foundational insights for further research. The Dancer Conditioning Impact Assessment Protocol, a three-step approach to analyzing training impact, offers a

framework for assessing dance performance. Overall, Pilates may improve dancers' strength, balance, and flexibility, but cross-training with other conditioning methods may be essential for optimal performance.

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## ACKNOWLEDGEMENTS

Beginning my doctoral research has always been a dream of mine, something I wanted to prove to myself. Researching Pilates and its connection to dancers is important to me because I am passionate about both. It has been a slow and sometime inconsistent journey, but the turtle did finally win the race. Many people have supported me in this journey and have been the force to keep encouraging me every step of the way.

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# ABBREVIATIONS AND TERMS

| ABBREVIATIONS | DEFINITIONS |
| --- | --- |
| ASIS | Anterior superior iliac spine |
| AUC | Area under the curve |
| BIOLD | Biofeedback legs diagonal |
| BIOLU | Biofeedback legs up |
| BIOLULD | Biofeedback legs up legs diagonal |
| ECG | Electrocardiography |
| FGCT | FITNESSGRAM curl test |
| IRED | Infrared light emitting diodes |
| LRA | Lower rectus abdominis |
| LD | Legs diagonal |
| LU | Legs up |
| LULD | Legs up legs diagonal |
| MVIC | Muscle voluntary isometric contraction |
| PEDro Scale | A scale to measure the validity and methodological quality of clinical trials |
| PSIS | Posterior superior iliac spine |
| RCT | Random control trial |
| ROM | Range of motion |
| sEMG | Surface electromyography |
| URA | Upper rectus abdominis |

# DANCE TERMS AND DEFINITIONS

| DANCE TERMS | DEFINITIONS |
|---|---|
| $5^{th}$ en haut | Both arms extended and placed over the head. |
| Alignment | The stacking of the body where the head is aligned over the shoulders which is aligned over the ribcage which is placed on top of the pelvis. The center of the knees and ankles are aligned under the pelvis. |
| Arabesque | Standing on one leg with the other leg extended fully behind the body. |
| Attitude | Standing on one leg with the other placed in front, side or back bent at a 90 degree. |
| Cambré | The spine extends to the back as the pelvis maintains neutral alignment. |
| Developpé | Developing movement. The working leg is drawn up to the standing knee and extended out in either the front, side or back position. |
| Elevé | To rise. Keeping the legs straight rise to the ball of the feet. |
| Fondu | Melting. Standing on one leg and "melting" down by bending the standing leg. |
| Grand battement | Big beat. Standing with the legs extended brush the leg along the floor and into the air in either the front, side or back positions. |
| Grand plié | Large bend. To bend both legs and lower the pelvis to the floor and back up again. |
| Grand rond de jambe | Round the leg. To extend the leg into the air and carry it through the front, side and back positions before bringing it back to the floor. Can also go from back to front. |
| Pelvic alignment | Neutral pelvis. The anterior superior iliac spine and the pubis are aligned in the coronal plane. |
| Penché | Extend one leg behind the body and bend over at the hip while the leg extends to the ceiling. |
| Plié | To bend. To bend both knees simultaneously . |
| Relevé | To rise. To rise to the ball of the foot from a bent leg position. |

# PILATES TERMS AND DEFINITIONS

| PILATES TERMS | DEFINITIONS |
|---|---|

| | |
|---|---|
| Cadillac | A raised horizontal mat surrounded by four poster frame posts with various straps and springs. |
| Catapult | Training system with belts and nylon covered elastics designed to increase speed. |
| Corealign | To tracks so the legs and arms can work independently with a ladder attached to one end. |
| Exochair | Similar to the wunda chair but with additional covered elastics attached. |
| Foot corrector | A pedal with straps to stretch the foot. |
| Guillotine | A tall frame with a horizontal bar attached to springs. |
| Head Harness | A strap that supports the head for improving muscle function in the neck. |
| Ladder barrel | A tall arc with a ladder attached. |
| Magic circle | A circle with handles that provides resistance training. |
| Ped-o-pull | A tall pole with two springs attached for postural alignment training. |
| Pilates arc | An light weight arc the sits upon the floor for use to correct spinal alignment. |
| Spine corrector | Original Pilates arc (see above). |
| Toe & finger correctors | A pedal with attachments to strengthen fingers and toes. |
| Trapeze table | Another term for the cadillac (see above) |
| Wall unit | Two posts attached to a wall with springs, bars, and strap attachments. |
| Wunda chair | Backless chair with pedals attached to springs. |

# 1: Introduction

## 1.1 Background and Definitions of key areas

### 1.1.1 Pilates

Joseph H. Pilates was born in Mönchengladbach, Germany on December 9, 1883. As a young child he was plagued with ailments such as rheumatic fever, rickets, and chronic asthma. In pursuit of better health, Pilates sought out physical activities including gymnastics, bodybuilding, diving, fencing and other physical regimens. He studied yoga, Zen meditation, karate but was drawn to exercise programs of ancient Greek and Roman origin. After moving to England, in 1913, he was interned as an "enemy alien" at a civilian camp during World War I. It is here that he developed his exercise regimen to remain healthy (Latey, 2001). At the end of the war, he was transferred to the Isle of Man where he worked as a hospital orderly and helped rehabilitate injured soldiers. Working with patients who were unable to leave their hospital beds, Pilates experimented with the use of the hospital bedsprings to add resistance to his exercises and discovered this would allow his patients to regain muscle tone more quickly (Latey, 2001). This led to the development of complementary equipment, such as the reformer, originally known as the universal reformer, incorporating the concept of the hospital bedsprings. After the war he returned to Germany where he built relationships throughout the dance community, most notable was his lasting relationship with Rudolph Laban. By the mid 1920's the German army became increasingly interested in his work and this led to his immigration to the United States in 1926. Pilates opened a studio in New York, Contrology Gymnasium, where he continued to improve his work and develop more equipment such cadillac or trapeze table, wunda chair, magic circle, foot corrector, ped-o-pull, head harness, toe and finger correctors, spine corrector, ladder barrel, guillotine, catapult, and a variety of devices that he used to correct and improve postural stability.

He developed an extensive repertoire of exercises which he later branded, Contrology. Pilates first published his ideas in his book *Your Health*, in 1934 and published his second book, *Return to Life Through Contrology* in 1945.

Although Pilates began a teacher training program, he lacked trust that others would stay true to his philosophies as he believed that each body is different, and exercises needed to be adapted to meet individual's needs. He only taught a few individuals who opened their own Pilates studios throughout the United States. Many of his protégées disagree on how Pilates should be taught, and this led to two different Pilates schools; Classical Pilates and Modern Pilates (Latey, 2001). Classical Pilates remains close to Joseph Pilates' original exercises including the order of exercises, while Modern Pilates embraces current ideas on movement principles, modifies the original exercises and utilizes new pieces of equipment, such as the corealign. Over the years, another form of Pilates evolved, Clinical Pilates (Owsley, 2005). Clinical Pilates is influenced by physical therapy and biomechanics to create new exercises and modifications focused on injury rehabilitation.

### 1.1.2 Dance Training and Performance

Dance combines both artistry and athleticism imposing unique biomechanical and physiological requirements, which changes across genres. Dance is physically demanding with daily practice including class, rehearsal, and added conditioning resulting in up to 10 hours per day of physical practice. Outside of daily practice, performance seasons can include up to 8 or more performances a week, intense travel schedules, and teaching masterclasses (Welsh, 2009). The physical aspect of dance pushes the body beyond normal physical limits to master complex choreography while maintaining the desired aesthetics and artistry dance requires. Different styles of dance require specialized movements. Ballet emphasizes external hip rotation, high levels of flexibility, and pointe work which requires joint stability and plantar flexion (Bird, 2015). Pirouettes, a turn on one leg, is a common movement in ballet and can be done in both directions (en dehors and en dedans). This movement requires proper alignment of the spine and pelvis with rotational torque managed by core and hip stability. Modern or contemporary dance involves floor work and inversions, increased upper body strength, core stability, and flexibility to absorb impact during fall and floorwork (Bird, 2015). Floorwork requires eccentric control and proprioception for transitions and directional changes (Wilson, 2008 and Lee, 2025). Hip-hop and jazz rapid directional changes, explosive power for jumps, and joint isolations (Lee, 2025). Jumps require rapid force generation and absorption which puts stress on the knees and ankles (Wilson, 2008 and Lee, 2025). Jumps are used in all of these dance forms.

Historically, western trained dancers are seen as perfectionist and strive for excellence in each movement (Nordin-Bates, et al, 2014). In the chase for perfection, dancers often develop faulty alignment and increased muscular imbalances leading to an increased risk of injury (Malkogeorgos, et al 2011; Bowerman, 2015). Cross-training has been shown to decrease injury in dancers (Dang, et al, 2023) and should be part of a dancer's regular training protocol. One study by Farmer and Brouner (2021) showed that dancers, both professional and collegiate, believe strength training is important to their overall training and dance performance. According to Welsh (2009), dancers should develop seven physical capacities including proper alignment, neuromuscular coordination, full range of motion and flexibility, muscular strength, aerobic endurance, relaxation skills, and body composition as it relates to specific forms of dance to be successful as a professional dancer. Armstrong and Relph (2018) suggest similar physical skills to meet the performance demands of dancers including strength, speed, power, agility, cardiovascular endurance, flexibility, coordination, and balance.

### 1.1.3 Core Stability, Injury, Proper Alignment and Exercise

#### Core Stability

Kibler et al. (2006) defines core stability as the ability to control the position and motion of the trunk over the pelvis to allow optimum production, transfer and control of force and motion to the terminal segment in integrated athletic activities. Yu and Lee (2012), Willson et al. (2005) and Singh (2025) characterize core stability by hip and trunk strength, trunk endurance, and maintaining pelvic and spinal placement. Singh (2025) decreased anterior pelvic tilt in order to reduce low back pain by building a core stability program emphasizing core endurance activating deep core muscles including the transverse abdominis and multifidus. Okada et al. (2011) state core stability is achieved through stabilization of one's torso, controlling force and motion during an integrated kinetic chain activity. The core muscles are defined as a group of trunk muscles that surround the spine and abdominal viscera which include the diaphragm, abdominal muscles, paraspinal and gluteal muscles and the pelvic floor and hip girdle (Huxel Bliven & Anderson, 2013; Akuthota, et al, 2008). In Pilates, the infrastructure of the core, or commonly known to Pilates specialist as the powerhouse, includes the abdominals, back or spine, shoulder girdle, and pelvic stabilizers (Isacowitz, 2014). Specifically, the abdominal muscles for core stability include transverse abdominis, multifidus, rectus abdominis and internal and external obliques. The core supports the actions of the trunk, improves postural and balance, stabilizes the spine, and supports proper limb function (Akuthota, 2008; Key, 2013). Hodges and Richardson's electromyography study showed that the abdominal and multifidus muscles were activated prior to limb movement. This research supports the theory that core stability and control are developed through a core to extremity progression (Okada, et al., 2011). This progression and key core characteristics are foundational to the Pilates work making it a logical choice to use for a training and conditioning program.

**Injury**

Beyond improvement in spinal and pelvic stability, balance, and limb function, Willson's, et al. (2005) article supports the investigation of the correlation between weak core strength and injuries including injuries to the spine, low back, and shoulder girdle due to the theoretical foundation. There is a volume of literature which seems to also support this connection (Huxel Bliven & Anderson, 2013; Akuthota, et al., 2008; Leetun, et al., 2004). Koutedakis and Jamurtas' (2004) article addressing the physiological considerations of dancer as the performing athlete highlights that the dance athlete is less fit than other athletes at the same level. According to this investigation into dancer fitness, both professional dancers and student dancers demonstrate lower maximal oxygen uptake values, lower anaerobic values, and lower torque values in isokinetic measurements in comparison to other athletes. Injury rates in dancers have been recorded at a level of 5 - 8.4 hours per 1,000 hours (Koutedakis and Jamurtas, 2004; Vassalo, et al., 2018) leading to a financial burden for dancers and companies, reduced performance or employment, early retirement, and future medical complications. Most dance injuries are seen in lower extremities with some studies showing up to 73-90% of dance injuries occur in the low back, knee, and ankle/foot (Koutedakis and Jamurtas, 2004; Shah, et al., 2012; Swain et al., 2019). Low back injuries are significant in dancers, with some studies stating low back injuries are more prevalent in dancers than other athletes (Rickman, et al., 2012; Kahn, et al., 1995). Milan (1994) and Shah et al. (2012) reported 10-17% of injuries among ballet dancers were low back pain and 34% of injuries occurring in the spine. Seventy-five percent of these injuries occurred prior to age 25 and 52% prior to 18 years old suggesting that early intervention may be helpful in reducing injuries in the peak of their profession. Other common injuries include hip problems at 10%, (Reid, 2012), knee injuries account for 14-20% (Reid, 2012; Shah, et al., 2012), and ankle and foot injuries are significant, totally 18-54% of all injuries in ballet dancers (Shah et al., 2012). In Shah and colleagues' study (2012), dancers reported injuries were due to the demand of the role, fatigue, lack of proper warm-up, lack of training, and lifestyle habits including lack of sleep and diet. Dancers also reported that muscular weakness, joint instability, loss of balance, and lack of mobility kept them from dancing resulting in time loss in class and rehearsals. Studies indicate poor alignment, overuse, fatigue, and decreased muscle strength as causes of injuries in dancers (Koutedakis and Jamurtas, 2004; Deleget, 2010; Bowerman, et al., 2015; Malkogeorgos, et al., 2011). One study showed a correlation between thigh strength and injury rates (Koutedakis, et al., 1997) and Bejjani (1987) found that an increase in injury risk occurred when there was an imbalance between antagonist muscles. These study results indicate improved muscular strength may decrease injury risk.

**Proper Alignment and Exercise**

Proper alignment in dance includes stability of the pelvis and the alignment or "stacking" of the trunk over the pelvis (Yu and Lee, 2012; Willson et al., 2005). Krasnow, et al. (2001) describes proper alignment as stacking the 'plum line.' Gamboian, et al. (1999) refers to proper alignment through two functional measures of skeletal alignment including pelvic alignment and the angle of lumbar lordosis. Proper pelvic alignment in dancers indicates a neutral position where the anterior superior iliac spine (ASIS) and the posterior superior iliac space (PSIS) are in the same horizontal plane while a neutral lumbar spine has a slight anterior convexity (Kendall et al., 1993). Kendall et al. (1993) defines anterior tilt as a forward tilt of the pelvis decreasing the angle between the pelvis and the anterior thigh, is a common alignment problem among dancers and may kinder the successful performance of some dance movements (Kish & Morton, 2019; Franklin, 1996). Dang et al. (2023) reported the efficiency of a fitness program on improving injury rates in dancers, possibly due to their inadequate fitness levels as stated in several studies (Koutedakis and Jamurtas, 2004; Angioi, et al., 2009; Bennel et al., 1999). Improper alignment and poor dance mechanics has been seen as a major cause of dance injuries (Koutedakis and Jamurtas, 2004; Deleget, 2010; Bowerman, et al., 2015; Malkogeorgos, et al., 2011) therefore improving alignment is essential to improve dance injuries.

Exercise is often prescribed by physiotherapists to improve injury including core exercises. Core strengthening exercises are commonly used by medical practitioners to improve performance and prevent injuries (Akuthota, et al., 2008). Studies looking at decreasing injuries in dancers include various conditioning programs showing that exercise is seen to decrease injury rates in dancers. One study by Long et al., 2021, indicates that dancers agreed that core stability exercises (66.7%) were the most beneficial to decreasing and managing their injuries. The same study also showed that dancers improved their balance, temps levé (hop on one leg), and upper extremity stability.

Historically dancers have been cautious of supplemental training due to myths about muscle bulk and its impact on the body's aesthetic (McDougall, 2024). However, studies have shown resistance training can lead to improvements in leg strength without interfering with the aesthetic, artistic or physical performance required for dancers (Koutedakis, et al., 1996; Stalder et al., 1990). Even with studies that have existed for over 30 years, the dance community still operates under this myth. With the location of the first Pilates studio in New York and its proximity to dancers as well as its similarities in alignment, flow, and coordination (Ahearn, et al., 2018) Pilates seems to be the exception to this belief. Dancers have been known to embrace Pilates as a conditioning program as it can be found in numerous dance studios and university academic dance programs across the country. This integration of Pilates into dance training programs provides a unique opportunity to address lack of fitness levels in dancers and introduce conditioning as part of a regular training schedule for dancers.

### 1.1.4 Dance, Sport and Pilates

Historically dance and Pilates have a long lineage. Pilates established his New York gymnasium in 1923, where his studio was in the same building as the New York City Ballet. Here, he fostered a natural relationship with Pilates and the dancers who attended daily class and rehearsals. Dancers such as Martha Graham, Hanya Holmes, and George Balanchine endorsed his work with his early intervention in injury resulting in a quicker recovery (Anderson and Spector, 2000). Dancers were drawn to the Pilates method due to the objectives of flexibility, muscular strength, control, and body awareness. Two well-known dancers who frequented Pilates' studio were modern dancers, Ruth St. Dennis and Ted Shawn. Shawn invited Pilates to develop an exercise program for his dance intensive, Jacob's Pillow, where Pilates taught between 1942 and 1947. This partnership is where Pilates expanded his mat work.

Several dancers became "first generation" Pilates teachers and were taught the Pilates method from Joseph Pilates himself. Among these first-generation teachers were Ron Fletcher (former Martha Graham dancer), Kathleen Stanford Grant (former Arthur Michell dancer), Bruce King (former Cunningham dancer), Romana Kryzanowska (former Balanchine dancer), and Lolita San Miguel (formally with Joffrey Ballet). During the 1960's Pilates was being rooted into dance programs across organizations such as New York University, Dance Theatre of Harlem, the 92nd Street Y, and the Katherine Dunham School. By the mid 1960s, modern dance choreographers were adding Pilates mat exercises to their warm-ups (Redfield & Holmes, 2019).

Welsh (2009), Armstrong, and Relph (2018) all recognize the importance of strength, flexibility, and coordination in training the professional dancer. Pilates has a strong focus on strength and flexibility with an emphasis on core stability and controlled movement patterns which is essential for dancers especially in the lower legs, which is crucial for dancer performance and injury prevention (Amorium et al., 2012). Other key principles of dance training, including pelvic alignment, concentration, postural control, and flexibility are essential for dancers to execute movement safely and efficiently (Ahearn, et al., 2018).

Outside of the dance population, Pilates has been shown to help other athletes such as soccer and basketball players, swimmers, tennis and golf players, runners, and archers. Yilmaz's, et al. (2023) systematic review found that Pilates significantly improved postural stability, balance, agility, muscular strength, flexibility, core endurance, and coordination across various sports disciplines. According to multiple studies across sport disciplines Pilates benefits athletes such as:

- Swimmers benefited from improved spinal alignment and shoulder mobility, (Terrence, 2023)
- Runners gained hip stability and improved functional movement control (Laws, et al., 2017)
- Golfers and tennis players increased more trunk control, (Yilmaz, et al., 2025)
- Soccer and basketball players improved agility, technical skills, and dynamic balance (Yilmaz, et al, 2025)
- Archery and Tennis players improved body balance and reduced pain (Yoon and Kim, 2012)

The areas investigated in these research studies are also beneficial to dancers and important to the biomechanics of dance movements. Other popular areas of Pilates research includes the elderly (Newell, et al., 2012; Irez, et al., 2011), mental health

(Akabas, et al., 2021; Fleming and Harring, 2018), multiple sclerosis (Bulguroglu, et al., 2017; Sánchez-Lastra, et al., 2019) and Pilates as a rehabilitation tool (Anderson, 2024; Byrnes, et al., 2018). Newell, et al. (2012) examined fall risk in the elderly over an 8-week Pilates intervention program. The study evaluated walking speed, step cycle and length, and fall risk. All areas showed improvement with the Pilates group in comparison to the control group. Akabas, et al. (2021) examined the effects of Pilates on mental health, particularly people with schizophrenia. The study split the groups into a Pilates Exercise group (PEG) and a non-specific exercise group that served as their control group (NSEG). The results showed the PEG intervention group improved functional capacity, reduce depression, and improve psychiatric status. Bulguroglu, et al. (2017) which looked at three groups, Pilates mat, Pilates Reformer, and control and the impact of Pilates on functional mobility, core stability, fatigue severity, and quality of life, showed that both Pilates groups improved in all four areas in comparison to the control group. More investigation is needed to see if the benefits of these other populations, including athletes, would also improve balance, agility, core control, functional movement control, spinal alignment, shoulder mobility, and mental health within the dance population. These potential benefits show a natural relationship and seem to support Pilates as a supplement training regime for dancers; however, more investigation is needed.

# 2 Literature Review: Pilates Training for Dancers: A Systematic Review

**Parts of this chapter have been accepted for publication (Bergeron, et al., 2024)**

Bergeron, C. S., Greenwood, M., Smith, T., & Wyon, M. (2017). Pilates Training for Dancers: A Systematic Review. National Dance Society Journal, 2.

Roles of each author:

Bergeron, Christine – conducted literature review, analyzed literature, reviewed articles using PEDro scale, wrote first draft

Greenwood, Michael – mentored with methodology

Smith, Tina – provided suggested edits for publication

Wyon, Matt – reviewed articles using PEDro scale, provided suggested edits for publication

## 2.1 Introduction

As the popularity in Pilates increases, more research is being conducted on the general population to determine the effectiveness of Pilates for increased muscle strength, injury recovery, increased balance, and weight loss, among many other areas (Cruz-Ferrerura et al., 2011). Since dancers were one of the populations that first embraced the Pilates method, it would be reasonable to assume that there would be significant research on this population. However, as indicated in more than one literature review (Bernardo & Nagle, 2006), there has been limited research determining the impact Pilates has had on dancers and how it affects overall training and performance (Bernardo & Nagle, 2006). One would expect to see more publications since the last literature review in 2006, but disappointingly, little additional research has been conducted. Furthermore, the research lacks evidence on the various pieces of equipment and apparatus. Most studies use mat or reformer, and no publications included Pilates equipment such as the spine corrector, cadillac, wunda chair, ladder barrel, corealign, or other small apparatus to demonstrate their effectiveness on the dance population. Since dancers suffer from unique injuries (Wiesler et al., 1996) and Pilates is a method of training used by dancers to recover from injury, more research is needed. The purpose of this review was to systematically review the research on Pilates and its effectiveness on dance training and performance.

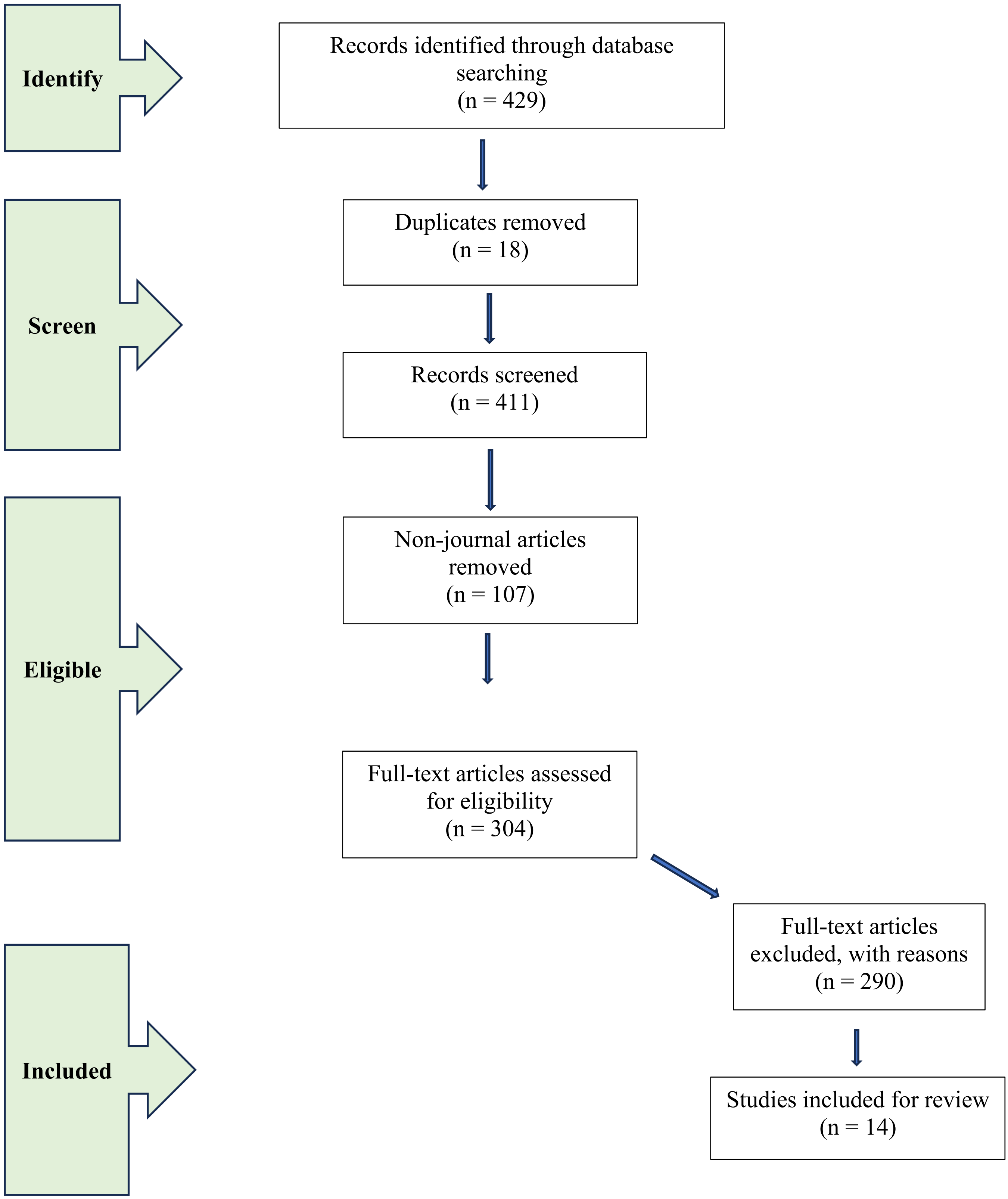
## 2.2 Methods

Excluding patents and including publications from 1980 to 2024, the MeSH terms Pilates and Dance were used within the EBSCO search engine (no date), including MEDLINE (PubMed), Scopus, SportDiscus, Art and Humanities Index, and CINAHL

(Cumulative Index to Nursing and Allied Health Literature) databases. To improve the search in these databases, other key words for dance and Pilates were used. For dance, the following alternative words or phrases were used: ballet, modern dance, jazz dance, tap, social dance, ballroom, and pointe. For Pilates, the following words or phrases were used: reformer, cadillac, trapeze table, somatics, wunda chair, exo chair, corealign, Pilates arc, and spine corrector. Study inclusion criteria included human subjects, published in a peer-reviewed journal, clinical trials, Pilates as the main intervention, and dancers as the population of the study (see Figure 2.1). Dance was included in all genres including ballet, modern, jazz, tap, pointe, and all cultural forms. Articles were excluded if Pilates was not the intervention, dancers were not the population, the study was not a clinical trial, or the work was a dissertation, part of conference proceedings, or a consumer publication.

**Figure 2.1:**

## Flow chart systematic review



Two separate reviewers assessed the inclusive clinical trials for method quality using the PEDro scale (PEDro, no date). The PEDro scale has been reviewed in the *Physical Therapy Journal of the American Physical Therapy Association* (Maher et al., 2003), and its reliability has been deemed acceptable. This scale, originally developed for physiotherapy, was chosen for this systematic review based on its high inter-rater reliability, accessibility to the scale, its focus on internal validity such as blinding and randomization, its ability to identify trials with sufficient statistical information, and for its frequent use in systematic reviews. The PEDro scale includes 11 criteria: specified eligibility criteria, random allocation, concealed allocation, baseline similarity, blinded subjects, blinded therapists, blinded assessors, measures of key outcomes from more than 85% of subjects, intention-to-treat analysis, between-group statistical comparisons, and point measures and measure of variability. PEDro scale scores range from 0 to 10 (higher score relates to a higher method quality) because the specified eligibility criteria are not used to calculate the score. A PEDro score of less than 3 indicates poor quality, a score of 4 to 5 is considered fair quality, and a PEDro score of 6 or higher designates high-quality research (Physiotherapy Evidence Database, no date). Independently, two raters scored the inclusive articles, and it was found that the randomized controlled trials (RCTs) received the same score from the assessors.

### 2.3 Results

The initial searches conducted through five different databases revealed 429 articles, of which 18 were duplicates, leaving 411 records to review. Of the remaining 411 records, 65 were consumer publications, 11 were conference papers, 31 were unpublished dissertations or thesis papers, and 304 were articles in peer-reviewed journals. Of those in peer-reviewed journals, 141 were not clinical trials, 74 did not use Pilates as the main intervention, 65 were not on dancers, and 10 were literature reviews. PEDro scale scores, in reviewed inclusive clinical trial articles, ranged from 1 to 6; one study scored a 1, one scored a 2, one scored a 3, three studies scored a 5, and eight scored a 6. The available 14 studies included in this review are addressed according to their effects on dance training and performance as follows: muscular strength, flexibility, and range of motion; muscular strength or flexibility and balance; posture, technique, and aesthetic movement; pelvic alignment and/or vertical jump.

### 2.3.1 Muscular Strength, Flexibility, and Range of Motion

Amorim, Sousa, and Rodrigues dos Santos (2011) (PEDro scale: 6) studied the influence of Pilates training on muscular strength and flexibility in dancers. A controlled repeated-measures experimental design was used on 15 dance students from the same school. Participants all had 10 years of daily practice in dance with no current injuries. Participants were divided into two groups, experimental and control. However, it is unclear whether the groups were randomly divided or selected for their group based on criteria such as scheduling. The experimental group consisted of seven dancers, six female and one male, age 15.7 + 0.8 years with 11 + 2.7 years of training. The control group consisted of eight dancers: six female and two males, age 16.3 + 0.9 years, with 11.9 + 3.7 years of training. Both groups continued their regular dance schedule throughout the study. Specifically, the experimental group had 8 hours of dance a week

(6 hours of ballet and modern technique, 1 hour pas de deux, and 1 hour of character dance) and the control group 9.5 hours per week (7 hours of ballet and modern dance technique, 1.5-hour pas de deux, and 1 hour of character dance). The experimental group performed mat-based Pilates exercises for 11 weeks consisting of 60-minute sessions twice a week, supervised by an experienced Pilates instructor. The Pilates-based intervention progressively intensified over the 11-week period, and the exercises were chosen based on their similarity to dance-specific movement: for example, the hundred, scissors, side bend, side kick, and back support. The session was divided into three parts: warm-up (15 minutes), Pilates exercises (35 minutes), and cool-down (10 minutes). Each group attended pre- and post-testing. Muscular endurance was measured using a protocol similar to the Fédération Internationale de Gymnastique (Physical Testing Program), with participants maintaining the ballet positions of penché and développé (front, side, back) at the barre for as long as possible. Range of movement was measured using two high-definition cameras and a calibration scale while dancers performed both right and left sides of arabesque, cambré back, and developpé (front, side, back). Results indicated that the two groups performed similarly in the pre- tests for muscular endurance and range of movement. At post-test, the experimental group showed significant improvement in muscular endurance and range of movement on the arabesque (right limb) and développé (front, side, and back). There was no significant change in range of movement for the cambré and arabesque on the left side.

Fitt, Sturman, and McClain-Smith (1993) (PEDro scale: 6) observed the effects of Pilates-based conditioning on strength, alignment, and range of motion in university ballet and modern dance majors. Twenty-nine participants who completed the trial were selected for the study on four different criteria: (1) a dance major in ballet or modern dance technique class, (2) recommendation by faculty for participation in the study, (3) availability at the times the sessions were to be conducted, and (4) willingness to commit the time to the class and independent practice sessions. The quasi-experimental pre-post-test study consisted of experimental (n = 14) and control groups (n = 15). The experimental group was required to attend one training session of 1.5 hours per week, work out individually on the reformer for two 0.5-hour sessions per week, and work out individually, performing Pilates mat exercises daily over a seven-week period. New exercises were introduced throughout the study in both the reformer and mat work. Exercises were supervised in the first phase of the study, but participants were expected to continue doing the mat exercises without supervision. The control group continued their regular schedule of technique classes, rehearsals, and conditioning practices, as did the experimental group. At the end of seven weeks after the post-tests, the control group was given the opportunity to complete a modified version of the experimental group's treatment plan. All participants were assessed for muscular strength, range of motion, alignment, and one complex task pretest and post-test. Muscular strength was determined using a pressure scale, which measured pounds of pressure exerted. The same examiner administered eight tests for muscle strength, which included hip extension, knee extension, shoulder extension, and shoulder flexion. Range of motion was measured using a protractor and included four tests. The four tests included seated outward rotation of the hip joint, spine outward rotation of the hip, flexion of the hip, and horizontal extension of the shoulder. Each test was administered on both the right and left sides of the body. Alignment was assessed from the side, recording the number of degrees of pelvic inclination. The vertical standing jump was used to reflect a complex skill. Evaluators noted at the end of the study that the experimental group showed substantial improvement of alignment ($p = 0.001$), and those who performed the reformer work showed a positive effect on hip and knee strength as well as mobility of the hip joint and pelvic alignment.

Wang, Lin, Huang, Liang, and Lee (2012) (PEDro scale: 6) detected the effects of an eight-week Pilates program on the limits of stability and abdominal muscle strength in young dancers. The experimental pre-post-test comprised 24 female dancers (age 17 + 3 years), who were randomly assigned to an experimental or a control group. Overseen by an experienced Pilates instructor, the experimental group underwent a 40-minute Pilates class three times a week for eight weeks. Limit of stability was evaluated using the Biodex Balance system, and abdominal endurance was evaluated using the 30/60 second sit-up test. Findings indicated considerable improvement of dynamic posture stability and abdominal strength over the period of the 8-week study.

### 2.3.2 Muscle Strength or Flexibility and Balance

Amorim, Sousa, Machado, and Santos (2011) (PEDro scale: 6) looked at the effects of a Pilates training program on muscular strength and balance in ballet dancers. The experimental study was conducted on 15 ballet students (3 males and 12 females) with more than 10 years of ballet and modern dance experience. The dancers were divided into an experimental group (n = 8) and a control group (n = 7). Participants in the experimental group were asked to perform a series of progressive Pilates mat exercises over 11 weeks. Each session consisted of basic and intermediate Pilates mat exercises with advanced exercises being added as the study progressed, but it was unclear as to the specific exercises used. Dancers from the control and experimental groups were evaluated before and after the study. Muscular endurance was measured using the Fédération Internationale de Gymnastique (Physical Testing Program). Participants executed a penché and développé (front, side, back) at the barre while assessors noted the maximal time obtained in each position. Balanced was measured using a Bertec force plate (4060-15) with a sample frequency of 1,000 Hz. Dancers were asked to maintain first position with the arms in bras bas and perform attitude derrière first flat for 5 seconds and then to rise to elevé for 5 seconds. The Pilates group showed significant improvement in muscular endurance especially in their technical skills of executing penché and développé back. However, no significant change was seen in the ballet dancers' balance.

Amorim, Sousa, and Rodrigues dos Santos (2012) (PEDro scale: 6) conducted an experimental study with 12 dancers over an 11-week period. The participants were split into two groups, a control group and an experimental group. The experimental group performed Pilates mat exercises twice a week while the control group did no Pilates. Both groups maintained their dance schedule and did not do any other conditioning during the length of the study. Both groups were measured before and after the study for muscular strength, flexibility, and balance. Isometric muscular strength was determined by recording the length of time participants were able to sustain a développé (front, side, and back). Flexibility was determined using a digital camera to capture the height of the leg during développé, front, side, and back, on both sides. Balance was measured using a Bertec force plate. Results of the study determined that Pilates mat exercises improved muscular strength and flexibility, but no significant changes in balance between the groups occurred. Since participants were able to increase the time, they sustained a développé movement and the height of the leg in développé increased, it was determined that overall dance performance was positively affected using Pilates.

Tumonytė, Aleksandravičienė, and Zaičenkovienė (2018) (PEDro scale: 6) conducted quasi-experimental 16-week study that investigated the effect of Pilates on balance and flexibility in 6–10-year-old Dancesport dancers. Thirty-eight Dancesport dancers, fourteen male and twenty-four female, aged 6-10 dancers who engaged in at least one 60-minute dance practices per week participated in the study. The experimental group included 20 dancers who, in addition to their regular dance schedule, participated in two 30-minute Pilates mat sessions per week. The control group participated in two 60-minute dance sessions per week. Participants were examined for static and dynamic balance using the flamingo (static) balance test and the star excursion (dynamic) dynamic balance test. Flexibility was investigated using the sit and reach flexibility test. Static and dynamic deep trunk endurance tests were examined in prone and supine with the use of a stabilizer. In dynamic deep trunk endurance testing the hip on the supporting surface was lifted while maintaining consistent pressure on the stabilizer.

Results showed a significant difference in all the tests for the experimental group proving that Pilates does impact flexibility, deep trunk endurance, and balance in young dancers.

Bergeron, Dardeau, Gerwing, Schraer, Armstrong, and Bergeron (2019) (PEDro scale: 3) conducted an eight-week experimental study with 16 female dancers (ages 18-24) from a university dance program. Participants were randomly divided into three groups: a control group, a reformer group, and a balance board group. The control group continued with their regular dance and exercise regimen with no balance training while both the reformer and balance board groups participated in 20-minute sessions, three times a week for 4 weeks. Prior to intervention, the reformer and balance board groups engaged in one week of training to learn and review the exercises performed during intervention. In pre and post-testing participants performed balance assessments including the Star Excursion Balance Test and the Stork Test in both parallel and external rotation. The results of the study showed a significant difference in all three groups in the Stork Test in parallel on the right side and in external rotation on the left side however, no significant difference was seen between the three groups.

#### 2.3.3 Posture, Technique, and Aesthetic Movement

McMillan, Proteau, and Lebe (1998) (PEDro scale: 6) conducted a quasi-experimental 14-week study that asked the question whether Pilates-based training would have an impact on a dancer's dynamic posture. Ten ballet dancers (ages 15 + 4 years), who had trained in ballet for 20 to 25 hours a week for four years, participated in the study. In addition to their regular technique schedule, five students in the experimental group participated in 23 one-hour private Pilates lessons using mat work, reformer, and rotator discs for 14 weeks. Additionally, dancers were asked to perform a daily regimen of Pilates exercises at home. At the beginning of the training, the program consisted of supine mat exercises, favoring exercises that focused on body awareness and control. Exercises also included limb movement while maintaining neutral spine and pelvis. By the end of the study, sessions focused on conditioning of the muscles of the pelvic girdle. Reformer exercises moved into positions in which participants were sitting, kneeling, and standing on the carriage. The control group maintained their regular technique schedule with no Pilates training. Posture during a grand plié was assessed using a WATSMART system pretest and post-test. During this test, markers were affixed to each participant in each of the following locations: earlobe, tuberculum majus, anterior superior iliac spine, the greater trochanter, and the epicondylus lateralis of the femur. Heel location was provided by infrared light- emitting diodes (IRED) affixed on a custom-made support attached to their heel. The last IRED was placed on a support fixed to the lab floor and served as a fixed reference. Participants were asked to perform five consecutive grand pliés starting from relevé in first position while the arms were held in second position. Participants performed the grand plié action to a metronome set to 1 beat per second. Looking specifically at pelvic placement during grand plié, researchers found that Pilates may be beneficial in improving dynamic alignment in dancers.

Parrott (1993) (PEDro scale: 5) conducted a study that had three aims: (1) to develop a standard by which improvements in dance technique can be evaluated, (2) to quantify what changes result from additional exercise protocols, and (3) to develop a program to improve the movement qualities of dancers. Eighteen female dancers aged 19

+ 11 years who were enrolled in a level I or II modern dance class and who participated in a winter concert were divided into three equal groups: a Pilates group, an aerobic conditioning group, and a control group. In addition to their regular dance schedule, the Pilates group attended 80-minute sessions three times a week. The aerobic conditioning group participated in 80-minute aerobic dance class three times a week as well as continuing to attend their regular dance schedule. The control group maintained their regular dance schedule with no additional training. Pre- and post-intervention, four judges blind to the group assignments evaluated two modern dance sequences, an adagio sequence and a rhythmic combination. Evaluation was based on the *Federation for International Gymnastics Code of Points* with modifications more specific to dancers. Five categories were evaluated during the study: alignment, clarity of intention of the movement, precision of movement, expressivity of the body, and musicality. Alignment was further divided into subcategories including sense of center, carriage of the body, and maintenance of correct position in motion. Intention of movement clearly defined in lines and shapes was divided into two categories including range of motion (ROM) and involvement of the entire body in movement. Articulation of the feet, articulation of the spine, balance and control, and coordination and transition of movement were the subcategories included in Precision of Movement. The subcategories of Expression of the Body were use of weight, appropriate use of energy, and facial expression. The participants in the Pilates group showed substantial increase from pre- to post-test. The Pilates group showed the most significant improvement ($p = 0 .029$) in the categories of alignment, intention of movement, and expressivity of the body. The aerobic conditioning group showed no significant difference overall ($p = 0.98$). The control group did not show any improvement in any of the dance technique categories ($p = 0.101$). The study determined that Pilates training might be helpful to improve a dancer's technique and aesthetic.

### 2.3.4 Pelvic Alignment and/or Jumps

McLain, Carter, and Abel (1997) (PEDro scale: 6) examined how a Pilates reformer would affect supine jump height and pelvic alignment. Twenty-four first- and second-year dance majors from the same university were divided into two groups, an experimental group ($n = 14$) and a control group ($n = 10$). In this quasi-experimental study, participants were tested before and after the experiment. Over eight weeks, dancers in the experimental group were enrolled in a conditioning class in which participants spent 30 minutes being instructed on proper alignment on the reformer followed by 60 minutes of unsupervised intervention. The group practiced 30 exercises and variations over the eight- week period. The exercises focused on developing muscular strength, ROM, and muscle elasticity for ankle-tarsus, legs, torso, and arms. Exercises were selected for intervention because they appeared to be the most applicable to supine jump. The control group maintained their regular dance schedule but refrained from participating in any conditioning program during the length of the study. Both groups were evaluated for jump height and pelvic alignment before and after the test. Jump height was measured by using markers on the reformer; this was recorded while participants executed a supine jump on the reformer using the footplate. The spring load for female participants was set at two medium (18 kg [39 .7 lb]) and for the male participants at two medium and one light (25.5 kg [55 lb]). Pelvic alignment was assessed through videotape and then evaluated by three assessors blinded to the group assignment. Spherical 3M reflective markers were bilaterally attached to the anterior superior iliac spine (ASIS) and the posterior superior iliac spine (PSIS). Judges evaluated each participant's pelvic alignment based on the amount of deviation from the desired neutral position. Assessors were told to score pelvic alignment using a 1 to 5 scale, 1 being the greatest deviation from neutral and 5 being the least deviation. Results from the study indicated that both groups improved significantly but that there was no significant difference between the control and Pilates group in jump height overall ($p = 0.45$). Intra-observer reliability varied greatly among the assessors when looking at pelvic alignment. Researchers indicated that reformer training has no significant impact on pelvic alignment during execution of a supine jump.

George, Vetter, Ludwig, Smith, and Gench (1996) (PEDro scale: 5) used reformer exercises to determine their effectiveness with regard to abdominal strength, hip flexibility, pelvic alignment, and vertical jump in modern dancers. The quasi-experimental study used 22 participants from two different university dance programs. Participants from one university acted as the control group while the other was divided into two experimental groups. Experimental group I exercised on a Pilates reformer once a week, and experimental group II performed exercises on the reformer three times a week. The control group had no Pilates reformer training. All participants were tested for abdominal strength, hip ROM, vertical jump, and pelvic alignment pre and post-test to determine the benefits of Pilates training. Abdominal strength was determined using a goniometer while executing a double leg-lowering test. Participants were filmed using a Peak 5 motion analysis system to assess pelvic alignment, hip ROM, and vertical height. The hip ROM and pelvic stability were measured during execution of a grand battement in parallel and external rotation. The vertical jump was assessed in parallel and external rotation. Each participant was asked to execute the vertical jump and grand battement four times, and the first correctly executed action was chosen for assessment. Experimental groups I and II executed the same Pilates exercises, but these groups varied on how many times the exercises were performed each week. The exercises during the 10-week trial consisted of demi plié, prances, jumps, hops, scooter, hamstring stretch, semicircle prep, grand battement, pointer, hip flexion in straps, and frog. All but the pointer and semicircle prep were executed in parallel and external rotation. Participants started with 1.5 spring load for five repetitions. The repetitions increased to 10 and the spring load increased to 3 springs over the 10-week period. All participants increased in resistance and repetitions over the trial, and prior strength capabilities were not considered throughout the study. The study shows no substantial difference among the three groups in abdominal strength, hip ROM, pelvis stability, or vertical jump.

Armstrong, Bergeron, and Boucher (2018) (PEDro scale: 5) examined the difference between plyometric training versus Pilates training on vertical and horizontal jump. Researchers randomly divided 28 dancers, male (n=2) and female (n=26) (ages 20 $\pm$ 1.05) into three groups including a control group (n=10), a Pilates group (n=9), and a plyometric group (n=9). The eight-week study consisted of one week of pre-testing, one week of training, five weeks of intervention, and one week of post-testing. Assessments taken during the pre and post-testing included a vertec vertical jump test with bilateral, right and left sides and a triple hop test with take-off on both the right and left sides. The Pilates intervention group performed 30-minute reformer exercises three times a week for five weeks while the plyometric group performed dance based plyometric exercises over the same time period. Results indicated a significant difference in the right and left sides of both the vertical and horizontal groups however, no significant difference between the groups was seen.

Panhan, Gonçalves, Eltz, Villalba, Cardozo, and Bérzin (2019) (PEDro scale: 1) assessed a 24-year-old ballerina for neuromuscular efficiency in multifidus and internal oblique muscles using the Pilates Method. The case study tested isometric strength through a dynamometer for flexion and torque extension of the trunk and the internal oblique and multifidus muscles using an EMG. The studies 8-week intervention consisted to two 45-minute Pilates mat sessions per week consisting of 18 exercises selected from the original Pilates exercises listed in *Return to Life Through Contrology* (Pilates, 1945) and the study guide from Pilates Method Alliance (Lessen, 2014). Results showed an increase in isometric contraction and isokinetic torque of the trunk flexors and extensors after Pilates training. Results also supports Pilates automatic recruitment of the trunk muscles lowering EMG expenditure with greater force.

### 2.3.5 Posture, Strength, and Flexibility

Ahearn, Greene, and Lasner (2018) (PEDro scale: 2) investigated Pilates training on pelvic alignment, strength, and flexibility in female dancers from ages 17-22. Twenty dancers from two university programs and one performing arts high school completed the study. The study was designed into six stages. Stage I, Screening I conducted five body assessment tests including the alignabod posture assessment, double leg lower test, upper abdominal manual muscle test, modified Thomas test, and the hamstring flexibility test. In stage II, which served as the control period, participants engaged in their normal dance, exercises, and sport activity for 14 weeks (with no Pilates). Stage III consisted of Screening II which evaluated any physiological changes that occurred in stage II. Stage IV consisted of a pelvic alignment workshop. In stage V, dancers performed one 50-minute Pilates apparatus session privately or in pairs and one 45-minute mat session with a certified Romana's Pilates instructor. Apparatus sessions included work on the reformer (majority of the exercises), wall unit, wunda chair, and large barrel. In the final stage, stage VI, screening III, participants were re-tested using the assessments in stage III and completed a questionnaire. Throughout the study participants were asked to maintain a reflective journal recording self-reported injury or pain. The results of the study indicated a significant difference in postural alignment from screening II to III, with no significant difference between screening I and II. Significant differences between screening II and III were also seen in the double leg lower test, the upper abdominal manual muscle test, and flexibility in both the iliotibial band and hamstrings. Questionnaire results showed overall the dancers perceived improvement in cores stability, pelvic alignment, strength, flexibility, and body awareness.

**Table 2.1 Summary of Results of Included Studies**

| Article | N= | Length of study | PEDro score | Weekly workouts | Main Outcome |
|---|---|---|---|---|---|
| Amorim, Sousa, & Rodrigues dos Santos (2011) | 15 | 11 weeks | 6 | Experimental Group: 2X/ week<br><br>Control Group: no intervention | Significant improvement in muscular strength and flexibility on the arabesque (right limb) and developpe (front, side and back). Flexibility on cambré back and arabesque (left limb) had no significant change in flexibility |
| Amorim, Sousa, Machado, & Santos (2011) | 15 | 11 weeks | 6 | Experimental Group: unclear of how many times per week<br><br>Control Group: no intervention | Significant improvement in muscular strength however no significant change was seen in the ballet dancers' balance |
| McLain, Cater, & Abel (1997) | 24 | 8 weeks | 6 | Experimental Group: 2X/ week<br><br>Control Group: no intervention | Reformer training has no significant impact on pelvic alignment while executing a standing jump or on overall jump height |
| McMillan, Proteau, & Lebe (1998) | 10 | 3 months | 6 | Experimental Group: 2X/ week with instructor; daily home program<br><br>Control Group: no intervention | Pilates may be beneficial in improving dynamic alignment |

| | | | | | |
|---|---|---|---|---|---|
| Parrott (1993) | 18 | unclear | 5 | Pilates Group 1: 80 min. session; 3X/week<br><br>Aerobic Conditioning Group 2: 80 min. session; 3X/week<br><br>Control Group: no intervention | Pilates may be helpful to improve a dancer's technique and aesthetic |
| Fitt, Sturman, & McClain- Smith (1993) | 29 | 7 weeks | 6 | Experimental Group: 1X/ week with instructor; 2X/ week reformer; daily floor exercises<br><br>Control Group: no intervention | Substantial improvement of alignment and the reformer work showed a positive effect on hip and knee strength as well as mobility of the hip joint and pelvic alignment |
| Wang, Lin, Huang, Liang, & Lee (2012) | 24 | 8 weeks | 6 | Experimental Group: 3X/ week<br><br>Control Group: no intervention | Considerable improvement of dynamic posture and abdominal strength over the period of the eight-week study |
| George, Vetter, Ludwig, Smith, & Gench (1996) | 22 | 10 weeks | 5 | Experimental Group 1: 1X/ week<br><br>Experimental Group 2: 3X/ week<br><br>Control Group: no Pilates training | No difference found on abdominal strength, hip ROM, pelvis stability or vertical jump |

| | | | | | |
|---|---|---|---|---|---|
| Amorim, Sousa, & Rodrigues dos Santos (2012) | 12 | 11 weeks | 6 | Experimental Group: 2X/week with instructor performed Pilates mat exercises<br><br>Control Group: no Pilates training | Muscular strength and flexibility improved for the experimental group. Balance was not significantly different between groups. Overall, dance performance improved due to longer duration in holding developpe positions and increase in leg height. |
| Tumonytė, Aleksandravičienė, and Zaičenkovienė (2018) | 28 | 16 weeks | 6 | Experimental Group: two 30-minute Pilates mat sessions per week<br><br>Control Group: no Pilates training | A significant difference was seen in flexibility, deep trunk endurance, and balance in young dancers. |
| Bergeron, Dardeau, Gerwing, Schraer, Armstrong, and Bergeron (2019) | 16 | 8 weeks | 3 | Reformer Group: reformer work, 20 minutes for 3X/week<br><br>Balance Board Group: training on a balance board, 20 minutes for 3X/week<br><br>Control Group: no intervention | Significant difference in all three groups in the Stork Test in parallel on the right side and in external rotation on the left side however, no significant difference was seen between the three groups. |

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|---|---|---|---|---|---|
| Armstrong, Bergeron, and Boucher (2018) | 28 | 8 weeks | 5 | Reformer Group: reformer work, 30 minutes for 3X/week<br><br>Plyometric Group: dance-based plyometric training, 30 minutes for 3X/week<br><br>Control Group: no intervention | Significant difference in the right and left sides of both the vertical and horizontal groups was indicated however no significant difference between the groups was seen. |
| Ahearn, Greene, and Lasner (2018) | 20 | unclear | 2 | Experimental Group: 50 Pilates apparatus/once per week; 45-minute mat session/once per week<br><br>No control group | Improvement was seen in postural alignment, abdominal strength, and hamstring flexibility. Dancers perceived that Pilates improves alignment, strength, and flexibility. |
| Panhan, Gonçalves, Eltz, Villablba, Cardozo, Bérzin (2019) | 1 | 8 weeks | 1 | Case Study: two 45 minutes for 2X/week | Increased efficiency in oblique and multifidus muscles |

## Table 2.2 PEDro Scale Results

| Author and Year | eligibility specified | subjects randomly allocated | allocation concealed | groups similar at baseline | blinding of all subjects | blinding of intervention therapists | blinding of assessors | measures from one outcome exceeded 85% of population | all participants received either intervention or control | between group statistical data complete | point measures and variability for outcomes | | PEDro Score |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Parrott (1993) | y | n | n | n | n | n | y | y | y | n | y | | 5 |
| Fitt et al (1993) | y | n | n | y | n | n | n | y | y | y | y | | 6 |
| George et al (1996) | n | n | n | n | y | n | n | y | y | y | y | | 5 |
| McLain et al (1997) | y | n | n | y | n | n | n | y | y | y | y | | 6 |
| McMillan et al (1998) | y | n | n | y | n | n | n | y | y | y | y | | 6 |
| Amorium et al (2011) | y | n | n | y | n | n | n | y | y | y | y | | 6 |
| Amorium et al (2011) | y | n | n | y | n | n | n | y | y | y | y | | 6 |
| Amorium et al (2012) | y | n | n | y | n | n | n | y | y | y | y | | 6 |
| Wang et al (2012) | n | y | y | n | n | n | n | y | y | y | y | | 6 |
| Ahearn et al (2018) | n | n | n | n | n | n | n | y | y | n | n | | 2 |
| Armstrong et al (2018) | y | y | n | y | n | n | n | y | y | y | n | | 5 |
| Tumonyte et al (2018) | n | y | n | y | n | n | n | y | y | y | y | | 6 |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Bergeron et al (2019) | y | y | n | n | n | n | n | y | y | n | n | | 3 |
| Panhan et al (2019) | y | n | n | n | n | n | n | n | y | n | n | | 1 |

### 2.4 Discussion

This section provides a summary of the research and elaborates on the use of PEDro scale scores to evaluate quality of research. Then some of the limitations of the fourteen studies included in this review are addressed.

#### 2.4.1 Summary of the Research

Overall, the research supports the effectiveness of Pilates on dancers in the areas of muscular endurance, posture, and flexibility however the results are inconclusive for balance and ineffective for increasing jump height. Additionally, matwork was the primary equipment used in the majority of the research indicating more research is needed on Pilates apparatus such as the wall unit/cadillac, wunda chair, reformer, spine corrector, and Pilates barrel to determine its effectiveness. It should also be noted that there are no studies comparing one piece of Pilates equipment against another.

#### 2.4.2 Interpreting PEDro Scale Scores

The PEDro scale scores for the reviewed articles (see Table 2.1 and 2.2) ranged from 1 to 6, with a mean score of 4.9. Three studies scored below a three, three studies scored a 5 and eight scored a 6. According to the PEDro scale's rules for quality research, 6 and above are considered high-quality research (Physiotherapy Evidence Database, no date). Fair quality is indicated by a 4 to 5 score, and poor-quality research is any score below a 3. Therefore, 21% of research included in this review on Pilates and dancers is poor quality, 21% of research done on Pilates and dancers is considered fair quality, with only 57% of the articles being high-quality research. The weakest criteria among these trials are the questions regarding blinding: whether blinding referred to participants, therapists, or assessors. In reviewing these articles, one sees that many of the blinding questions on the PEDro scale were not addressed in the literature, were stated unclearly, or were based on the logistics of scheduling and therefore not blind in the process. For example, in McLain and colleagues' (1997) study on Pilates effects on supine jump height and pelvic alignment, participants were chosen from a particular academic class. In Fitt and colleagues' (1993) study on Pilates effect on alignment and ROM, the participants were recommended by the faculty. In addition, the majority of these studies occurred in a conservatory or university dance program with members of the dance faculty being part of the research team who either conducted the intervention or collected and or analyzed the data; the assumption can be made that most of the participants were known to at least some of the researchers. Although steps may have been taken to attempt to be blind in the process (assigning numbers, for example), this relationship makes it difficult for the participants to remain blind throughout the entire process, thereby introducing a degree of bias.

## 2.5 Limitations of the Included Studies

It is obvious that the largest limitation in determining the effectiveness of Pilates in dancers is the relatively small number of studies that have been conducted. The total of fourteen studies limits the scientific evidence needed to support the effectiveness of Pilates in dancers. In comparison to the literature review conducted by Bernardo and Nagle (2006) and Bergeron, et al. (2017), additions to this area of research have been very limited. Four of the fourteen studies were also included in Bernardo and Nagle's review in 2006. If dancers are incorporating this type of conditioning into their daily routines, more research is needed to support acceptance of the practice of Pilates.

Looking more closely at the group of fourteen studies, one sees that three are from Amorim and colleagues (2011, 2011, 2012) and appear to be the same study divided into three parts and published in three different journals. Therefore, the overall number of studies looking at Pilates and dancers is brought down to twelve published studies with the three Amorim studies counted as one study. The participant number for each study is also significantly low. Participant pools need to be increased to provide stronger statistical data.

However, there are many other limitations to the published research. In the studies by Amorim and colleagues (2011, 2011, 2012), the words "endurance" and "strength" are used interchangeably. The authors state that researchers were looking for muscular strength, but the testing protocol addressed muscular endurance, not strength. Many of the reviewed studies used "homemade" testing tools or low-tech testing methods to determine outcomes. This dramatically decreased the validity of the data collected and therefore lacks significant statistical power. Additionally, many of the testing protocols included tests created for the general population rather than tests specific to a trained dancer. It is reasonable to conclude that tests developed for the general population would not be challenging enough for the trained dancer. This could be a factor in overall results showing minimal improvements, especially in standard balance testing where Pilates has been shown to have no or limited effects on dancers. According to the data collected, not only is the limited number of studies a factor, but also the scope of the study. Participant numbers ranged from 1 to 38 in the studies included in this review; consequently, the statistics on Pilates effectiveness are limited. These limited participant numbers are most likely a result of the single institutional setting in the majority of the studies. To have more statistical data to support the effectiveness of Pilates, larger participant pools are needed. The longitudinal studies were limited to eight weeks, with no information on how long these benefits lasted post intervention. Although conditioning effects on muscular strength can be seen in four to six weeks, a question that needs to be answered is "What are the long-term effects of Pilates?" More extensive studies could include the impact of Pilates on overall injury rate and proprioception.

Not all studies identified the specific Pilates exercises used or how the exercises were chosen for inclusion in the study. In view of this, it is unclear which Pilates exercises were effective and what the main purpose was in the selection of the exercises. In some of the studies (Fitt, et al., 1993; McMillan, et al., 1998; McLain, et al., 1997), participants were asked to perform mat exercises daily at home. The studies did not report how this protocol was recorded; in view of this, the validity of the overall study comes into question. The published research indicates that studies are using the Pilates mat and reformer as intervention, yet other pieces of equipment need to be examined. Most likely the lack of research in this area is due to inaccessibility of equipment, as the mat and reformer are the most commonly used. In future studies, not only should more equipment such as the cadillac and wall unit, the wunda/exo chair, spine corrector, and corealign be included, but comparisons of the effectiveness of one piece of equipment to others are needed. Pilates needs to be compared to other forms of exercise to determine its true effectiveness. Currently, only one published study examines Pilates in comparison to other forms of exercise such as running, CrossFit, Zumba, yoga, plyometrics, or other movement forms.

One of Joseph Pilates' main beliefs was that there is not only one way to do a specific exercise. He had several variations of each exercise to zero in on the person's strengths and weaknesses as well as adapt for injuries. A modification is to focus on a weakness or alter for an injury, whereas a variation is used to increase the difficulty of an exercise. In Pilates training, session exercises are personalized for the individual. If RCTs are not adjusted to include this methodology, how can the true Pilates method be tested? Scientifically, if exercises are individualized and executed differently, how would it be determined that one way to do the exercise is more effective than the other?

### 2.6 Conclusion

The purpose of this review was to evaluate the evidence and the quality of research on Pilates conducted specifically on dancers and to determine its effectiveness on dance training and performance. Although there are many testimonials and articles about the Pilates method, there is insufficient research showing its effectiveness in dance performance and injury rehabilitation. Other literature reviews (Bernardo & Nagle, 2006; Cruz-Ferrerura et al., 2011; Bergeron et al., 2017) have noted the small number of research studies examining Pilates, specifically in dancers. One would have expected to see more publications since the last literature review in 2006, but disappointingly, little additional research has been conducted. Furthermore, the research lacks evidence pertaining to the various pieces of equipment and apparatus. Most studies use mat or reformer, and only one publication included Pilates equipment such as spine corrector, cadillac, wunda chair, ladder barrel, corealign, or other such equipment to demonstrate effectiveness in the dancer population.

The strength of the studies on Pilates and dancers lies in who conducted the Pilates training sessions within the study. In most studies, experienced Pilates instructors performed the training sessions, ensuring the validity of the Pilates method. Each study had a strong purpose, asked clear questions, and had a well-defined hypothesis. Weaknesses within the studies lay within the design. Some lacked control groups: many were not random in their selection of participants; and therapists or assessors were not always blind to the groupings. More statistical data are needed to measure effective outcomes to make the research on the usefulness of Pilates for dancers more reliable. A limitation of this review may be that articles were unavailable through the selected search engines (requested between 1980 and 2024). The search indicated eleven conference proceedings and thirty-one dissertations involving studies on dancers that used Pilates as the intervention; these for one reason or another have not been published. Clearly more research is needed; but overall, the fourteen studies included here generally supported the effectiveness of Pilates in dancers with respect to muscular endurance, posture, alignment, and flexibility. However, based on the limited research available, Pilates may be ineffective with respect to balance and vertical jump in dancers.

Future research should examine some of the weaknesses seen in these studies as identified in the systematic review and the PEDro scale analysis. These weaknesses include research methodologies such as (a) blind procedures, (b) randomized groups, (c) small sample sizes, (d) specialized assessments designed for dancers, (e) research examining various pieces of Pilates equipment, (f) connection of the impact of the conditioning program on dance performance, (g) qualitative data looking at dancer perspective on the impact of Pilates and (h) assessment of dynamic rather than static movement to align more with the demands of dance performance. This thesis addresses (1) blind procedures (chapter 6), (2) randomized groups in method design (chapter 6), (3) specialized assessments designed for dancers (chapters 4, 5, and 6), (4) research examining various pieces of Pilates equipment (mat and wall unit) (chapters 5 and 6), (5) impact of the conditioning program on dance performance (chapter 5), (6) assessment of dynamic movement (chapter 5), and (7) dancer perspective (chapters 5 and 6).

# 3 Thesis structure, aims, and hypotheses

This body of research was inspired by the overwhelming inclusion of Pilates as a training regimen in university dance programs and professional dance companies, the growing popularity of Pilates, practitioner observations over a 20+ year career and the lack of research conducted to show Pilates is a conditioning method dancer should be using. The systematic review in Chapter 2 highlights the lack of research on dancers and Pilates and the limitations of those studies including low participant numbers therefore weak statistical data, a limited span across dance genres, lack of varied Pilates equipment used in clinical trials, limited testing tools specifically designed for dancers, and how Pilates improves the physical skills required of dancers and how those skills translate to the physical practice of dance. The purpose of the thesis was to add to the body of research in support of Pilates as a training regime for dancers, to investigate testing tools designed for dancers, to incorporate Pilates apparatus, the wall unit, into a clinical trial, and to investigate strengthening core stability in dancers to improve dance performance. A progressive order of studies was designed to examine core stability, examine new testing tools, and concluding with a Pilates intervention study for undergraduate collegiate dancers involving the use of the Pilates wall unit. In addition, there is limited research showing the impact of conditioning programs on increasing the physical attributes of a dance to enhance dance performance. Most studies look at specific, more easily measured, indicators such as hamstring flexibility and muscular strength. This thesis also examined testing protocols designed for dancers to connect the impact of a Pilates training program on a dancer's performance and training. Due to research funding limitations in dance science and the current lack of testing procedures specific to a dancer's needs, innovative, assessable, and simple testing protocols were used throughout the course of these studies.

This thesis is organized in chapters emphasizing the overall design plan for this research beginning with a systematic review and an examination of core muscle engagement during abdominal exercises to improve core stability. The two concluding intervention studies examine the effectiveness of a Pilates intervention program on dancers' core stability and dance performance as well as dancer perceptive on the impact of Pilates on improving their skills. The core thesis comprises three studies including an examination of muscle amplitude and studies investigating the impact of Pilates mat and apparatus work on core stability and dance performance.

**Study 1:** Chapter 4 - The efficacy of Pilates-based Exercises on Rectus Abdominis engagement in comparison with the FITNESSGRAM in Collegiate Dancers

<u>Aim:</u> The study was designed to examine and compare the muscle amplitude during a commonly used abdominal curl test and three Pilates based curl exercises with and without a sphygmomanometer in order to identify a core endurance test designed for dancers. This data will be the foundation for creating a new assessment test for abdominal strength in dancers, adding to the lack of evaluations designed specifically for dancers. Surface electromyography (sEMG) was used to examine upper and lower rectus abdominis during four repetitions of each exercise. Pelvic placement is essential to both dance and Pilates which informed this study and its investigation on how pelvic placement impacts muscular engagement in various leg positions.

Hypothesis: The sphygmomanometer will have no effect on muscle amplitude in either the upper or lower rectus abdominis. The type of exercise performed will have no effect on muscular amplitude.

**Study 2:** Chapter 5 - The Effects of Pilates Mat Classes on Abdominal Core Stability and Dance Performance: A Pilot Study

Aim: This study addressed new assessment tools for dancers, expansion of the use of Pilates equipment in research, connected a Pilates conditioning program to dance performance, incorporated dynamic movement into the testing protocol and used questionnaires to examine dancer perception on the impact of Pilates on dance training. It examined the effectiveness of a Pilates Mat program on core stability and how it relates to the success of a dance movement phrase. In current literature there is no clear evidence which shows how an increase in core strength improves dance performance and currently research protocols lack specific dance testing procedures measuring dance performance. There is limited qualitative and quantitative research in Pilates and Dance. Therefore, this study uses questionnaires to capture participants perception of the impact of Pilates and develops new testing procedures to measure an improvement or lack of improvement in dance performance.

Hypothesis: There will be no impact on dance performance or core strength after a Pilates mat intervention. Dancers will not perceive a significant relationship between core stability and dance performance using the Pilates method.

**Study 3:** Chapter 6 - Pre-Experimental Analysis of the Pilates Wall Unit on Core Stability in Collegiate Dancers and Perceived Impact on Dance Performance

Aim: This study included blind methodology and randomized groups into the research design, utilized a new assessment tool based on data from chapter 4, used the wall unit to add to the use of various Pilates equipment in research, and looked at dancer perspective of Pilates on dance training through qualitative methods. It investigated a new testing procedure for measuring dance performance and examined additional testing measurements analyzing alignment specific to dancers. As seen in the literature review, Pilates mat is the most commonly used intervention program in the current research. This is most likely due to the accessibility and cost efficiency of Pilates mat work. However, Pilates was initially developed using various equipment and is often used to assist participants in exercises when they had difficulty executing them on the mat. Therefore, the use of the equipment is essential in analyzing the overall effectiveness of Pilates. Consequently, this study examined the Pilates wall unit, which is commonly used in Pilates but is one of the least investigated in the current research on Pilates and dancers. <u>Hypothesis</u>: No significant difference will be between the control group and the intervention group. Participants will not perceive a difference in core stability after intervention.

Bringing the work together, the final chapter (Chapter 7) is a discussion of findings and how the body of work may influence current practice in conditioning dancers. It summarizes the contributions this dissertation (or thesis) project has made to the field and suggests future research needs in Pilates, analyzing the use of various Pilates equipment, assessing dance performance and developing testing procedures specific for dancers.

# 4 Study 1: The efficacy of Pilates-based Exercises on Rectus Abdominis engagement in comparison with the FITNESSGRAM in Collegiate Dancers

Parts of this chapter have been accepted for publication.

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Author Contributions
Bergeron, C.S.: data collection, data analysis, author of original draft, article preparation for publication
Smith, T.: mentored and assisted in initial data analysis, co-author and editor of results section in final draft
Greenwood, M.: (deceased): assisted in original methodology before his death
Wyon, M: mentor in data collection, editor of final draft

## 4.1 Introduction

According to Rickman et al. (2012) poor core stability in dancers leads to biomechanical changes at the truck indirectly affecting their lower extremities, resulting in impairment of force production and injury. Kline and colleagues (2013) state that dancers need strong muscles in the truck for stability, balance and muscle coordination to perform complex movements. Lack of pelvic stability and changes to the function of the lower extremities can result in improper alignment in dance movements such as developpé, fondu, and attitude positions. Discovering a dancer's baseline for pelvic stability can be an essential component to improving their overall technique. The purpose of this study was to identify a core endurance test that incorporates neutral pelvic alignment during testing to assess dancer core strength and stability.

Therapists use the concept of lumbar stabilization to prevent and rehabilitate injuries and to improve overall performance in athletes and other individuals. (Cynn, et al., 2006) The sphygmomanometer instrument, a biofeedback three chamber pressure cell, was designed by physical therapists to aid in re-educating the muscle stabilizers of the lumbar spine (Jull, et all, 1993). Cairns et al. (2000) states the sphygmomanometer instrument is used to retrain clients in detecting movement of the lumbar spine by providing visual feedback when their pelvis is no longer in neutral. This retraining protocol has been shown to be a reliable tool for indicating abdominal function. During a curl exercise the rectus abdominis is the major contributor to flexion of the torso in comparison to other abdominal muscles and serves a role in spinal stability (Silva et al, 2015; Norwood et al, 2007). Studies exploring the impact of abdominal exercises on muscle activation are inconsistent in the placement and alignment of the pelvis during exercise. However, studies which emphasis pelvic placement, such as Saeterbakken, et. al (2014), show a significance difference in abdominal engagement. A study by Deckert, Barry, and Welsh (2007) provided individual pelvic placement training to participants and was successful in improving pelvic alignment; changes occurred soon after the onset of intervention. This study highlights the possible need for individual instruction to optimize results. Pilates is widely used by physical therapists to strengthen trunk stability and realign and stabilize the lumbar spine (Silva et al., 2015; Latey, 2001). The sphygmomanometer could be helpful in maintaining a neutral pelvis while stabilizing the lumbar spine (Jull et al., 1993) and has proven to be a useful tool in conducting research which looks at lumbar stabilization (Cairns, et al., 2000).

Surface electromyography (sEMG) is more than a century old and provides quantitative data concerning muscular amplitude (Campanini, et al., 2020). It plays an important role as an assessment tool that measures muscle activation. There are several studies which use sEMG to assess pelvic stability (Lee, 2021; San Juan, 2005; Chan, et al., 2020) however, there is limited sEMG studies which investigate a Pilates or Pilates-based exercise. None that compare a series of Pilates or Pilates-based exercises to examine the differences in muscular amplitude among them.

The FITNESSGRAM is a series of exercises used in physical education to assess abdominal strength and endurance, truck extensor strength and flexibility, upper body strength and endurance, and flexibility. According to Plowman et al. (2006) and The

Cooper Institute (2022), the FITNESSGRAM is the most trusted and widely used fitness assessment, education, and reporting tool used across the globe. The FITNESSGRAM Curl Test (FGCT) assesses a person's abdominal strength and endurance.

Pilates abdominal exercises such as the 100's is designed to strengthen core abdominal muscles. Unlike the FGCT, Pilates or Pilates-based exercises require the dancer to maintain a neutral pelvis throughout the exercise. This key area of posture and dance alignment is essential for proper technique therefore should be reinforced in not only exercises but also in assessment tools designed to measure a dancer's core strength.

This study aimed to assess the sEMG amplitude of the upper rectus abdominis (URA) and lower rectus abdominis (LRA) during the FGCT and Pilates-based mat exercises with and without the use of a sphygmomanometer. The FGCT is widely used in elementary and secondary schools to measure abdominal endurance (Plowman et al, 2006), however pelvic placement during the FGCT is not noted. The null hypothesis for this study indicates no effect on muscle amplitude in either the upper or lower rectus abdominis with or without the sphygmomanometer. There will be no muscular amplitude difference between the exercises.

## 4.2 Methods

### 4.2.1 Study Design

Using a cross-sectional design, differences in sEMG amplitude were examined across four different abdominal exercises, three Pilates-based exercises with and without the use of a sphygmomanometer and a standardized abdominal curl test (FGCT). During execution of all Pilates-based exercises participants were expected to maintain a neutral pelvis. The loss of neutral pelvis was confirmed by a 10mmHg increase or decrease in pressure on the sphygmomanometer dial (Lanning, et al., 2006). Neutral pelvis, as it is used in the Pilates Method, is defined by the ASIS and pubic bone being on the same coronal plane when lying supine (Isacowitz, 2014).

### 4.2.2 Participants

The study was reviewed and approved by the university's IRB (IRB2016-0392D). Thirty-five participants in a university dance program, volunteered for the study. All participants signed a consent form and filled out a physical activity and medical history questionnaire. Participants had to be a minimum of 18 years old, be enrolled in a ballet and/or modern dance class three times a week, and be free from injury in the neck, back, abdominals and hip flexors. For the purposes of this study, an injury was defined as the need for medical attention due to the injury and/or loss of time from dance activities. One participant was a screen failure due to a low back injury and five participants did not complete all testing sessions, so were removed from the study. The remaining twenty-nine female participants (age = 19yrs ± 1.12, height = 163.26cm ± 6.5, mass = 59.8kg ± 8.93) finished all the required sessions therefore completing the study.

### 4.2.3 Measures

**Data Recording**

Using the four channel IX-BIO8 (iworx, USA), sEMG data was collected at 2000 Hz with a band pass filter with cut off frequencies at 20-500HZ (Silva et al., 2015) to record muscle activation. Muscle activation in the upper and lower abdominis was monitored during the 7 exercises using disposable surface disc electrodes (iworx, A-GC-7165). Electrodes measured 10mm in diameter with an inter-electrode distance of 20mm. Before electrode placement, the skin was abraded with sandpaper and cleaned with alcohol as recommended by the sEMG for the Non-Invasive Assessment of Muscles (SENIAM). The electrodes were positioned on the muscle bellies and parallel to the muscle fibers as described by Silva et al. (2015) and as recommended by SENIAM. Electrodes for the URA were placed just below the midpoint between the umbilicus and xiphoid process, but not at the tendon intersection, and 3cm lateral from the midline. Electrodes for the LRA was placed approximately at the midpoint between the umbilicus and the pubic symphysis and 3cm lateral from the midline. The reference electrode was placed on the tibial tuberosity of the left knee.

**Exercise Descriptions**

Each exercise was performed in supine at the same tempo using a metronome set at 35bpm. Each participant performed the exercises in the same order and each exercise was performed four times.

**FITNESSGRAM Curl Test (FGCT)**

The participants laid supine on the mat with back flat, head touching, arms outstretched at sides with fingertips touching the top of a 4.5-inch strip and feet flat on the mat with knees bent, hip width apart. Participants were asked to perform the test by curling up far enough off the mat, so their fingers crossed the measuring strip to the bottom of the strip. There is no reference to maintenance of a neutral pelvis throughout the exercise, so participants were allowed to move the pelvis throughout the exercise. Form errors included: not getting the shoulders and back off the mat enough to reach across the measuring strip, feet lifting up off the mat, head not returning to the starting position on the mat and/or the inability to maintain the proper pace. (See Figure 4.1).

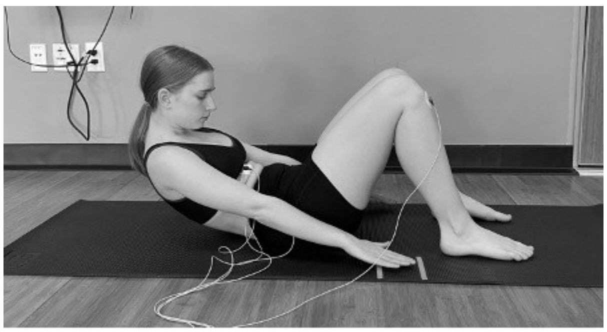


**Figure 4.1**
**FITNESSGRAM (FGCT)**

**Pilates-based Exercises**

**Pilates-based Legs Up (LU) (see Figure 4.2).**

Participants were asked to lie supine on the mat with knees bent and arms straight by the sides of the body with a neutral pelvis placement. To prepare the legs, participants were asked to extend one leg up to the ceiling then the other, straightening them at 90-degree while maintaining neutral pelvis. The participant was then asked to perform a curl rounded up to just past the tip of the scapulae while the legs stayed in the straight 90-degree position. Form errors included: not curling up to just past the tip of the scapulae, not maintaining neutral pelvis (determined by the proper alignment of the ASIS and pubis), head not returning to the starting position on the mat, legs not being sustained as described throughout the exercise, and/or the inability to maintain the proper pace. (See Figure 4.2).

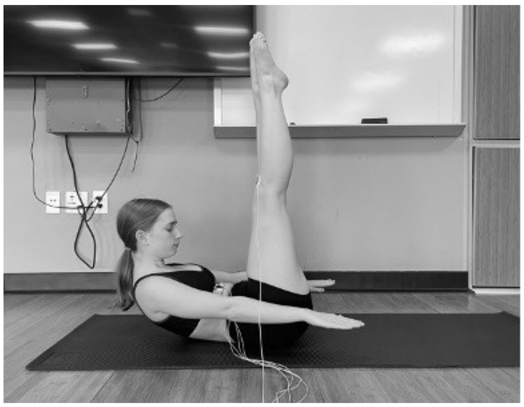


**Figure 4.2**
**Pilates-based Legs Up**

**Pilates-based Legs on Diagonal (LD) (see Figure 4.3)**

Maintaining the description as it is listed in LU participants placed the legs on an angle or diagonal whilst maintaining a neutral pelvis. The degree of the diagonal was determined by the ability for the participant to maintain neutral or imprinted pelvic alignment with the absence of anterior pelvic tilt therefore, no predetermined degree was set for each participant. While retaining the leg position, participants were asked to curl up just past the tip of the scapulae. The legs remained on the diagonal as the participant lowered the torso to the mat, finishing the curl. (See Figure 4.3).

**Figure 4.3**
**Pilates-based Legs on Diagonal (LD)**

**Pilates-based Legs Up to Legs Diagonal (LULD)**

Keeping the alignment and placement as it is described previously for LU, this exercise was a combination of the previous two exercises. Participants started with the legs at 90 degrees and moved the legs to the diagonal while maintaining proper pelvic placement when they curled up just past the tip of the scapulae. The diagonal to which each dancer extended their legs was calibrated to the level that allow them to avoid anterior pelvic tilting. As the torso lowered from the curl position and the head returned to the mat, the legs returned to 90 degrees in relation to the torso.

**Pilates with Sphygmomanometer**

The remaining three Pilates-based exercises, BIO Legs Up (BIOLU) (see Figure 4.4), BIO Legs Diagonal (BIOLD) and BIO Legs Up to Legs Diagonal (BIOLULD), were all performed like the previous three Pilates-based exercises (LU, LD and LULD) using a sphygmomanometer, a three-chamber pressure cell, placed under L4-L5 (lumbar spine) and set at 40mmHg as per the guidelines set by the manufacture (DJO, LLC Vista, 2009) and used in other studies including Chan, et al., (2020). As with the previous Pilates-based exercises these exercises were also performed in a neutral pelvis and the legs were set at 90 degrees for BIOLU and participants chose the degree or angle of the legs they could perform while maintaining neutral pelvis for both the BIOLD and BIOLULD. The participant received visual feedback throughout the exercises by their observation of a change in the dial on the sphygmomanometer.

**Figure 4.4**
**Pilates-based BIO Legs Up (BIOLU)**

### 4.2.4 Procedures

**Training Session Protocol**

Participants were asked to attend two 30-minute training sessions the week prior to the initial sEMG testing to learn the mechanics, timing, and correct alignment during seven exercises and the maximum voluntary isometric contraction (MVIC) test. It was observed in previous testing during a dance wellness screen that participants did not understand the muscle activation required to maintain consistent pressure on the three-chamber cell stabilizer therefore, during training sessions, participants were guided on the use of the sphygmomanometer during three Pilates-based exercises. Participants were instructed on the proper sphygmomanometer placement, anatomical alignment with particular focus on neutral pelvic placement during the proper curl position, and appropriate usage of the sphygmomanometer during the execution of the Pilates-based exercises. Participants were educated on how the change in their pelvic placement impacted the pressure and levels of the sphygmomanometer and how to maintain consistency in pelvic alignment while executing the Pilates-based exercises. Regarding MVIC training, participants were informed on proper body placement and alignment while maintaining persistent muscle engagement during applied resistance by the examiner.

Exercise Procedures

To minimize fatigue, participants performed four repetitions of seven different exercises over three separate sessions with a two-day rest period between each session. sEMG electrodes were attached to the upper and lower abdominis to measure muscle activation.  Participants performed three Pilates-based exercises (with and without a sphygmomanometer) while maintaining a neutral pelvis as described in the Pilates work (Muscolino & Cipriani, 2004; Ahearn et al, 2018). The exercises examined within the study were performed to a set rhythm of 35bpm. Prior to the first sEMG session participants were trained on how to use the sphygmomanometer while maintaining neutral pelvis during the prescribed exercises.

During the first sEMG test session, MVIC data and four repetitions of the FGCT were collected. A six second MVIC was performed with the participant in supine with the legs secured.  Participants completed two MVIC tests and an average of the two were analyzed. The participant flexed the torso until the scapulae lifted slightly off the mat with the arms crossed on the chest. The examiner then applied resistance by placing the hands on the shoulders and pressing down for six seconds. Enough resistance was given to apply pressure but not to force the participant to collapse into the mat. A five-minute rest period was implemented between each MVIC test. After two MVIC tests and another five-minute rest period, participants were asked to execute four repetitions of the FGCT.

During the second visit, four repetitions of the three Pilates based exercises, LU, LD and LULD were performed.  A five-minute rest period between each of the three exercises was given to reduce fatigue.

On the last visit, the three Pilates-based exercises were repeated with a sphygmomanometer placed under the lumbar spine. As participants performed the exercises, they were asked to keep the sphygmomanometer at 40mmHg, as recommended by the Stabilizer Manual (DJO, LLC, item #9296) and were allowed a maximum of 10mmHg deviance (Chan, et al., 2020) A five-minute rest period between each exercise was given to help reduce fatigue.

### 4.2.5 Data Processing & Analysis

**Data Processing**

Using Labscribe software, raw sEMG signals were band-pass filtered (20 – 500Hz). The data was exported from the Labscribe software into Excel where it was full-wave rectified and smoothed, using a Butterworth low-pass filter (30Hz) (Hu et al, 2005) to obtain the linear envelope. After the data was rectified and smoothed, it was checked for electrocardiography (ECG) contamination. Data contaminated by ECG was removed and Area Under the Curve (AUC) mean was found for the remaining trials. For the sEMG data of 406 trials (7 exercises with EMG data for upper and lower rectus abdominis for each participant), 33 trials were contaminated with ECG. To determine onset of sEMG, baseline mean and standard deviation (SD) of 50ms of data was calculated and the following formula was applied: mean baseline signal + (1.96 x SD of baseline signal) = onset threshold. sEMG amplitude was calculated as the area under the curve (AUC) trapezium method, for each repetition of each of the exercises and MVIC trials. Each participant's mean AUC was calculated for the four trials of each exercise and expressed as a percentage of the MVIC mean AUC (%AUCMVIC).

Shapiro-Wilk and Kolmogorov-Smirnov tests indicated the data were not normally distributed and therefore Independent-samples Kruskal-Wallis tests were used to compare the AUC of different exercises and the AUC of the URA and LRA of the different exercises. Wilcoxon Signed Rank Sum Tests were used to test for differences in %AUCMVIC when the sphygmomanometer was incorporated into the Pilates exercises and when it was not. Initial analysis indicated a large disparity in group data for each exercise and in an attempt to control for inter-participant variations (Table 4.1), the variation of the %AUCMVIC for each Pilates exercise was calculated in comparison to the FGCT %AUCMVIC for each participant. Each participants' FGCT %AUCMVIC data became "0" and the %AUCMVIC for the Pilates exercises were either greater (positive) or less (negative) than this. IBM SPSS Statistics software version 25 (IBM, Armonk, New York, USA) was used to analyze the data and the level of statistical significance for all tests was $p \leq 0.05$.

## 4.3 Results

The %AUCMVIC for the upper and lower rectus abdominus of each exercise can be found in Table 4.1. The Independent-samples Kruskal-Wallis test indicated a significant difference in %AUCMVIC between the exercises for the URA ($p=0.015$); the FGCT was significantly greater than the BIOLULD ($p=0.05$). Although some difference was seen, there were no significant differences for %AUCMVIC between the different exercises for LRA data.

**Table 4.1**
**AUC as % of MVIC (mean 95%CI) for Upper and Lower Rectus Abdominis for each abdominal exercise**

| Exercise | Upper Rectus Abdominus (%) | Lower Rectus Abdominis (%) |
|---|---|---|
| Fitness Gram (FGCT) | 21.9 (15.99 – 27.99)* | 23.4 (14.66 – 32.22) |
| Pilates based Legs Up (LU) | 23.3 (13.51 – 33.17) | 24.4 (14.18 – 34.53) |
| Pilates based Legs Diagonal (LD) | 22.4 (13.83 – 30.94) | 22.1 (14.51 – 29.72) |
| Pilates based Legs Up to Legs Diagonal (LULD) | 23.5 (12.82 – 34.18) | 18.3 (12.51 – 24.01) |
| Pilates based BIO Legs Up (BIOLU)^ | 12.1 (8.12 – 16.01) | 23.4 (13.65 – 33.19) |
| Pilates based BIO Legs Diagonal (BIOLD) ^ | 15.4 (10.33 – 20.48) | 24.9 (13.22 – 36.53) |
| Pilates based BIO Legs Up to Legs Diagonal (BIOLULD)^ | 12.4 (7.07 – 17.74)* | 18.1 (7.95 – 28.18) |

^BIOLU, BIOLD, and BIOLULD were the repeated Pilates exercise using the sphygmomanometer
*Significant difference ($p \leq 0.05$)

**Use of the sphygmomanometer**

Within the Pilates exercises, the use of the sphygmomanometer had a significant effect on abdominal engagement. When comparing the Pilates based tests while the legs were raised off the floor, without the sphygmomanometer, LU and LULD, in comparison to the same exercises with the sphygmomanometer, the URA had a significantly smaller %AUCMVIC (BIOLU, $p=0.001$and BIOLULD, $p=0.011$). Although a difference was seen in BIOLD versus the FGCT it was not significant ($p=0.23$). Therefore, there was no significant differences in %AUCMVIC for the LRA were reported with and without the sphygmomanometer.

**Pilates exercises in comparison to FGCT**

The Independent-samples Kruskal-Wallis test indicated a significant difference in %AUCMVIC between the Pilates exercises and FGCT for the URA ($p=0.013$); both the BIOLULD ($p=0.032$) and the BIOLU ($p=0.001$) %AUCMVIC were significantly lower than the reference FGCT (see Figure 4.4). Although some differences were seen, there were no significant differences between the Pilates exercises, with and without the sphygmomanometer, and the FGCT for LRA data (see Figure 4.6).

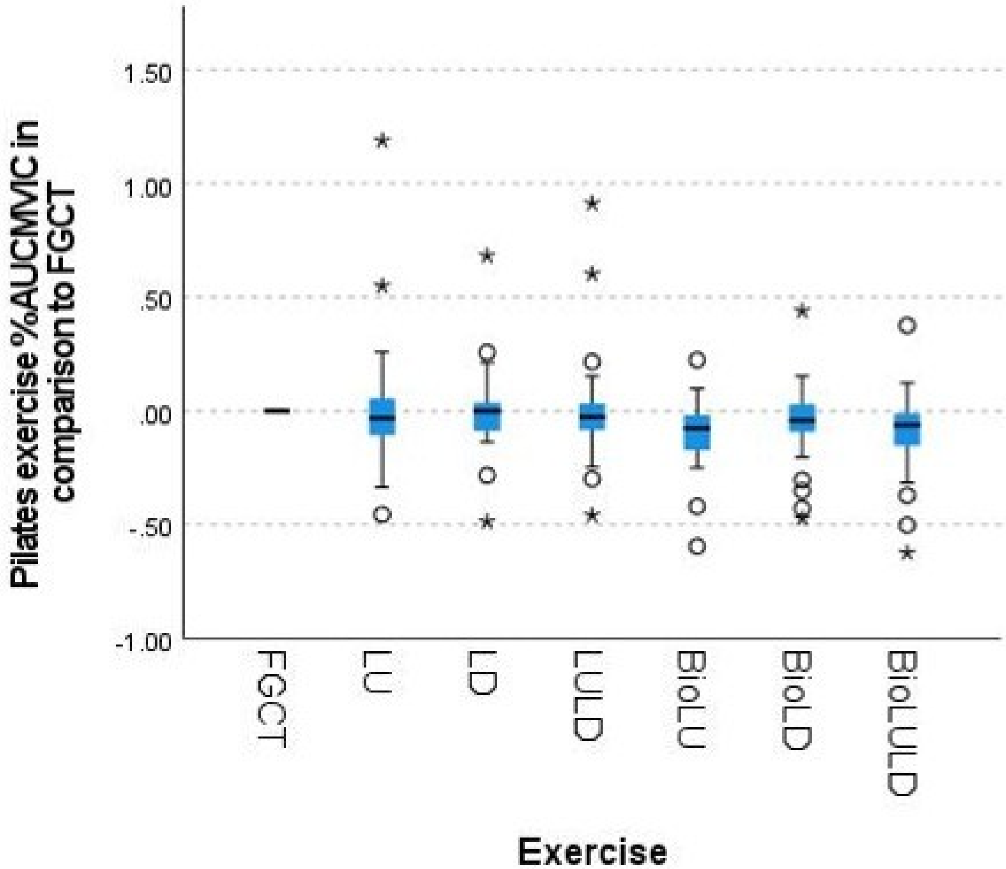



**Figure 4.5**
**URA %AUCMVIC comparison of Pilates-based vs. FITNESSGRAM**

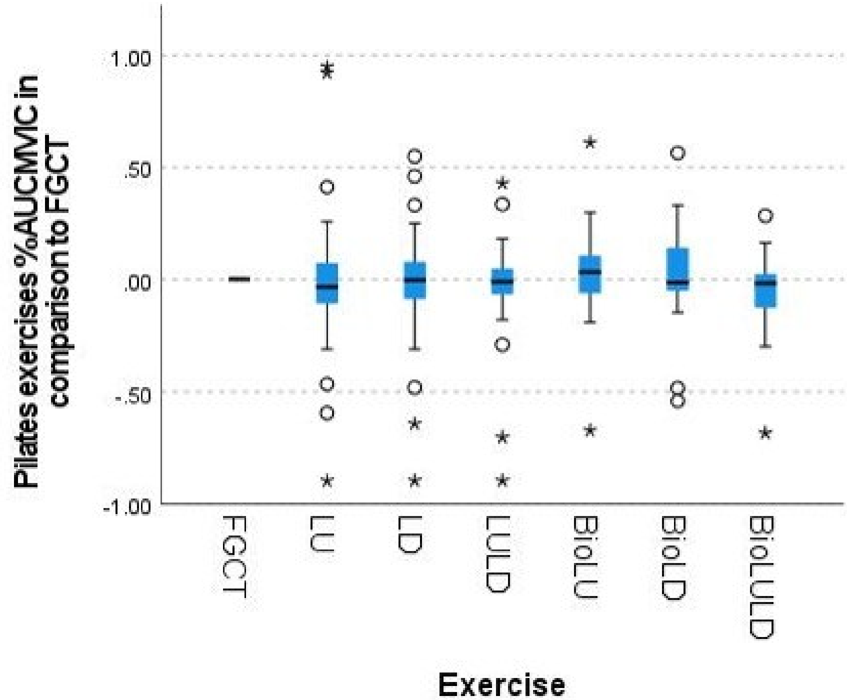



**Figure 4.6**
**LRA %AUCMVIC comparison of Pilates-based vs. FITNESSGRAM**

## 4.4 Discussion and Implications

Using a cross-sectional design, this study examined the difference in muscle amplitude in both the URA and LRA during three different Pilates-based exercises, with and without a sphygmomanometer and a standardized abdominal endurance test, the FGCT. Despite the variations in the placement of the legs during the three Pilates based exercises, no significant difference in muscular amplitude of the LRA was reported. There was a difference in URA engagement with the use of the sphygmomanometer in two of the three Pilates-based exercises with only a small difference seen in the LRA for the BIOLD, although not significant. This may indicate maintaining neutral pelvis while using the sphygmomanometer may contribute to a less active RA in the execution of an abdominal curl. Based on these results, the sphygmomanometer perhaps should not be used as a training tool to increase RA activation. Investigation is needed to determine the effect of the sphygmomanometer on other abdominal muscles such as the internal/external obliques and the transverse abdominis. The results showed the FGCT had greater muscular amplitude in the URA than in the Pilates-based exercises especially with the BIOLULD (p=0.032) and no significant difference between the exercises for LRA data.

There were some inconsistencies among the participants regarding the execution of the FGCT that may have impacted the results. The FGCT uses a 2-point reference measurement and the age of the participant to indicate how far a participant rounds up into the curl position. This external measurement does not take into effect the length of the torso, the length of the arms, or the placement and movement of the pelvis during the exercise. During testing, it was noted by the examiner a wide range in how far the participants came up into the curl position to meet the test criteria. This assessment approach is contrary to the Pilates approach which indicates a subject to curl up to just past the point where the tips of the shoulder blades lift off the floor. The absence of focus of pelvic placement instruction during the FGCT, in contrast to the Pilates-based exercises, could explain some of the inconsistencies. As noted by the examiner, most participants moved their pelvis into a posterior tilt during the FGCT which increases the activation of the rectus abdominis (Queiroz et al, 2010) compared to the pelvis in a neutral position (Pilates-based movements). These variations in the FGCT versus the

Pilates exercises suggest that the Pilates curl may not be the most effective position for URA engagement. However, in classical dance forms, such as ballet and modern, the dancer is often taught to work in a neutral pelvis position. Therefore, training and/or measuring fitness levels without regard to proper placement seems counterproductive to training ballet and modern dancers. More investigated is needed to determine why there was a decrease or non-significant difference in RA engagement. Additional abdominals within the curl position should be examined to determine if similar results would be found. Continued investigation is needed to determine which tests and exercises may be appropriate and beneficial for dancers and their aesthetic and training needs.

## 4.5 Limitations

There were different levels of knowledge regarding proper neutral pelvis during exercise within the participants which could have impacted the results. Additionally, participants indicated lack of understanding on how to control the range of the sphygmomanometer while performing the exercises. This lack of awareness could have affected overall results, and further testing should include additional training on the use of the sphygmomanometer prior to recording muscular amplitude. This study only recorded upper and lower rectus abdominis; future research should include other abdominal muscles such as the internal and external obliques and the transverse abdominis.

## 4.6 Conclusion

The purpose of this study was to find a more relevant assessment tool for dancers to analyze core strength. The initial hypothesis for this study was there would be no significant difference seen with or without the use of the sphygmomanometer in the Pilates-based exercise. The hypothesis also stated there would be no difference between the FGCT and the Pilates-based exercises in either the URA or LRA. With the increase muscular amplitude seen in the FGCT for URA the null hypothesis is rejected. However, the results are validated in regards to the LRA and the effect of the sphygmomanometer on muscular amplitude. Results from this study indicate the need for greater understanding of the effect of abdominal curls in RA engagement.

# 5 Study 2: The Effects of Pilates Mat Classes on Abdominal Core Stability and Dance Performance: A Pilot Study

Parts of this chapter have been accepted for publication (Bergeron, et al., 2024)

Bergeron, C. S., Smith, T., Welsh, T., & Wyon, M. (2024). The Effects of Pilates Mat Classes on Abdominal Core Control and Dance Performance: A Pilot Study. Journal of Dance Education, 1–9. https://doi.org/10.1080/15290824.2024.2348466.

Author Contributions:

Bergeron, Christine – methodology, conducted intervention and pre/post testing, analyzed data, wrote original article

Smith, Tina – editor of article for publication

Welsh, Tom – assisted with discussion session and editor of article for publication

Wyon, Matt – editor of article for publication

## 5.1 Introduction

Ballet and modern dance techniques are athletic, artistic, expressive and skilled art forms that require years of training to master. For dancers to have long careers and maintain proper health, good technique is required (McMillian, et al., 1998). Dancers, amateur and professional, with a dance only training program find their muscular power, strength, balance, and bone and joint integrity problematic (Koutedakis and Jamurtas 2004). With increasing physical demands of choreography over the past 20+ years so has the need to train outside of the traditional dance class. Koutedakis and Jamurtas (2004) state "the physical demands placed on dancers from current choreography and performance schedules make their physiology and fitness just as important as skill development." Research has shown physical conditioning improves technical performance in dancers including strength, flexibility, balance, and posture (Amorim et al. 2011; Angioi et al. 2009; Grossman and Wilmerding, 2000; Kloubec, 2010; Twitchett et al. 2011). However, the mindset of supplemental physical conditioning impacting the dancer's aesthetic appearance makes dancers hesitant to incorporate conditioning programs into their training regime (Koutedakis and Jamurtas 2004; Rafferty 2010).

Dance and the Pilates Method are known to share similarities including attention to alignment, focus, flow of movement, precision, planes of movement and recognized movement patterns, and therefore may be a compatible training method for dancers (Ahearn, 2006). The Pilates Method has a long history within the dance community beginning with the relationship between Pilates founder, Joseph Hubertus Pilates, and well renowned modern dancer and choreographer, Ted Shawn at the famous Jacob's

Pillow summer workshops[1] during the 1930's (Latey, 2001). According to Friedman, Eisen and Miller (1980), Joseph Pilates and his training method had the ability to return dancers to the stage after injuries, increasing the relationship between Pilates and dancers such as Hanya Holm, Martha Graham, and George Balanchine. Over the years, many dance companies and schools have incorporated Pilates into their curriculum including universities (Ahearn, 2006). Even though there is a long history and relationship between dance and the Pilates Method and as seen in Chapter 2, Pilates has yet to be sufficiently investigated to prove its effectiveness for training dancers (Bernardo & Nagle, 2006; Bergeron, et al, 2017). To validate Pilates as a training method for dancers, this study investigated the effectiveness of a progressive Pilates mat program on core strength and stability during a dance movement phrase. It also investigated the dancers' perception of Pilates and its impact on their core strength, awareness, and dance ability and training.

## 5.2 Methods

### 5.2.1 Study Design

Using a Pre/Post Case Series Intervention Design, improvement in overall core stability and core engagement during dance performance was examined.

### 5.2.2 Participants and Setting

**Participants**

Prior to pre-testing all participants signed an approved IRB (IRB2020-09993D) consent form and filled out an injury questionnaire. Three university dance science

[1] The Jacob's Pillow summer workshops continue to the present.

majors (age = 18yrs, height = 163cm $\pm$ 8, mass = 68kg $\pm$ 12) completed the ten-week study. They were free from back, hip, ankle, or knee musculoskeletal injuries in the six months prior to the study. For the purposes of this study, an injury was defined as loss of time from dance activities. Participants were taking a ballet and modern class that met three times a week as well as rehearsal hours ranging from three to ten hours per week. All participants had been exposed to Pilates mat work but were not currently training in the Pilates Method or participating in any other fitness programs throughout the study. All intervention sessions were conducted in a university dance program Pilates studio.

**Assessment Protocol**

Assessing participants included a questionnaire for participant's perception, plank test for core strength, and a modern dance phrase for impact on dance performance. Beginning at pre-testing, a movement phrase was recorded every two weeks throughout the study to evaluate the impact of a Pilates mat program on overall dance performance and to examine at which point in the study impact was observed. Prior to each movement phrase recording participants were brought through a warm-up program (Table 5.1) to ensure safe dance practice protocol.

**Training Protocol**

Participants completed a 45-minute Pilates mat session twice a week for eight weeks. The three participants were led by a Physical Mind certified Pilates mat instructor with 20 years' experience through a series of Pilates mat exercises which progressed every two weeks.

### 5.2.3 COVID Protocol

This study was conducted during the COVID-19 pandemic therefore protocols were put into place to ensure the safety of researchers and participants. Equipment was cleaned according to Center for Disease Control and Prevention (CDC) guidelines prior to and after each pre and post and intervention sessions pre and post-testing appointment times were staggered and only one participant was in the testing room at a time. All research staff and participants were required to do a temperature check and COVID screening questionnaire prior to each testing and intervention session. Hand sanitizer was used by the researcher and the participant before and after all sessions. Participants and the Pilates instructor wore masks throughout all sessions and mats were placed at a minimum of six feet apart to maintain social distancing. Increased verbal cues were used with minimal prolonged tactile feedback to ensure the safety of participants and researcher during intervention sessions. Due to this study being conducted during the COVID -19 pandemic, limited tactile feedback was provided.

### 5.2.4 Testing Procedures and Intervention

**Plank Test**

Once participants were screened for COVID symptoms, participants were asked to perform a static core assessment test, the plank (Strand, et al., 2014). Participants were asked to perform the test on their forearms and to maintain proper placement for as long as possible without a form break. The time, in seconds, was recorded when the participant broke form, stopped on their own or experienced pain. Participants were asked to stop the test if a form break was seen. Form breaks were assessed by a single qualified researcher and included:

1) adduction or elevation of the scapulae

2) deviation in pelvis alignment such as anterior tilt of the pelvis, pelvis elevated above or dropping below the height of the shoulder girdle,

3) dropping of the head, and/or

4) bending of the knees.

Scoring for the plank test is based on norms for the isometric muscle endurance test (Strand, et al., 2014). See table 5.0 for the plank rating/score chart.

**Table 5.0**
**Rating/Scoring for Plank Test**

| | |
|---|---|
| Excellent | Greater than 6 minutes |
| Very Good | 4-6 minutes |
| Above Average/Good | 2-4 minutes |
| Average | 1-2 minutes |
| Below Average | 30-60 seconds |
| Poor | 15-30 seconds |
| Very Poor | Less than 15 seconds |

**Warm-up**

In order to prepare participants for the execution of the movement phrase, they were guided through a warm-up session by a qualified movement specialist (see Table 5.1).

After completing the warm-up, participants were video recorded performing a movement phrase.

**Table 5.1**
**Pre/Post Warm Up Exercises**

| Exercise | Reps |
|---|---|
| high knees | 20X |
| side lunge reach (alternating sides) | 10X |
| alternating plié prances in parallel | 20X |
| jumping jacks | 15X |
| walk out to plank | 5X |
| plié pulse 3X to relevé in $2^{nd}$ position | 8X |
| plank to side plank alternating sides | 4X |

**Movement Phrase**

After completing the warm-up in Table 5.1, participants were asked to perform a movement phrase set to a metronome with 35bpm (see Table 5.2). The movement phrase was designed to address varied performance levels among participants, executed on both the right sides to show any deficiency between sides, and incorporated movement that required core stability to maintain the position after or during movement. For example, the circle through second required maintenance of the pelvic alignment while the upper body was in motion, the tilt occurred immediately following a circling movement, and the handstand came after a roll on the floor, requiring the participant to change levels in space. These movements also follow definitions of proper alignment as described by Krasnow et al. (2001), Yu and Lee (2012), and Willson et al. (2005). Immediately following the warm-up, the movement phrase was video recorded and executed on the right and left sides. The movement phrase was repeated and recorded every two weeks to determine at what point Pilates training may impact a dancer's movements. Absolute values from a rubric based on a 3-point scale ranged from 0-2 with "0" meaning no core control, "1" meaning some core control but not consistent, and "2" meaning maximum core control throughout. Three dance teachers, who were not aware of the order of the movement videos and to each other's results, independently viewed the recorded performance by each dancer and assessed core stability during the movement phrase. They were asked to analyze specific movements within the phrase including 1) the circle to the tilt, 2) the tilt position, 3) the handstand (See Appendix 14.4). All three evaluators had earned an MFA (Master of Fine Arts) in dance with a focus on body sciences. Two evaluators were actively teaching modern dance to dance majors on a routine basis. The third evaluator had a background in modern dance but was not teaching modern dance regularly. Reviewers looked at five criteria to score each participant's performance. The criteria included: the appearance of muscular engagement in the abdominals, differences in bilateral side bend in the inversion, scapulae engagement in the circle through second and inversion, balance in the tilt, and correct torso placement in the tilt. Beyond a list of the criteria the reviewers were not provided with any additional instruction.

**Table 5.2: Movement Phrase for Video Analysis (performed right and left sides). Table description reflections combination on the right side.**

| Begin in a large 2nd position (hips externally rotated & abducted) | |
|---|---|
| Counts | Movement |
| 1-4 | Lateral curve left |
| 5-8 | Circle through the center in plié to tilt on the right leg (left leg in tilt) |
| 1-4 | Pique to left leg (right leg in passé) |
| 5-8 | Step out right to side lunge |
| 1-4 | Tuck and roll to the floor |
| 5-8 | Roll to stand and step to second to repeat to the other side |

## Questionnaires

Participants were asked to complete a questionnaire during the pre and post-test protocol, found in Appendix 13 (13.1 and 13.2). The questionnaire consisted of 3 (post-test) to 5 (pre-test) interval scale questions and open-ended questions to collect anecdotal information. Additional open-ended questions were added to the post questionnaire to capture the perceived impact of the Pilates mat program on their dance training and performance. Participants were asked to rate their current core strength and stability. The interval scale ranged from 1–5-point with: 1) poor, 2) below average, 3) average, 4) good, 5) excellent. During the pre-test questionnaire, participants were asked the open-ended question, “What do you perceive will happen in the next 8 weeks?” In the post-test questionnaire, participants were asked the same Likert scale questions and additional open-ended question, “Do you have any comments you would like to share about the improvements or lack of improvements you have made with this training method?" Participants were also asked if they felt there was a connection between core strength and how well they perform in a dance class. They were also asked to report their current training schedule including the number of dance classes and rehearsals weekly.

**Intervention Protocol**

After initial evaluation, the eight-week, progressive Pilates mat intervention began using a yoga mat and medium resistance TheraBand. During intervention sessions, a detailed breakdown of the exercises was provided, including a physical demonstration, along with corrective cues for performing the exercises in the appropriate Pilates alignment. Sessions were no larger than two participants at a time to ensure the instructor was able to provide each participant with precise and well-timed individual cueing and feedback as they performed the exercises. Every two weeks the Pilates program progressed to include new and/or more complex exercises to keep up with the increased strength and flexibility of the participants. The Pilates mat program was divided into a warm-up (5-10 min.), conditioning exercises (30-35 min.), and a cool-down (5 min.). The warm-up and cool-down aspect of the program did not change throughout the study and included a total of six exercises. Exercises were the same for each participant to ensure the quality of the research methods, but the participants enrolled in the study were similar in dance ability therefore could all perform the exercises without any increasing injury risk. However, one modification was given for participant two. During the cool-down sequences, participant two had tight hip muscles which required placing a small pad under the hip for support during pigeon pose. There were no other modifications throughout the training period.

**Table 5.3**
**Warm-up Exercises**

| Exercise | Reps |
|---|---|
| Pelvic Mobility and Stability - Pelvic Clock | 5X |
| Scapulae Engagement - Angel Arms | 5X |
| Articulation Bridging | 4X |
| Pelvic Stability - Marching II (right/left) (knee floats) | 4X |
| Pelvic Stability – Leg Slides | 4X |
| Curl Preps with legs bent in chair position w/Theraband placed across shins | 10X |

In the first two weeks of the study participants learned the Pilates warm-up (Table 5.3), the initial conditioning exercises (Table 5.4) and the cool-down program (Table 5.5). Neither the warm-up nor cool-down exercises changed throughout the study. The warm-up group included six exercises that was designed to increase pelvic stability and scapulae engagement. The cool-down program included eight exercises and included more static stretches to decrease muscle soreness. Every two weeks, as participants become more familiar with the exercises, variations to exercises were added for all participants to increase the level of difficulty. Additional exercises were also added as participants became more comfortable with the sequence to continue to challenge their strength throughout the length of the study. Additional adjustments included exercises with increasingly complex positions, additional repetitions, additional use of a TheraBand, and/or new exercises. The first change to the program came during weeks three and four, with straight legs added to the 100s, additional reps in single leg stretch, coordination, and swan, and the addition of new exercises including small circles in the side lying leg work, roll down oblique, and twist II (see Table 5.6).

Additional changes/additions were made during weeks five and six (see Table 5.7) including lower legs during the 100, changing the leg sequence in coordination, adding reps in the side lying leg work, and adding exercises such as grand rond de jambe in the side lying leg work, swimming, and full twist (twist III). In weeks seven and eight, more changes were made to continuing challenging the participants during training sessions (see Table 5.8). These changes included adding leg variation during the 100, increased the reps for the side lying leg series, increased difficulty in the opposite arm/leg reach, and the addition of leg pull back.

**Table 5.4**
**Exercises performed in weeks 1-2 of intervention**

| Exercise | Repetitions | Page Numbers |
|---|---|---|
| Hundred with knees flexed to 90 degrees w/Theraband across shins | 10X | *Isacowitz,* pg. 56 |
| Single Leg Stretch | 8X | *Page, pg 71* |
| Coordination, legs open and close three times | 8X | Not found in text |
| Double Leg Stretch | 8X | Page, pg 70 |
| Single Straight Leg Stretch/Hamstring Pull | 8X | *Isacowitz,* pg 66 |
| Side Lying (right and left side) w/Theraband<br>▪ Ab/adduction<br>▪ Flexion and Extension<br>▪ Side Kick | 8X each | *Page, pgs 36-45* |
| Prone Heel Beats between right and left side lying work | 10X | Not found in text |
| Swan w/Theraband | 5X | Page, pg 54 |
| Spine Twist (right/left) | 5X | *Isacowitz,* pg 101 |
| Saw (right/left) | 5X | *Isacowitz,* pg 102 |
| Roll down with three biceps curl w/Theraband | 5X | Not found in test |
| Scapulae Support (Sternum drop) w/Theraband | 5X | Page, pg 32 |
| Opposite Arm/Leg Reach (right/left) | 5X | Not found in text |
| Twist I (right/left) | 4X | *Isacowitz,* pg 109 |
| Leg Pull Front (right/left) | 3X | Not found in text |

**Exercises can be found in text by Isacowitz, 2014 and Page, 2011*

**Table 5.5**
**Cool Down Exercises**

| Exercises | Repetitions |
|---|---|

| | |
|---|---|
| Child’s pose | 20 sec. |
| Child’s Pose inner thigh stretch (right/left) | 30 sec. each side |
| Downward Dog | 30 sec. |
| Cobra | 30 sec. |
| Lunge (right/left) | 30 sec. each side |
| Lunge with chest expansion (right/left) | 30 sec. each side |
| Pigeon Pose (right/left) | 30 sec. each side |
| Standing hamstring stretch | 30 sec. |

**Table 5.6**
**Intervention exercises changes/additions, weeks 3 and 4**

| Exercises | Repetitions | Page Number |
|---|---|---|

| | | |
|---|---|---|
| Hundred– straight legs held at 90 degrees with Theraband placed on balls of the feet | 10X | Isacowitz, pg 56 |
| Increased Single Leg Stretch reps | 10X | Page, pg 71 |
| Increased Coordination reps | 10X | Not found in text |
| New Exercise: Side Lying Leg Work: Small Leg Circles (both directions) | 5X | Page, pgs 36-45 |
| Increased Swan reps | 8X | Page, pg 54 |
| New Exercise: Roll down oblique w/Theraband right and left sides | 5X | Not found in text |
| New Exercise: Twist II (right/left) | 4X | Isacowitz, pg 109 |

**Exercises can be found in text by Isacowitz, 2014 and Page, 2011*

**Table 5.7**
**Intervention exercise changes/additions, week 5 and 6**

| Exercises | Repetitions | Page Number |
|---|---|---|
| Hundred on diagonal while maintaining neutral pelvic alignment with Theraband placed on balls of the feet | 10X | *Page, pg 65* |
| Coordination legs change to one open/close, and 2 single leg lowers | 10X | Not found in text |

| | | |
|---|---|---|
| Increase side lying reps (ab/adduction, flexion/extension and side kick) | 10X | *Page, pgs 36-45* |
| New Exercise: Grand Rond de Jambe (en dehors/en dedans) | 3X each direction | *Isacowitz,* pg 96 |
| New Exercise: Swimming | 8X | Page, pg 54 |
| New Exercise: Twist III (right/left) | 4X | *Isacowitz,* pg 109 |

**Exercises can be found in text by Isacowitz, 2014 and Page, 2011*

**Table 5.8**
**Intervention exercise changes/additions, week 7 and 8**

| Exercise | Repetitions | Page Number |
|---|---|---|
| Hundred – legs on diagonal while maintaining neutral pelvis – single leg lowers | 10X | Page, pg 65 |
| Increase side lying: Small circles reps | 8X | Page, pg 36-45 |
| Opposite Arm/Leg Reach – Hover position - without Theraband | 5X | Not found in text |
| New Exercise: Leg Pull Back (right/left) | 3X | Not found in text |

**Exercises can be found in text by Isacowitz, 2014 and Page, 2011*

### 5.2.5 Data Analysis

To analyze the plank test, the duration recorded in seconds pre and post intervention for each dancer was used as well as the difference between these durations, followed by the percentage change and then applied to the plank rating scale as defined by Strand et al. (2014). Percentage difference was calculated using the following formula % = ((v2-v1)/v1 x 100). In this formula, v1 was the pre-test value and v2 was the post-test value. For the movement test, the results of the performance rubric were first calculated for each participant and then averaged among the 3 reviewers from pre to post-test. Closed-ended questions on the pre and post questionnaires were analyzed comparing values on the 1-5 Likert Scale. For open-ended questions, the qualitative thematic analysis by Braun and Clarke (2006) was applied and themes were developed based on the data found.

## 5.3 Results

### Plank Test

All three participants showed a significant difference from pre to post-test for the plank test (Figure 5.1). Participant 1 increased from 81 seconds to 104 seconds which is an increase of 25% from pre to post-test however still within the average range within the plank rating scale. Participant 2 increased from 53 to 124 which is an increase of 134% improving from below average to average on the rating scale. The final participant, dancer 3, increased from 28 seconds to 56 seconds which is an increase of 100% over the eight-week study. Dancer 3 started at a poor rating in pre-test and increased to below average and 4 seconds shy of an average rating. After eight weeks with working two times a week for 45 minutes, participants increased their overall strength during the plank test by an overall mean of 75%. The average increase across all three participants was 41 seconds with two of the participants increasing one level on the plank rating scale. These results suggest that Pilates mat work may be an effective training program for dancers to increasing core endurance which is connected to improving core stability (Singh, 2025).

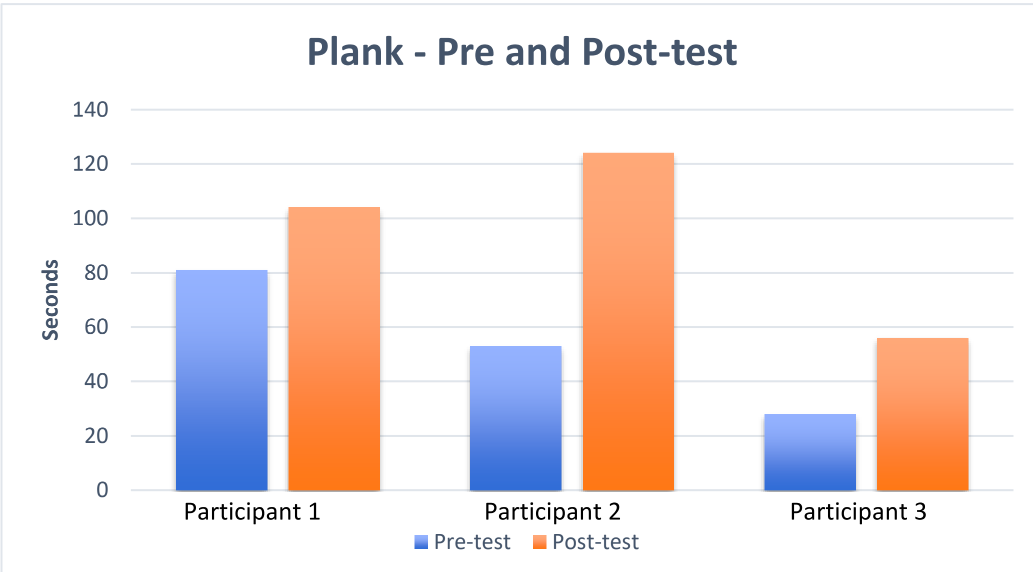



**Figure 5.1**
**Plank Test (Pre and Post Test)**

**Questionnaires**

A thematic analysis based on Braun and Clarke's (2006) qualitative analysis was conducted to examine dancers' perception of how Pilates, specifically matwork, may influence dance training and core control. Three main themes emerged from the data: (1) Core Strength and Control, (2) Body Awareness, (3) Support for Dance Practice. Each theme is presented below with participant quotes and its potential significance for conditioning dancers. (See Figure 5.2)

### Core Strength and Control

Participants consistently described improvements in their core strength and control following their engagement with the Pilates matwork. They highlighted impact on both functional movement and aesthetics, stating an increased ability to stabilize their core during dance movement phrases. Two quotes which directly highlight these ideas include: "*Core strength has improved, better awareness on how to control my core*" and "*improved in core strength and dance training.*"

These reflections show how Pilates support dancers in developing deeper muscular activation, especially in the core, contributing to more controlled movement in dance. Improved control in core engagement may also be associated with increased confidence in performing technically demanding choreography.

### Body Awareness

The second theme developed focused on the dancers' heightened awareness of body placement and alignment. Participants describe becoming more aware of their bodies, particularly engaging specific core muscles during movement. Participant quotes which reflect this idea includes: "*improved awareness of core and engagement*," and "*more engagement of the muscles in the back*." These comments reflect the mind-body connection reinforced by Pilates, enhancing the dancers' kinesthetic awareness.

**Support for Dance Practice**

The final theme expresses participants belief that Pilates, specifically matwork, functions as a tool to prepare them for dance training. It serves as a warm-up and a conditioning method enhancing readiness for dance. "Warm-up for my body; improvement" and "improved dance training" are quotes from questionnaires that support this theme.

This theme shows how dancers perceive Pilates as a complementary conditioning program for dancers, strengthening and mentally preparing them for class and rehearsals. The integration of Pilates into their training protocol may contribute to an overall sense of readiness for training.

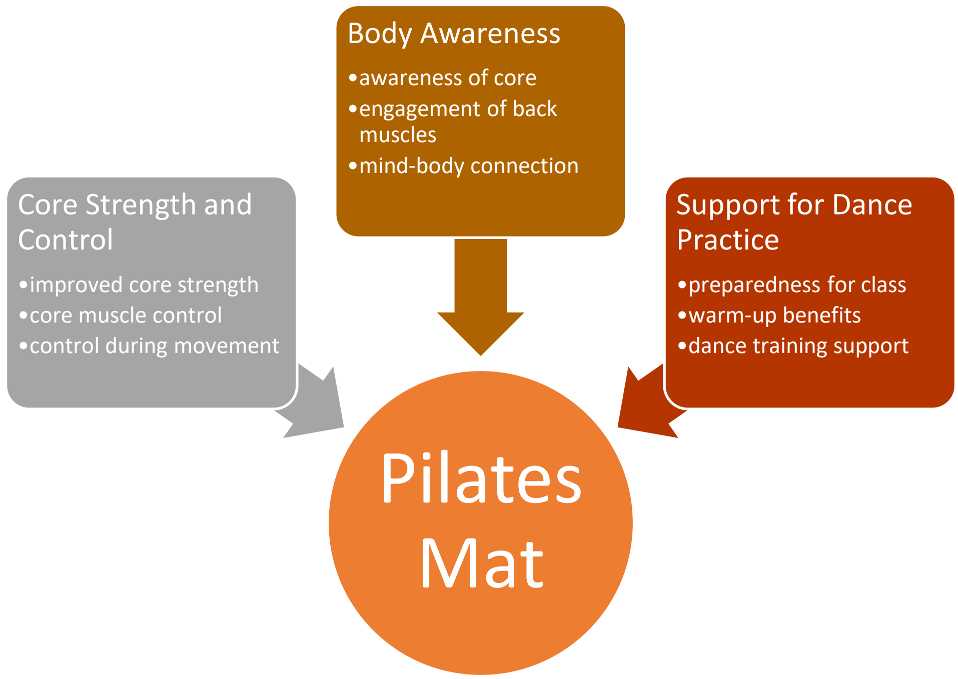



**Figure 5.2**
**Thematic Map**

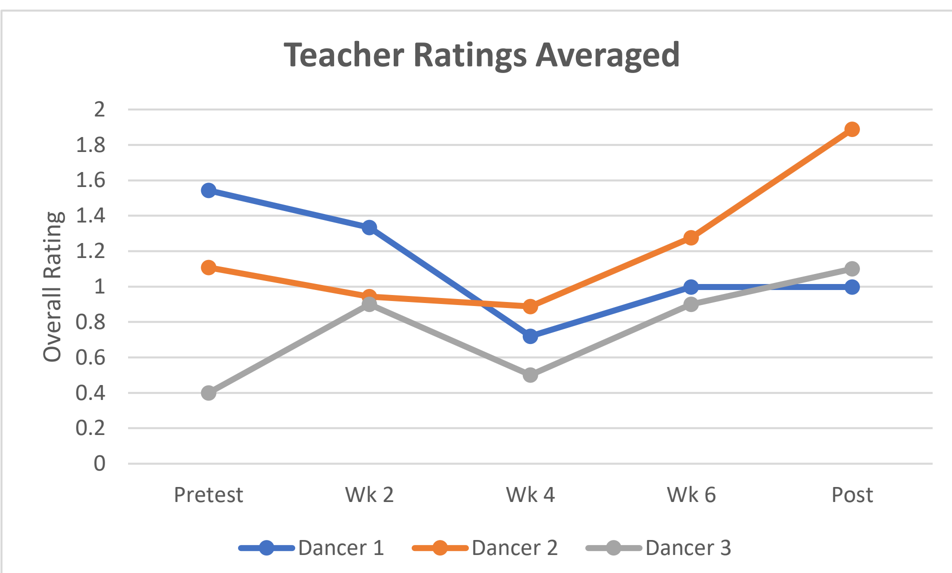
## Movement Phrase

There were 30 videos over the course of the study for the three participants resulting in 90 videos to be assessed by the reviewers. The videos for each of the three evaluators were viewed and scored independently. The scores were combined, and an average was taken among all three reviewers.

Reviewers agreed there was improvement seen in participants two and three throughout the study. Participant two showed the most improvement among all three participants. All three dancers showed a decline during week four in all movements (See Figure 5.3).

Overall participants showed improvement throughout the study regardless of which side the movement was performed on. The circle through à la seconde was seen with a decline of 50% in Participant 1 with an increase in participants two and three with increases ranging from 25% to 67%, respectively. The greatest improvement was seen in the handstand for participant two with a 100% increase in improvement on the right side and a 333% improvement on the left side. Out of the three participants, participant 3 improved the most during the tilt with a 100% increase on both the right and left sides. Participant 3 declined in all three areas, but reviewers began to see improvement by the end of the eighth week.

**Figure 5.3**
**Overall Teaching Ratings Averaged**



Of the 90 recorded performances, all three reviewer ratings agreed on 58 (64%) of the assessments, two of the three reviewer ratings agreed on 77 (86%) of the performances. There were no instances where all three evaluators disagreed with one another. Additionally, there were no differences found between the right and left sides in regard to reviewer discrepancy. The greatest variations were seen on the amount of improvement in a participant, such as a 0 to 1 or 1 to 2 rating.

## 5.4 Discussion

This study used a Pre/Post Case Series Intervention Design to evaluate the effects of a Pilates mat program on core stability in three university dance science majors. The results indicated that all three participants, who experienced the eight-week Pilates mat program outside of regular technique classes, increased core strength by a mean of 75% as measured with the plank test with two of the participants meeting a minimum of average on the plank scale and one seconds shy. The questionnaire shows that dancers perceive Pilates to have an impact on their core stability and control in their dance classes. Additionally, dancers stated that a Pilates regime made them feel more prepared and more aware of alignment in class. This may indicate that there may be additional benefits beyond improving core stability. Further research should evaluate the perceived improvement by dancers and how this impacts their training.

Teacher observations indicated some improvement throughout the study on core stability during the execution of a dance movement phrase. However, the amount of improvement varied in different movements and was only seen in two of the three participants. A decrease in results was seen in week four of the study for all the participants with no singular cause being determined. However, one potential factor could have been fatigue due to the timing of multiple performances and the testing for this study; two of the three participants were dancing in multiple performances in the previous 10 days leading up to the video recording at the end of week four. The third participant was not dancing but was experiencing late hours as they were working crew for a dance concert. According to Fullagar, et al. (2015), sleep is crucial to human physiological and cognitive function. When an athlete experiences sleep disruption, their performance can be impacted. (Hanton, et al., 2005; Lastella, et al., 2014).

Additional research methodologies need to be explored to improve the analysis on how training programs affect dance performance. Current mechanisms to evaluate how exercise impacts dance performance may be flawed making it difficult to analyze how this impacts the dancer in studio practice.  Dance instructors come from different backgrounds with varied training and their own aesthetic biases. This may result in variations (or variability) that makes it difficult to connect scientifically how conditioning impacts the aesthetics and performance of dancers. More investigation into what dancer teachers find important to specific movements, alignments versus aesthetics in order to develop an assessment tool that is meaningful to dancers as well as being scientifically sound.

In order to maintain scientific integrity, a group exercise program was design for this study with little to no variances for individual needs. However, Pilates understood that each person has anatomical and muscular differences resulting in variances in abilities which can be seen in the type of equipment he created. Variances in improvement in the plank test and teacher observations may indicate a group Pilates mat regimen may not necessarily be appropriate and perhaps individual programs based on the needs of the dancer should be recommended. One must also question if Pilates original intent was to design fitness program based on individual needs rather than satisfying economic benefits of group exercise perhaps research methodologies should be explored in order to truly assess the impact of Pilates methods.

### 5.4.1 Limitations

There were some inconsistencies within the results of the reviewers' evaluation of the participants. Body markers and alternative video angles may have decreased this inconsistency. Although the reviewers had no contact with the participants during the study, two of the reviewers had taught the participants in dance movement and lecture courses outside of the study. That experience may have influenced the reviewers' ratings in an indeterminant manner.

Two study methodologies might have limited the potential to detect improvements in performance of the movement phrases: (1) the small range on the Likert rating scale, and (2) the simplicity of the movement phrase for some dancers. A scale with a range (e.g., 0-5), might have allowed the reviewers to make a finer assessment of each dancer's performance. In addition, using a more complex movement pattern may have provided more opportunity to observe improvements in core stability, particularly for the more skillful dancers participating in the study.

While findings from this study suggest that a Pilates mat program may be beneficial to increase core stability through improving core endurance as seen in the plank test, the small sample size presents limitations in terms of generalizability. With the limited number of participants, it is difficult to extend these results to the broader dance population, especially outside of modern dance. These small participant numbers may be suspectable to individual variability and may not represent the diversity within dance including variances in training backgrounds, body types, and overall movement patterns in dancers. Despite these limitations, the study offers insight into the potential benefits of Pilates core stability, core engagement, and postural alignment and is aligned with existing literature that supports Pilates as a conditioning method for dancers. Future research should include larger sample sizes with more diverse participants to validate these findings and explore how Pilates can be applied into dance training.

## 5.5 Conclusion

The purpose of this study was to assess the impact of a Pilates Mat program on core stability during a modern dance movement phrase and participants perception of Pilates and its impact on dance training and performance. The study's null hypothesis states no significant difference would be seen on core strength or dance training with the implementation of a Pilates Mat regimen. Additionally, the hypothesis states that participants would not perceive Pilates to positively impacts their dance training and performance. Seen by the increased strength and core stability during the standardized plank test the null hypothesis is rejected. Even though scores varied among the three reviewers, results indicated overall improvement in the dance movement phrase for two of the three participants rejecting the null hypothesis that there would be no difference seen pre and post-test. Questionnaires filled out by participants indicated a perceived increase in strength and awareness in core stability therefore rejecting the null hypothesis.

More investigation is needed to determine the relationship between the dancer's individual awareness of core stability and the dance teacher's observation of the effectiveness of Pilates training on the dancer's alignment. In order to evaluate Pilates impact on dance performance, more investigation is needed to develop a more validated dance assessment tool, which should address variances in genres. As stated earlier, a larger sample size is essential for future researchers to validate the effectiveness of Pilates as a conditioning program for dancers.

# 6 Pre-Experimental Analysis of the Pilates Wall Unit on Core Stability in Collegiate Dancers and Perceived Impact on Dance Performance

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## 6.1 Introduction

Two main characteristics of the Pilates method is the focus on body awareness (Latey, 2001) and maintaining the stability of the pelvis while performing exercises (Muscolino & Cipriani, 2004; Barbosa, et. al, 2018). The consensus among educators is that Pilates is promoted to heal injuries, prevent injury, and improve body posture (Long et al., 2021; Isacowitz, 2022). Dancers have generally accepted Pilates as a conditioning program due to enhanced balance, improved strength, muscular endurance, and spinal stability. The historical connection between dance and Pilates can be seen as far back as when Pilates moved to New York in 1926. According to Korobka (2024) choreographers and modern dance pioneers used Pilates in various ways including:

- Martha Graham incorporated Pilates into her warm-up,
- Doris Humphrey, Alvin Ailey and Merce Cunningham used Pilates to improve dancers' strength, flexibility, and control,
- Charles Weidman incorporated Pilates exercises into his teaching and choreography
- Trisha Brown incorporated Pilates into her choreographic process and dance training

This historical connection and dancers willing to adopt Pilates as a conditioning program is key to its use for training possibilities within the dancer population. In physical therapy, Pilates has been used to restore joint function, to improve lumbo-pelvic stability, and to treat low back injuries (Phrompaet, et al.2011). Therapists use specialized Pilates equipment such as the reformer, the barrel, and the cadillac to address these issues. The cadillac, first known as the table, was a raised mat with attached springs and resistance from the overhead structure. The elevated mat accommodated clients with limited mobility such as older or injured clients. The springs can be adjusted to either assist or resist movement, depending on the intention and focus of the exercise (Shedden & Kravitz, 2006). A similar, more economical and space-efficient version of the cadillac is the wall unit. Comparable to the cadillac, the wall unit uses adjustable resistance and assistance from the springs to achieve the purpose of each exercise. Providing more versatility, the wall unit can be used with a mat or be connected to the end of a Pilates reformer. Research in Pilates is found more commonly on the mat and reformer with limited research on other apparatus including the cadillac or wall unit.

This purpose of this study was to add to the limited research on the use of the wall unit in research studies and to validate its use in conditioning programs for dancers. The null hypothesis states that there will no significant difference in core strength between the control and interventions groups. Additionally, there will be no perceived difference on the impact of Pilates in regards to dance training.

## 6.2 Methods

### 6.2.1 Participants

Using a pre-experimental design (static group comparison), improvement in overall core stability and core engagement after intervention on a Pilates wall-unit was examined. Prior to pre-testing all participants signed an approved IRB (IRB2021-1039D) consent form and filled out an injury questionnaire. Eleven university dancers (age = 18 $\pm$ 7, height = 163cm $\pm$ 8, mass = 68kg $\pm$ 12) completed the seven-week study. Sixteen participants signed up for the study however five were withdrawn from the study due to missed intervention or post-testing sessions.

Inclusion criteria for the study included: proficient in the English language (in order to fill out questionnaires and receive verbal instruction during intervention), be between the ages of 18-25, be free from injury in the six months prior to the study, not currently enrolled in Pilates or another conditioning program, and be training in a ballet or modern class at least 3 times a week. An injury was defined as loss of time from dance activities. Exclusion criteria included was any conditions that did not meet the inclusion requirements.

All participants in the study had some Pilates mat training prior to the study due to their course requirements. After signing the consent form, participants were randomly divided into two groups: a control group and an intervention group. Participants in the intervention group (n=5), attended two 45-minute sessions a week for five weeks. They were led by a certified Pilates Mat instructor through a warm-up based on the Ron Fletcher standing towel work (Fletcher Pilates, 2009; Fletcher, 2024), a series of Pilates exercises on the wall-unit apparatus and, a five-minute cool-down. Participants in the control group (n=6) continued with their normal dance training schedule.

### 6.2.2 COVID Protocol

This study was conducted during the COVID-19 pandemic which required some additional protocols to be followed. The following protocols were adapted throughout the study in accordance with CDC evolving guidelines and to ensure the safety of the researchers and participants.

1) Equipment was cleaned according to CDC guidelines prior to and after each pre/post and intervention sessions.

2) Pre and post testing appointment times were staggered so only one participant was being tested at a time.

3) All research staff and participants completed a COVID screening questionnaire prior to each testing and intervention session.

4) Hand sanitizer was used by the researcher and the participant before and after all sessions.

5) Masks were not required by the state, but the participants and the Pilates instructor were encouraged to wear one.

6) No more than 3 participants were schedule at an intervention session.

7) Wall units were placed at a minimum of 6ft apart to maintain social distancing.

8) Verbal cues were amplified and tactile cues were minimized to ensure the safety of participants and researcher during intervention sessions.

### 6.2.3 Pre and Post-testing Protocol

During pre and post testing, participants filled out a questionnaire, were assessed for their knowledge of neutral pelvic alignment in two positions, and performed a Pilates-based curl test, participated in a lower abdominal test, and executed a plank test in pre and post-testing sessions. All tests were monitored closely by the same investigator to ensure consistency and proper alignment and exercise mechanics.

**Questionnaire**

As found in appendix 13 (13.3 and 13.4), dancers completed a 4-10 item questionnaire (control and experimental groups respectively) as the first step in the pre and post-testing sessions. The questionnaire consisted of Likert scale ratings as well a open-ended questions which collected anecdotal information. Participants were asked to rate their current pelvic placement, and core strength and core stability. The rating scale ranged from 1–5-points: 1) poor, 2) below average, 3) average, 4) good, 5) excellent. The pre-test open-ended question included: "What do you perceive will happen in the next five weeks?" Post-test question included: "Do you have any comments you would like to share about your participation in this research study or the impact this training had on you." Participants were also asked about their perceptions of the correlation between their performance in dance and their pelvic placement, core stability, and abdominal strength. Participants also recorded their current dance activities and their fitness plan prior to the study to improve core stability, pelvic placement, and abdominal strength.

**Neutral Pelvic Alignment Tests**

During pre and post-testing participants were asked to perform two tasks with the sole purpose of maintaining neutral pelvic alignment. The Pilates definition of neutral pelvis was used in the study which uses the origination of the anterior superior iliac spine (ASIS) and the pubis in relationship to the coronal plane (Isacowitz, 2014). In the first task, inactive neutral pelvis test, participants were asked to lie supine on a mat with their arms by their sides, feet on the floor, and their knees flexed in the hook lying position. Once in the position, they were asked to bring their pelvis into a neutral alignment. The participants were not instructed on how to achieve the neutral position but were instead allowed to do any preparation they needed to align their pelvis in neutral such as: placing their hands on the ASIS and symphysis, rocking their pelvis from anterior to posterior tilt and settle it into neutral, and checking the space between their lumbar spine and the mat. No instruction or explanation was given by the examiner. Once the participant felt they were in neutral they informed the examiner. The examiner, a dance and certified

Pilates instructor with knowledge in the body sciences, analyzed their pelvic alignment to determine if they were or were not in neutral. For a positive score in the supine position, the examiner determined if the ASIS and the pubis had to be in the same coronal plane.

Participants were then asked to perform the active neutral pelvic alignment test. The participant stood at the ballet barre with their left hand on the barre and their legs in ballet first position. They were then asked to solely focus on a neutral pelvic alignment while executing cambré back with the arm in 5$^{th}$ en haut. Once the dancer was in full extension, the same examiner recorded whether the ASIS and pubic symphysis were in the same coronal plane.

**Pilates-based Curl Test (BIOLD)**

After completing the neutral pelvis tasks, participants were asked to perform a Pilates-based curl test (BIOLD), from Study 1 of this thesis. Participants were supine with a sphygmomanometer (Stabilizer ©, a device used to assist in neutral pelvis training) positioned under the lumbar spine. Participants were instructed to flex at the hips and place their legs straight in the air at a 90-degree angle with the head on the mat and the hands by their sides. While maintaining a neutral pelvis participants were asked to lower their legs to a diagonal. If pelvis could not be maintained, the legs were stopped and positioned on a diagonal while in correct neutral pelvic placement. As indicated in the manual for the sphygmomanometer (a device used to assist in neutral pelvis training), the biofeedback device was then inflated to 40mmHg while participants maintained a neutral pelvis. This position was checked by the examiner and corrections on pelvic placement were given if necessary. Using a frequency of 35bpm and keeping the hands on the mat, participants were asked to curl up until they reach just past the tip of the shoulder blades.  Maintaining their leg position, participants curled up while maintain a neutral pelvis while in the curl position. Then participants returned to supine on the mat maintaining the diagonal in their legs and returning the head to the mat. The number of repetitions completed without a form break were recorded by the examiner. Form breaks during this test included:

1) Pressure on the sphygmomanometer (dropping below 30 or rising above 50mmHg)
2) Head not returning to mat between repetitions
3) Not maintaining legs on the diagonal
4) Not maintaining neutral pelvis in the transverse plane
5) In ability to continue with correct form due to fatigue as determined by the participant

**Lower Abdominal Strength Test**

Following the Pilates-based curl test (BIOLD), participants completed a lower abdominal strength test using a sphygmomanometer set at 100mmHg (Galbraith, 2014) and an enlarged protractor. Participants were instructed to lie supine on a mat with the sphygmomanometer placed under the lumbar spine and their hip joint in line with the 90-degree mark on the protractor. They started with the arms by their sides, the head on the mat and their legs straight in the air at 90-degrees. Once the sphygmomanometer was set at 100mmHg, participants lowered their legs towards the ground while maintaining a neutral pelvis. If participants dropped the sphygmomanometer measurement below 80mmHg or increased it above 120mmHg, the participants were instructed to stop the test and the angle of the legs as seen on the protractor was recorded. The angle of the legs was measured by where the center of the femur aligned with the marks on the protractor. This test was repeated three times, and the third trial was used in data analysis. The examiner also noted whether the units on the sphygmomanometer dropped below 80mmHg (indicating anterior tilt) or rose above 120mmHg (indicating posterior tilt). To allow participants to get used to the sphygmomanometer, three attempts were performed, and the 3rd attempt was recorded.

**Plank Test**

Participants were asked to perform a plank test on their forearms and to maintain proper placement of the pelvis, shoulders, and head for as long as possible without a form break. The total time was recorded, in seconds, for the length the time the dancer held a plank with no form breaks. Participants were also stopped if they ended the test due to fatigue or experienced pain during the test. Form breaks included:

1) adduction or elevation of the scapulae (noted when the scapulae visually elevated)
2) deviation in pelvis alignment such as, pelvic anterior/posterior, pelvis elevated above or dropping below the height of the shoulder girdle, pelvic rotation (any deviation from horizontal alignment between the ASIS and the pubis)
3) dropping of the head (noted when the head visually dropped out from its starting point)
4) bending of the knees (noted as soon as the knees visually softened and began to bend)

Scoring for the plank test is based on norms for the isometric muscle endurance test (Strand, et al., 2014). See table 6.0 for the plank rating/score chart.

**Table 6.0**
**Rating/Scoring for Plank Test**

| | |
|---|---|
| Excellent | Greater than 6 minutes |
| Very Good | 4-6 minutes |
| Above Average/Good | 2-4 minutes |
| Average | 1-2 minutes |
| Below Average | 30-60 seconds |
| Poor | 15-30 seconds |
| Very Poor | Less than 15 seconds |

### Pilates Wall Unit Intervention Program

After pre-testing, participants in the intervention group began their 5 weeks of training on the Pilates wall-unit. All intervention sessions were conducted in a university dance program Pilates studio. The participants were led through each session by the same certified Physical Mind Pilates instructor. During intervention sessions, a detailed breakdown of the exercises was provided to the participants along with corrective cues to perform exercises with proper form. Sessions were no larger than three participants at a time to ensure the quality of each session and to follow COVID protocol. Every two weeks the Pilates program progressed to include new and/or more complex Pilates exercises. The program included a warm-up, conditioning exercises, and a cool-down. The warm-up did not change throughout the study and included 6 exercises based on the Ron Fletcher standing towel work using a medium weight resistance band (see Table 6.1). The warm-up portion of the program lasted 5-10 minutes.

**Table 6.1**
**Warm-Up Done Standing**

| Exercises | Repetitions |
|---|---|
| Ribcage arms with scapulae isolation | 5X |
| Spinal rotation with arms at shoulder level, alternating right and left sides | 5X |
| Lateral Side Bend, alternating right and left sides | 5X |
| Spinal circle contract through $2^{nd}$ position, alternating right and left sides | 3X |
| Walk out to plank | 3X |

**Exercises can be found in text by Isacowitz, 2014*

After warm-up, participants moved to the wall unit and completed the conditioning program. After the initial two sessions, where more instruction on the mechanics was needed, this portion of the program lasted about 30-35 minutes. The initial exercises for the first two weeks of intervention can be found in Table 6.2. To progress the workout throughout the study, new exercises were added, and more complex movements were included in weeks three and four (see Table 6.3) and progressed again in week five (see Table 6.4). To comply with the requirement of the research design, these additions were not individualized (as is common in Pilates training); they were standardized for all participants. Spring loads were not altered throughout the study and were set the same for all participants. Spring loads for each exercise are notated in Tables 6.2 - 6.4.

**Table 6.2**
**Exercises: Intervention Weeks 1 and 2**

| Exercise | Repetitions | Spring Load | Page Number |
|---|---|---|---|
| Upper arms with articulation bridge | 4X | Long yellow | Isacowitz, pg 233 |
| Supine Arms – Ab/adduction | 4X | Long yellow | Isacowitz, pg 254-255 (adjusted to prone) |
| Supine Arms – Triceps press | 4X | Long yellow | Isacowitz, pg 254-255 (adjusted to prone) |
| Supine Arms – Triceps press in external rotation | 4X | Long yellow | Isacowitz, pg 254-255 (adjusted to prone) |
| Abdominal Curl Prep (legs in hook lying) | 6X | Long yellow | Isacowitz, pg 232 |
| Hundred | 10X | Long yellow | Page, pg 57 |
| Coordination with ab/adduction 3X | 8X | Long yellow | Not in text |
| Feet in Straps: Double leg lowers | 4X | Long purple | Isacowitz, pg 239 |
| Feet in Straps: Diamond leg lowers | 5X | Long purple | Isacowitz pg 238 |
| Feet in Straps: Frog | 4X | Long purple | Isacowitz, pg 238 |
| Side Lying: Parallel hip flexion and extension | 6X | Long purple | Page, 86-87 |
| Side Lying: Parallel ab/adduction | 6X | Long purple | Page, pg 86-87 |
| Side Lying: Side kick | 6X | Long purple | Page, pg 48 |
| Roll Down (with wooden bar) | 4X | Long yellow | Isacowitz, pg 234-236 |
| Roll Down: biceps curl (with wooden bar) | 3X | Long yellow | Isacowitz, pg 234-236 |
| Roll Down: triceps press (with wooden bar) | 3X | Long yellow | Isacowitz, pg 234-236 |
| Chest Expansion | 3X | Short yellow | Isacowitz, pg 250 |
| Teaser Prep (push through bar) (one with legs down, one with one leg up – each side) | 2X | Short yellow | Isacowitz, pg 237 |
| Swan shoulder mobilization (push through bar) | 4X | Short yellow | Isacowitz, pg 261-263 |

| | | | |
|---|---|---|---|
| Swan pull elbows back (push through bar) | 4X | Short yellow | Isacowitz, pg 261-263 |
| Swan – Prone I and II (push through bar) | 5X | Short yellow | Isacowitz, pg 261-263 |

**Exercises can be found in text by Isacowitz, 2014*

**Table 6.3**
**Exercises: Intervention Weeks 3 and 4: Additions and Variations (Isacowitz, 2014)**

| Exercise | Repetitions | Spring Load | Page Number |
|---|---|---|---|
| Upper Arms with arm pumps 3X and articulation bridge | 4X | Short yellow | Isacowitz, pg 233 |
| Hundred with legs at a diagonal | 10X | Long yellow | Page, pg 57 |
| Coordination with ab/adduction 1X; leg lower R/L | 8X | Long yellow | Not in text |
| Prone Arm: ab/adduction | 5X | Long yellow | Isacowitz, pg 254-255 (adjusted to prone) |
| Prone Arm: circles | 5X | Long yellow | Isacowitz, pg 254-255 (adjusted to prone) |
| Thigh Stretch | 4X | Long yellow | Isacowitz, pg 248 |
| Teaser with both legs up | 3X | Short yellow | Isacowitz, pg 237 |

**Exercises can be found in text by Isacowitz, 2014*

**Table 6.4**
**Exercises: Intervention Week 5: Additions and Variations (Isacowitz, 2014)**

| Exercise | Repetitions | Spring Load | Page Number |
|---|---|---|---|
| Hundred with single leg lower | 10X | Long yellow | Page, pg 57 |

| | | | |
|---|---|---|---|
| Feet in Straps: Frog extended | 4X | Long purple | Isacowitz, pg 238 |
| Cat (with push through bar) | 3X | Short blue | Isacowitz, pg 248 |
| Teaser with leg ab/adduction 3X | 3X | Short yellow | Isacowitz, pg 237 |

**Exercises can be found in text by Isacowitz, 2014*

**Cool-down**

After completing of the exercises, participants were completed a five-minute cool-down (see Table 6.5). This cool-down series remained the same throughout the study.

**Table 6.5**
**Cool-down Series**

| Exercises | Time held |
|---|---|
| Child's pose | 20 sec. |
| Hip flexor stretch, right and left sides | 20 sec. each side |
| Standing Piriformis stretch (figure 4), right and left sides | 20 sec. each side |
| Standing hamstring stretch | 20 sec. |

**Exercises can be found in text by Isacowitz, 2014*

### 6.2.4 Data Analysis

To analyze the tests in this study including static and dynamic neutral pelvis, upper and lower abdominal strength, upper abdominal strength, and core endurance through the plank test, the difference between pre and post-test was calculated, followed by the percentage change. Percentage change was calculated using the formula % = ((v2-v1)/v1 x 100). In this formula, v1 was the pre-test and v2 was the post-test value. Leg angle during the low abdominal test and pelvic placement in the upper and lower abdominal test was also assessed as it may be an indicator of improved core strength and core stability. Due to low participant numbers, statistical data and a p value could not be found. Qualitative data was assessed using Braun and Clarke's (2006) Thematic Analysis Framework.

## 6.3 Results

### Neutral Pelvis

Both active and inactive neutral pelvis tests demonstrated improvement across the intervention and control groups. The most notable gains were observed in the inactive neutral pelvis test within the intervention group (see Tables 6.6 and 6.7).

#### Inactive Neutral Pelvis Test

In the inactive neutral pelvis test, the intervention group improved from 60% of participants achieving neutral pelvis in the pre-test to 100% in the post-test. The control group also showed improvement, rising from 16.7% in the pre-test to 66.7% in the post-test. Among participants who did not achieve neutral pelvis in the pre-test, 85.7% exhibited a posterior pelvic tilt, while 14.3% demonstrated an anterior pelvic tilt. In the post-test, the 20% of participants who failed to achieve neutral pelvis were all noted to have posterior pelvic tilt.

#### Active Neutral Pelvis Test

In the active neutral pelvis test, the intervention group improved from 40% achieving neutral pelvis in the pre-test to 80% in the post-test. The control group showed a smaller margin of improvement, increasing from 83.3% to 100%. Among pre-test failures in the active test, 50% of participants exhibited anterior pelvic tilt, and 50% showed posterior pelvic tilt. In the post-test, only one participant failed to achieve neutral pelvis, with posterior tilt noted by the examiner. These findings suggest that the Pilates-based intervention may have contributed to improved pelvic alignment, particularly in inactive conditions, and helped reduce variability in pelvic tilt patterns among dancers.

## Abdominal Tests

### BIOLD Curl Test

The impact of a Pilates-based core stability intervention was also assessed using the BIOLD curl test noting leg angle measurements during the test. In the intervention group, 60% of participants improved from pre to post-test, while one participant showed a decline in performance. On average, the intervention group demonstrated a 26.34% improvement, whereas the control group showed a slightly higher average improvement of 35.2% (see Table 6.8). Observations of the leg angle was used as a proxy for core strength, with lower angles indicating stronger core engagement. In the intervention group, the mean leg angle decreased from 72.5° (SD = 15.0) in the pre-test to 70.0° (SD = 0.0) in the post-test. This reduction was accompanied by a complete elimination of variability, suggesting uniform improvement across participants. In the control group, the mean leg angle decreased from 77.1° (SD = 7.6) to 70.7° (SD = 11.0). These results suggest that while both groups showed improvements in leg angle performance, the intervention group demonstrated more consistent gains, potentially attributable to the structured Pilates-based core training.

**Lower Abdominal Test**

The lower abdominal test was administered three times per participant, with the mean score used for analysis. In this test, lower leg angle values indicate stronger core engagement, as participants are able to maintain their legs closer to the floor.

Participants in the intervention group demonstrated a decrease in average leg angle from 37.08° in the pre-test to 32.92° in the post-test, reflecting an 11.24% improvement in core strength. This reduction suggests enhanced lower abdominal control and stability following the Pilates-based intervention. The control group also showed a decrease in average leg angle, from 38.24° in the pre-test to 36.43° in the post-test, representing a 4.73% improvement. See Figure 6.1 for individual participant data in regard to leg angle. While the control group exhibited some gains, the magnitude of improvement was notably smaller compared to the intervention group.

These findings support the effectiveness of Pilates-based core training in improving lower abdominal strength and control among dancers, as evidenced by the greater reduction in leg angle scores in the intervention group.

**Table 6.6**
**Inactive Neutral Pelvis Test**

| Participant # | Pre-test *Positive/Negative | Post-test *Positive/Negative | Difference |
|---|---|---|---|
| Intervention | | | |
| 1 | neutral | neutral | 0% |
| 3 | neutral | neutral | 0% |
| 5 | Not neutral | neutral | 100% |
| 13 | Not neutral | neutral | 100% |
| 30 | neutral | neutral | 0% |
| Group Average | 60% achieved neutral | 100% achieved neutral | |
| Control | | | |
| 2 | Not neutral | neutral | 100% |
| 4 | Not neutral | Not neutral | 0% |
| 6 | Not neutral | Not neutral | 0% |
| 10 | Not neutral | neutral | 100% |
| 12 | Not neutral | neutral | 100% |
| 28 | neutral | neutral | 0% |
| Group Average | 16.7% achieved neutral | 66.7% achieved neutral | |

**Table 6.7**
**Active Neutral Pelvis Test**

| Participant # | Pre-test *Positive/Negative | Post-test *Positive/Negative | Difference |
|---|---|---|---|
| Intervention | | | |

| | | | |
|---|---|---|---|
| | | | |
| 1 | neutral | neutral | 0% |
| 3 | Not neutral | neutral | 100% |
| 5 | Not neutral | Not neutral | 0% |
| 13 | neutral | neutral | 0% |
| 30 | Not neutral | neutral | 100% |
| Group Average | 40% achieved neutral | 80% achieved neutral | |
| Control | | | |
| | | | |
| 2 | neutral | neutral | 0% |
| 4 | neutral | neutral | 0% |
| 6 | Not neutral | neutral | 100% |
| 10 | neutral | neutral | 0% |
| 12 | neutral | neutral | 0% |
| 28 | neutral | neutral | 0% |
| Group Average | 83.3% achieved neutral | 100% achieved neutral | |

**Table 6.8**
**Pilates-based Curl Test**

| Participant # | Pre-test *Number of Repetition | Post-test *Number of Repetition | Difference |
|---|---|---|---|
| Intervention Group | | | |
| 1 | 2 | 3 | 1 |
| 3 | 1 | 1 | 0 |
| 5 | 1 | 14 | 13 |

| | | | |
|---|---|---|---|
| 13 | 12 | 4 | -8 |
| 30 | 7 | 13 | 6 |
| Control Group | | | |
| 2 | 1 | 2 | 1 |
| 4 | 1 | 1 | 0 |
| 6 | 1 | 3 | 2 |
| 10 | 1 | 11 | 10 |
| 12 | 4 | 5 | 1 |
| 28 | 1 | 2 | 1 |

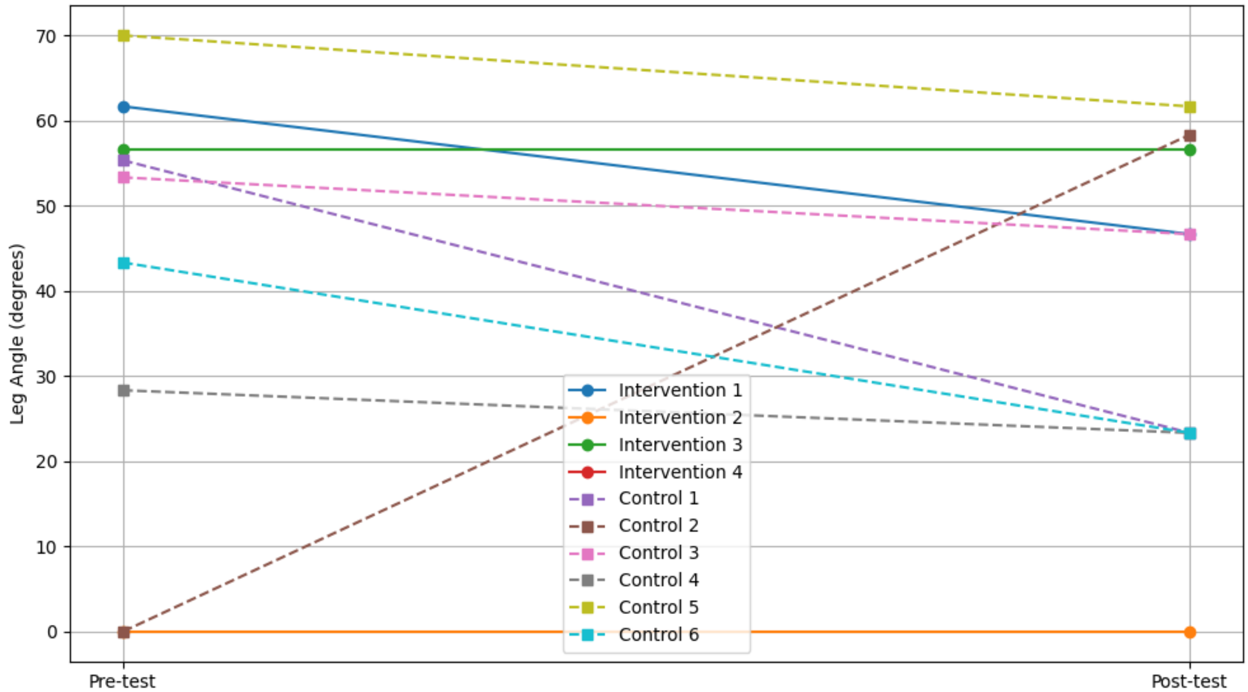


**Figure 6.1**
**Lower Abdominal Test (Mean leg angle pre and post testing)**

## Plank Test

The Plank test indicated that four of the five dancers in the intervention group improved an average improvement of 22.3% from pre to post-test (see Table 6.10). Two dancers increased one level on the plank rating scale while two remained the same. Once dancer decreased from below average to very poor on the plank rating scale. All six dancers in the control group improved an average of 55.5% from pre to post-test. Four dancers increased their rating on the plank scale while two remained the same. Out of the four dancers who increased, one increased two levels, while three increased one level on the rating scale. Out of the four possible form breaks, participants fell into one of two categories. The shoulder girdle collapsing was the most common form failure, 72.7% of participants, with arching the low back being the second most common form break at 27.2% of participants. No other indicators of form breaks were recorded.

**Table 6.9**
**Plank Test**

| Participant # | Pre-test *in seconds | Post-test *in seconds | Difference *in seconds | Change in rating scale |
|---|---|---|---|---|
| Intervention Group | | | | |
| 1 | 17 | 49 | 32 | Increased from poor to below average |
| 3 | 40 | 55 | 15 | Stayed the same: below average |
| 5 | 61 | 95 | 34 | Stayed the same: average |
| 13 | 113 | 120 | 7 | Increase from average to above average |
| 30 | 52 | 0* | -52 | Decrease from below average to very poor |
| Control Group | | | | |
| 2 | 29 | 66 | 37 | Increased from poor to average |
| 4 | 12 | 27 | 15 | Increased from very poor to poor |
| 6 | 32 | 49 | 17 | Stayed the same: below average |
| 10 | 43 | 63 | 20 | Increased from below average to average |
| 12 | 35 | 50 | 15 | Stayed the same: below average |
| 28 | 6 | 21 | 15 | Increased from very poor to poor |

*Participant never achieved proper form and defaulted immediately

## Questionnaire

Results were generated by the responses in the pre and post-questionnaire including questions on the participant's perception on abdominal strength, neutral pelvis placement, and core stability. Data was analyzed using Braun and Clarke's (2006) six phases of thematic analysis; (1) familiarization with the data, (2) generating initial codes, (3) searching for themes, (4) reviewing themes, (5) defining and naming themes, (6) producing the report. Through the coding process and theme development, two key themes emerged: (1) Strength and Progression, (2) Awareness and Control. Themes are presented below including participant quotes and interpretations of significance.

### Strength and Progression

Participants consistently described noticeable improvements in core strength and core stability. This theme reflects dancers' perceived physical improvement over the course of the study and emphasizes how repeated engagement with the Pilates Method contributed to dancer observation of increased control and ease of movement. One participant wrote, "*It made me feel a lot stronger in my core strength, and as the study progressed, most of the exercises became easier*."

Dancer reflection shows how participants interpreted the progression of the work not only as increased strength, but as a functional improvement in their dancing. The reported ease that participants could perform exercises with more ease over time was seen as evidence of physical adaptation, increased muscular endurance, and stability. This theme highlights the role of Pilates in promoting strength, an experience of physical ability that extends into dance performance.

### Awareness and Control

In additional to perceived physical changes, participants mentioned increased awareness of body mechanics and alignment, particularly noting pelvic placement and core engagement. This theme represents the shift that occurred as dancers developed a stronger understanding of their own movement patterns and alignment. One participant stated, "*I enjoyed this study because I could notice the exercises getting easier the stronger we got, as well as learning more about pelvis placement – not something I have fully focused on before*."

These thoughts suggest that participants were not only improving physically but were also developing the ability to control and understand movement. Increased awareness of pelvic placement, essential to dance alignment, shows that Pilates supports similarities to dance. This knowledge and awareness may assist dancers in improving misalignments seen in their dance training.

## 6.4 Discussion

This study used a pre-experimental design to evaluate the effects of a Pilates program on core stability in collegiate dance students. The results indicated that dancers in both the intervention and control group showed improvement over the 7-week study with greater improvement seen in the intervention group in the inactive neutral pelvis test, active neutral pelvis test, and the lower abdominal test indicating that a Pilates wall unit exercise program may improve pelvic alignment and abdominal strength improving core stability. Improvement in both groups could have been a result of all participants being actively engaged in ballet and/or modern dance classes, which also emphasizes neutral pelvis. Anecdotal evidence (questionnaire ratings) indicated the dancers in the intervention group perceived an improvement in abdominal strength, pelvic alignment and core stability from pre to post intervention. The themes that emerged (1) Strength and Progression and (2) Awareness and Control, highlight Pilates' relevance as a holistic training method. The findings suggest that Pilates can be more than a cross-training method, it can integrate into a dancer's technical training. Integrating Pilates into dance practice may promote technical longevity, elongating a dancer's career.

### 6.5 Conclusion

The purpose of this study was to incorporate Pilates wall unit into a study on dancers to assess its impact and to analyze the participant's perception of Pilates on core stability. The null hypothesis for this study indicates there would be no difference in core strength between the control and intervention groups and that participants would have no perceived difference in dance training. Based on the results of this study, the null hypothesis on core strength was validated. However, the null hypothesis on dancer perception was rejected. Questionnaires indicated dancers perceive Pilates to benefit their dance training. Due to sample size, more investigation is needed to determine Pilates impact on dance training.

# 7 Summary Discussion

## 7.1 Introduction

This chapter discussion will bring together the key findings from the studies in this thesis, discuss the implication of the findings, make recommendations for future studies, and address the overarching research question.

The original research question was: Does Pilates improve core stability and dance performance in collegiate dancers? This laid the foundation to investigate new assessment tools for dancers to assess core strength and dance performance. To gain a holistic view of Pilates and dance, qualitative measures were used to examine how dancer's perceive Pilates impact on dance training. To address the question, a literature review was conducted, followed by a sEMG study, and two intervention studies with both qualitative and qualitative data collection. These were devised to (1) investigate the existing research on Pilates and dancers; (2) compare a validated abdominal test against several Pilates-based exercises to assess muscle amplitude while maintaining neutral pelvis; (3) to examine the effects of Pilates on core stability; (4) to investigate the dancer's perception of Pilates impact on dance training and ability; (5) and to develop an evaluation tool for assessing dance performance.

## 7.2 Summary of the main findings

The summary of the findings in these studies can be summarized into five main parts: (1) the literature review, (2) data analysis of the sEMG, (3) quantitative data using assessment tests to examine the impact of Pilates conditioning programs, (4) qualitative research looking at dancer perception of Pilates impact, and (5) analysis of an assessment tool designed to assess the impact of conditioning on dance performance.

The systematic review was the first to methodologically examine the strength of evidence on the relationship between Pilates and dance. The findings indicated mixed reviews of the effect of Pilates on dancers. Studies investigated balance, postural alignment, muscular strength, flexibility, and jumps however, there were no replicated studies included. Only one study assessed the aesthetics of movement but used a gymnastic based assessment tool rather than one specific to dance. Overall, the studies had low number of participants which resulted in lack of statistical data and some demonstrated low scores on the PEDro scale, questioning the validity of the current evidence. The systematic review revealed eight weaknesses in the current research in dancers and Pilates. These weaknesses include:

(1) blind procedures,
(2) randomized groups,
(3) small sample sizes,
(4) specialized assessments designed for dancers,
(5) research examining various pieces of Pilates equipment,
(6) connection of the impact of the conditioning program on dance performance,
(7) qualitative data looking at dancer perspective on the impact of Pilates and
(8) assessment of dynamic rather than static movement to align more with the demands of dance performance.

This thesis addressed seven of the eight weaknesses identified including:

(1) blind procedures (chapter 6),
(2) randomized groups in method design (chapter 6),
(3) specialized assessments designed for dancers (chapters 4, 5, and 6),
(4) research examining various pieces of Pilates equipment (mat and wall unit) (chapters 5 and 6),
(5) impact of the conditioning program on dance performance (chapter 5),
(6) assessment of dynamic movement (chapter 5), and
(7) dancer perspective (chapters 5 and 6).

Small sample size was not addressed in this thesis based on the restrictions and lack of participants due to the COVID-19 pandemic. Study 1 (electromyography analysis of Pilates exercises vs FGCT) was the first study that compared a widely used abdominal endurance test, the FGCT, against 3 Pilates-based exercises with and without a sphygmomanometer by measuring sEMG activity of the upper and lower rectus abdominis. The results indicated the FGCT test had increased muscle amplitude in the URA however no significant difference was seen in LRA. All exercises with the sphygmomanometer showed a decrease in muscle amplitude overall. This study's aim was to determine which test would have the greatest muscle activation while also considering postural alignment for dancers during assessments.

Studies 2 (Pilates Mat) and 3 (Pilates wall-unit) were the first studies to investigate the effects of Pilates training programs on dancer core stability, dance performance, and dancer perception. The results of this study showed mixed outcomes on the impact of Pilates. The plank test (Tong, et al., 2014; Strand, et al., 2014) was selected to assess core stability and function. In the study using Pilates mat training, differences in core strength were seen pre and post-test. In contrast, the Pilates wall unit training, showed no substantial difference between the control and intervention groups. This suggests there may be differences in the use of Pilates apparatus rather than in the Pilates Method itself. However, both studies had low participant numbers so more investigation is needed in order to show p value results. Inactive and active neutral pelvis testing was used to evaluate understanding and analysis of pelvic placement. Based on results from the sEMG study in chapter 4, and the importance of pelvic alignment in dancers, abdominal strength was assessed using the Pilates-based test, BIOLD and lower abdominal strength test (Galbraith, 2014). Although some improvement in both pelvic assessments and the Pilates-based curl test was seen in all participants, results suggest a combination of Pilates training and dance technique class may have an impact on postural alignment.

Studies 2 and 3 were the first to incorporate qualitative data to assess dancers' perceptions of Pilates' impact on dance training. Through thematic analysis, the data revealed that dancers generally believe Pilates enhances core stability and improves their understanding and awareness of pelvic placement during dance performance. However, further research is needed to explore the reasons behind dancers' beliefs regarding the benefits of Pilates for core stability and alignment. Additionally, it is important to examine the correlation between dancers' perceived improvements and objective, measurable assessments. Factors such as the placebo effect and the absence of reliable measurement tools to capture the changes dancers report experiencing warrant further investigation.

Due to the innovative nature of this project, several assessment tools used to analyze dance alignment during movement have not yet been validated. Study 2 of this thesis employed a rubric-based method to evaluate movements in a modern dance phrase. While the results indicated improvements in dancers' performance, variability among evaluators highlighted the challenges involved in developing a standardized tool for assessing dance technique. Further research and refinement of methodology are needed to create an assessment tool that not only measures alignment during dance movements but also accounts for aesthetic differences among evaluators. Additionally, researchers need to determine if there is one type of assessment tools for dance or if additional tools are necessary in order to capture the differences in dance techniques such as ballet, modern, and jazz.

### 7.3 Strengths of the present research and contribution to the literature

The strengths of this research can be summarized into four parts, each contributing positively to the existing body of work. The systematic review, which is only one of two reviews done on Pilates and dancers (Bernardo & Nagle, 2006) includes a detailed description of the search methodology. MeSH terms were used, the PEDro scale (Maher, et al, 2003; De Morton, 2009) was incorporated to assess the quality of research, which was not included in the original literature review by Bernardo & Nagle (2006). The literature review also categorization the studies into similar research providing a different perspective on the work. This organization gives future researchers a clear understanding of dancer needs and allows teachers to understand how the work impacts specific areas such as muscular strength and flexibility. Study 1 is the first study to collect data on the muscular amplitude on Pilates when compared to current validated abdominal tests (FGCT). It is also the only study that compares Pilates exercises with the use of a sphygmomanometer to determine muscular engagement. Data from this study enabled researchers to develop a new abdominal test designed for dancers, utilizing strong muscle engagement while maintain proper pelvic alignment. This assessment tool allows future researchers to use this tool to assess dancer abdominal strength without sacrificing proper dance alignment. Most current research looks at a singular movement in a stationary position, most commonly the developpé and arabesque positions. Study 2 was the first study to investigate the impact of Pilates on a modern dance movement phrase rather than comparison of a singular dance movement, usually ballet. In addition, this study developed an assessment tool with 67% inter-rater reliability. In future application of the tool should include evaluator training to increase reliability between examiners. This assessment tool gives teachers and researchers a tool to use to assess dancer performance and how a conditioning program may impact dance training. Study 3 is the first study to use the wall unit as the main apparatus in an intervention study on dancers, expanding the research on various Pilates equipment, and only one of a mixed apparatus study in the general population (Mueller, et al., 2021). Data from this study will give future researchers a foundation for additional research on the wall unit. Future research should consider looking at comparing Pilates equipment against each other to gain a better understanding of its impact on dancers. Although the test has not yet been validated, a Pilates-based assessment tool designed to maintain pelvic stability was utilized to collect data as the first step in its validation process. Additionally, this study was also the first to examine core stability using a range of assessment tools, including the inactive/passive neutral pelvis test, Pilates-based curl test, lower abdominal test, and plank test. This approach allowed for a comprehensive evaluation of a dancer’s core stability across different levels of activity. This comprehensive approach is one that should be used in future research on dancer population as core stability and pelvic alignment are essential to dancer training and performance. This will also allow teachers to better understand the areas their dancers are weak so they will be able to focus on any alignment deficiencies in their technique classes. These tests were designed for accessibility for dance educators as they use key dance alignment principles and do not require expensive equipment to administer.

A key strength and significant contribution of this body of work lies in the mixed methodology employed in studies 2 and 3. Both studies not only examine the impact of Pilates on core strength and pelvic stability but also collect evidence on the impact of Pilates on dance training and, through qualitative methods, examined dancers' perceptions of how Pilates enhances their dance training and performance. Study 2 is the first study to use a dancer assessment tool to analyze the effects Pilates has on dance performance, specifically on core stability. This is the first study to establish a protocol for examiners to follow before using the assessment and reviewing videos for analysis. The assessment tool was designed to align with existing rubrics commonly used by dance educators, facilitating more straightforward analysis of the data. Variation in dance genres, teacher knowledge and background, and additional assessment training protocols merits further investigation in the validity of a dancer assessment tool. This assessment tool can be used not only in dance research studies but also in practical application of assessing dance technique in studio practice. Qualitative measures gave an insight into how dancers perceive the impact of Pilates on dance training. This perception can lead to greater confidence, more body awareness, and improved focus. Incorporating Pilates into warm-ups potentially could prepare the dancer for class and may be beneficial to incorporate into pre-class preparations. The results of this body of work are consistent with the current literature regarding the impact of Pilates which are generally favorable, though some mixed outcomes were observed.

### 7.4 Limitations

Within this body of research, it is reasonable to assume there are a number of limitations including a global pandemic, COVID-19, which impacted the methodology and participant numbers in studies 2 and 3. This led to a case series methodology rather than a controlled group intervention as originally planned. It has been reported that COVID -19 had a significant impact on research studies across the globe. Harper, et al. (2020) and Sohrabi, et al. (2021) report that there was a 20-25% decrease in research studies, as many were suspended due to travel restrictions, lacked strong sample sizes, alterations to research design, increased harm to participants, and overall supply shortages. Studies in this thesis also experienced some of these limitations including, low participant numbers, methodology change, and limitations on tactile feedback. The Pilates instructor in studies 2 and 3 was severely limited on providing tactile feedback, which is a taught teaching practice in Pilates (Gurtner, no date) and incorporated into other studies such as Lynch's et al. (2008) study on learning Pilates with and without mirrors and Vera-Saura, et al. (2024) on the importance of body-mind in the Pilates Method.

Addressing the lack of assessment tools for dancers requires extensive testing for validation of the assessment tool. Assessment tools introduced in studies 2 and 3 was the first step in this validation process; additional testing of these tools should continue to valid them for dance. The Pilates-based test (BIOLD), has not been used as a testing mechanism across other studies and only used as an exercise in Pilates training. Prior to this research, the use of the sphygmomanometer has been used as a teaching tool for pelvic stability, however, has not been used in research to measure pelvic stability and the activation of the rectus abdominus during abdominal curls.  Even with training, the participants seem to have a lack of understanding on the use of the sphygmomanometer in the sEMG study and during BIOLD test (Study 3). This lack of understanding could have impacted active abdominal engagement (EMG Study) and total repetitions in the BIOLD test (Study 3). The other pelvic assessments, active and inactive neutral pelvis test, used in study 3, although common placements in dance and Pilates, has not been validated as a tool to assess pelvic alignment. The field of dance science is relatively new and there are limited tests designed for dancers, which deemed it important to challenge new testing protocols to build upon the current methodologies currently in the field. Continued research in these assessment tools should continue.

The current literature looks at a singular movement to assess flexibility or strength but does not look at a movement phrase which would be more applicable to the performance of dancers. Finding one movement phrase to assess for research is complex in regard to varied levels of dancers, technical differences not only within diverse dance techniques but even within the same genre of dance, backgrounds and aesthetic differences among evaluators, and scoring values. Based on the differences in levels of the dancers, the movement phrase used in study 2 was only moderately challenging for some and not challenging at all for others.

The dance assessment tool was based on a measurement tool used in technique classes to assess dancer progress but is unvalidated. Variation in evaluator aesthetic preference, their own dance training and background, the use of 2D video and the absence of body markers to analyze participants affected how evaluators viewed the degree of improvement in participants. Other studies have reported similar concerns with limitations of aesthetic tests in dance. (Ngo, et al., 2024)

The field of dance science is vast, relatively new, and has an overarching issue of low participant size which impacts the statistical outcome. Compounded by the global pandemic, reaching a level of participation that resulted in a p value was challenging therefore, alternative methods of analysis were used. Study 2, a case series study, examined the effect of Pilates Mat training on dancer's performance and this influenced the choice of data analysis. Diagrams of data distribution across the three participants were incorporated to provide a clearer understanding of the findings. Additional testing assessments were added to the methodology in study 3 to generate additional results and add to the findings, giving more validity to the outcome.

### 7.5 Applied implications and recommendations for future research

The findings of this thesis present several implications. Current validated core strength tests, designed for the general population, have failed to challenge a dancer's alignment. New assessment tools to analyze dancer alignment such as the ones developed in this thesis including the active and inactive neutral pelvis test, the Pilates-based curl test, and teacher evaluation tool are essential and useful in dance science research and practical applications for teachers. The incorporation of the sphygmomanometer in study 1 and 3 challenged dancers to maintain the stability of their pelvis during a series of Pilates-based abdominal tests, which aligns with proper pelvic alignment in classical concert dance. Future research in this area might investigate other abdominal muscles, beyond the rectus abdominus, for muscular engagement. Dancers cross train to support their dance performance and improve their overall alignment. An assessment tool designed to analyze a dancer's technique is needed to measure the impact of any training protocol. With this recommendation key areas to investigate should include evaluator training in a dance movement assessment tool (seen in study 2) and how it can be used on other dance genres. An assessment tools was designed to be assessable to not only researchers but to dance educators to evaluate proper dance alignment to improve dance training and performance.

Study 3 demonstrated the effects of the wall-unit on a dancer's core stability. This study, and the lack of studies overall, emphasizes the need for future research on various Pilates apparatus and the comparison of one piece of apparatus to another. This study developed a solid foundation for an exercise program to be used on the Pilates wall unit which can also be used on the Pilates cadillac. Furthermore, as Pilates is investigated, current research methodologies do not align with the individualized adjustments expected by the Pilates Method. Research methodologies need to be challenged to align with Joseph Pilates' original intent of his work. Adjustments in methodologies should account for the individual needs of the dancer including possible lack of flexibility, muscular weakness, misalignments, and the use of small props and aids to allow the dancer to execute exercises within their physical limitations.

The outcome of the qualitative research collected in studies 2 and 3 demonstrated the dancer's perception of Pilates on their dance training and performance. This perception may address dancer misconception of how conditioning may impact dance aesthetics, opening the possibility to incorporate new conditioning programs into a dancer's training. The results of these questionnaires showed that dancers felt more confident, focused and aware of body alignment. These qualities may improve dancer readiness, possibly impacting the success and progression of their training. More investigation is needed to determine how a dancer's perception translates to the teacher's observation of its impact on dance training and the quantitative data.

# 8 Concluding Remarks

This body of research examined the effectiveness of Pilates on core stability in dancers. Three studies were conducted to test the impact of a Pilates training program on a dancer's core stability and performance, muscular engagement differences between Pilates-based exercises with and without the use of the sphygmomanometer, and dancer's perception of Pilates on their training. The collection of studies showed inconclusive results. Study 1 showed muscular activation in LRA had no significant difference between the Pilates based exercises, with and without the sphygmomanometer, and the FGCT however showed the FGCT has significant difference in URA compared to all the Pilates-based exercises. The initial findings of studies 2 and 3 demonstrated improvement in core stability. Study 2 showed dancer improvement in their performance during the modern dance movement phrase. Study 3 demonstrated some improvement in the wall unit group over the control group, however the results were not significant. Further research is needed to investigate the role of dance training on core stability with assessment tools designed for dance. Qualitative research yielded positive results on the dancer's perspective of Pilates impact on dance training and alignment however more investigation on the connection between the qualitative and quantitative data is needed.

This thesis contributes to the existing research by examining different Pilates apparatus in an intervention study, utilizing qualitative research to gain the dancer's perception, and the physiological differences between Pilates-based exercises and a validated abdominal endurance test. This research provides new insights into the mixed findings of the effectiveness of Pilates on dancer training and performance and the complexity of developing an assessment tool to measure dancer performance.

# 9 My Personal Journey

When I began this journey in December 2014, I didn't know how long it would take or what would happen in my personal life or the world that would impact my progress. When I started, I had been a faculty at Texas A&M University for fourteen years and the Director of Dance for seven years. In this position, I oversaw 3 faculty members, a dance minor (started in 2002) and a Kinesiology: Dance Science degree (started in 2010). I had a vision for the program to offer an MFA with an emphasis in dance science so thought this degree would be essential to achieving that goal. I also had a desire to prove to myself that a PhD was achievable for me, a dancer of average intelligence.

Pilates has been a passion of mine since I took it as an undergraduate student in the early 90's and when I became a practitioner over 20 years ago. I have seen the impact Pilates can have on a dancer's alignment, mechanics, and injury recovery. The lack of Pilates research on dancers however did not support what I was seeing in the studio, so it made sense for me to focus on this area of practice for my PhD. Through my PhD body of work and other studies I did on the side with other colleagues and students, we have only begun to scratch the surface, and I realize that Pilates will be my life's work.

I began this journey with two young children, ages 4 and 9, and a partner of 14 years. Through the span of the last 10 years, I have moved from the Director of Dance to an Associate Dean for Academic Affairs to Senior Associate Dean for Academic Affairs and have been one of the key faculty members to begin a new college within the Texas A&M System. A task that Texas A&M University hadn't taken on for over 30 years. No one prepares you for upper administration, they hand you a key to a bigger office, congratulate you, and expect you to begin your work within this new role with limited training on what it truly means to be in this position. The same can be said for beginning a new college of the arts, within a R1 university where the arts hadn't been a priority for the past 100 years. I was in no way prepared for this new role and continuing my PhD at the same time seemed daunting. There were several times along the PhD journey that I questioned what I was doing it for and if it would just be easier if I stopped. I didn't need it for career advancement, I was simply doing it to prove to myself that I could. Did I need that justification of my own self-worth? Well, something kept me going, because here I am almost at the end of it.

In addition to the administrative roles, I became a Full Clinical Professor (a non-tenured line) in 2016. During the last 10 years I have written 9 peer reviewed journal articles, 6 outside my PhD work, written 3 online book chapters, gave 51 teaching presentations, 27 research presentations, and was the choreographer for 92 performances. I mentored 16 undergraduate students in their own intervention research and 20 in creative work, many which presented at the regional or national level and a few that got published. I also received over $100,000 in grants to support my creative work. During this PhD journey, I wasn't given a course reprieve and with my own stubbornness, didn't let go of many other work-related projects which I am sure contributed to how long this has taken me.

On top of work projects, I also had some personal roadblocks; my elderly mother was in and out of the hospital a few times; my daughter went into therapy for cutting; I got divorced after almost 20 years of marriage; my eldest daughter was a national travel soccer player which took us all over the United States to play; my eldest also had ACL and meniscus surgery that took her a year to recover from, both physically and emotionally; I met the love of my life, got married and gained two sons; oh, and there was a global pandemic that almost closed the dance program at Texas A&M, stopped my research in its tracks, and closed the schools my children attended so now I was homeschooling 2 kids, on with ADHD.

I could go into each of these in more depth but ultimately it doesn't matter. Many PhD students go through life's challenges. I think what I am most proud of is that I am seeing it through to the end. I am proud that my girls will see that even through all of life's challenges mom didn't give up on her dream. It may have taken her twice as long to finish, but she completed what she set out to do. I hope it gives them the inspiration to push through when life gets hard, when it throws so many obstacles in the way that you question why you are doing it, and that some things are important enough for you to finish, no matter what. I am so thankful for all the people who helped me along the way and wouldn't let me give up even when I wanted to; especially my mom and sister who watched the girls when I needed to make progress and my wife Lindsay who allows the space and gives me gentle reminders to get it done. The PhD light is finally at the end of the tunnel, and it is beginning to shine brighter.

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# 11 Appendices – Consent Forms, COVID Protocol, Medical, and Injury History Forms

## 11.1 Consent form for Study #1

**TEXAS A&M UNIVERSITY HUMAN SUBJECTS PROTECTION PROGRAM CONSENT FORM**

**Project Title: Physiological Impact of the FITNESSGRAM vs a Pilates-based Curl Tests**

You are being invited to take part in a research study being conducted by Texas A&M University. You are being asked to read this form so that you know about this research study. The information in this form is provided to help you decide whether or not to take part in the research. If you decide to take part in the study, you will be asked to sign this consent form. If you decide you do not want to participate, there will be no penalty to you, and you will not lose any benefit you normally would have.

**WHY IS THIS STUDY BEING DONE?**

The purpose of this study is to evaluate the outcomes of the muscle activation during the fitness gram and 6 Pilates based exercises to help determine which might be more effective.

**WHY AM I BEING ASKED TO BE IN THIS STUDY?**

You are being asked to be in this study because you are enrolled in the Texas A&M University Dance Program as a dance minor, University Studies: Dance concentration student, a BS in Kinesiology: Dance Science track student.

**HOW MANY PEOPLE WILL BE ASKED TO BE IN THIS STUDY?**

Up to 100 participants will be enrolled in this study locally.

**WHAT WILL I BE ASKED TO DO IN THIS STUDY?**

Participants will be tested using an electromyography (EMG) for muscle activation during seven abdominal exercises. EMG pads will be stuck to your rectus abdominus, internal/external obliques and electrodes will be recorded as you perform each exercise 4 times. You will need to attend two 30-minute training sessions to learn the exercises while using proper alignment and technique. You will then be asked to attend three 30-

minute testing sessions where you will perform the abdominal exercises while connected to an EMG machine.

You may be removed from the study by the investigator for these reasons:

- An injury preventing you from being able to execute the exercises.
- You become pregnant.
- Failure to attend training, workout or testing sessions.

If you leave the study early, you may be asked to complete the following activities: Meet with one of the researchers to explain why you are leaving the study.

**WILL VIDEO OR AUDIO RECORDINGS BE MADE OF ME DURING THE STUDY?**

No.

**WILL PHOTOGRAPHS BE TAKEN OF ME DURING THE STUDY?**

Yes. Photographs will be taken during the study and used in presentations and publication for the findings of this research. Please check one of the following:

_____ I give permission for photographs to be made of me during my participation in this research study.

_____ I do not give permission for photographs to be made of me during my participation in this research study.

**ARE THERE ANY RISKS TO ME?**

The things that you will be doing have a little more risk than you would come across in any beginning/intermediate movement class. Some risks may include muscle soreness and/or fatigue. Some participants may incur minor injuries such as a muscle strain. The surface EMG may induce minuscule skin irritation.

If you are or were to become pregnant, this study procedure might involve risks to the embryo or fetus, which are currently unknown.

**ARE THERE ANY BENEFITS TO ME?**

There may be no direct benefit to you by being in this study. What the researchers find out from this study may help determine which exercise demonstrates more muscle activation.

**WILL THERE BE ANY COSTS TO ME?**

Aside from your time, there are no costs for taking part in the study.

**WILL I BE PAID TO BE IN THIS STUDY?**

You will not be paid for being in this study.

**WILL INFORMATION FROM THIS STUDY BE KEPT PRIVATE?**

The records of this study will be kept private. No identifiers linking you to this study will be included in any sort of report that might be published. Research records will be stored securely and only Christine Bergeron will have access to the records.

Information about you will be stored in computer files protected with a password. This consent form will be filed and secured in a locked filing cabinet in an official area.

Information about you will be kept confidential to the extent permitted or required by law. People who have access to your information include the Principal Investigator and research study personnel. Representatives of regulatory agencies such as the Office of Human Research Protections (OHRP) and entities such as the Texas A&M University Human Subjects Protection Program may access your records to make sure the study is being run correctly and that information is collected properly.

**WHOM CAN I CONTACT FOR MORE INFORMATION?**

You can call either Principal Investigator to tell them about a concern or complaint about this research study. The Principal Investigator Christine Bergeron, MFA who can be reached at [tel. no. redacted] (Christine Bergeron) or emailed at [e-mail address redacted].

For questions about your rights as a research participant; or if you have questions, complaints, or concerns about the research and cannot reach the Principal Investigator or want to talk to someone other than the Investigator, you may call the Texas A&M Human Subjects Protection Program office.

- Phone number: (979) 458-4067
- Email: irb@tamu.edu

**MAY I CHANGE MY MIND ABOUT PARTICIPATING?**

You have the choice whether or not to be in this research study. You may decide not to participate or stop participating at any time. If you choose not to be in this study, there will be no effect on your student status.

**STATEMENT OF CONSENT**
I agree to be in this study and know that I am not giving up any legal rights by signing this form. The procedures, risks, and benefits have been explained to me, and my questions have been answered. I know that new information about this research study will be provided to me as it becomes available and that the researcher will tell me if I must be removed from the study. I have been given contact information for people to contact with any questions I may have throughout the study. will be given to me.

___________________________________ Participant's Signature

___________________________________ Printed Name

**INVESTIGATOR'S AFFIDAVIT:**
Either I have or my agent has carefully explained to
project. I hereby certify that to the best of my knowledge the person who signed this consent form was informed of the nature, demands, benefits, and risks involved in his/her participation.

___________________________________ ____________________________________
Signature of Presenter Date

___________________________________ ____________________________________
Printed Name Date

IRB NUMBER: IRB2016-0392D

IRB APPROVAL DATE: 04/12/2018

### 11.2 Medical Information Form for Study #1

**Physiological Impact of the FITNESSGRAM vs a Pilates-based Curl Tests**
**Medical History Inventory**

Directions. The purpose of this questionnaire is to enable the staff of the Exercise and Sport Sciences Laboratory to evaluate your health and fitness status. Please answer the following questions to the best of your knowledge. All information given is CONFIDENTIAL as described in the Informed Consent Statement.

Name: ___________________________________ Age: _____ Date of Birth:_________________ Height: __________ Weight: ___________ Dance Technique Level at TAMU: ______________

MEDICAL HISTORY

Do you have or have you ever had any of the following conditions? (Please write the date when you had the condition in blank).

- ____ Heart murmur, clicks, or other cardiac findings?
- ____ Frequent extra, skipped, or rapid heartbeats?
- ____ Chest Pain of Angina (with or without exertion)?
- ____ Emphysema/lung disease?
- ____ Heart attack or any cardiac surgery?
- ____ Muscle or joint problems?
- ____ High blood sugar/diabetes?
- ____ Thyroid Disease?
- ____ Nerve disease?

____ Asthma/breathing difficulty?
____ Stroke or Blood Clots?
____ Frequent dizziness/fainting?
____ Ulcers?
____ Epilepsy/seizures?
____ Anemia's?
____ Liver or kidney disease?
____ Autoimmune disease?

Do you have or have you been diagnosed with any other medical condition not listed?
____________________________________________________________________________
____________________________________________________________________________

Please provide any additional comments/explanations of your current or past medical history.

___

___

Please list any recent surgery or injury (i.e., type, dates etc.).

___

___

Do you know of any medical problem that might make it dangerous or unwise for you to participate in this study? ____ If yes, please explain:

___

___

___

Recommendation for Participation

- No exclusion criteria presented. Subject is cleared to participate in the study.
  Exclusion criteria is/are present. Subject is not cleared to participate in the study.

Signed: ________________________________ Date: ______________________

## 11.3 Consent form for Study #2

**TEXAS A&M UNIVERSITY HUMAN SUBJECTS PROTECTION PROGRAM CONSENT FORM**

**Title of Research Study: The Effectiveness of Pilates Mat Classes on Core Stability and Dance Performance**

Investigator: Christine Bergeron
Funded/Supported By: There is no funding for this research.

**Why are you being invited to take part in a research study?**

You are being asked to participate because you are enrolled in the Texas A&M University Dance Program as a dance minor, University Studies: Dance concentration student, a BS in Kinesiology: Dance Science track student.

**What should you know about a research study?**

- ● Someone will explain this research study to you.
- ● Whether or not you take part is up to you.
- ● You can choose not to take part.
- ● You can agree to take part and later change your mind.
- ● Your decision will not be held against you.
- ● You can ask all the questions you want before you decide.

**Who can I talk to?**

If you have questions, concerns, or complaints, or think the research has hurt you, you can talk to the IRB personnel at 979-458-4067.

This research has been reviewed and approved by the Texas A&M Institutional Review Board (IRB). You may talk to them at 1-979-458-4067, toll free at 1-855-795-8636, or by email at irb@tamu.edu., if

● You cannot reach the research team.
● Your questions, concerns, or complaints are not being answered by the research team.

- You want to talk to someone besides the research team.
- You have questions about your rights as a research participant.
- You want to get information or provide input about this research.

**Why is this research being done?**

The purpose of this study is to increase core strength in dancers and it evaluate how core strength impacts dance performance.

**How long will the research last?**

The length of this research study is for 10 weeks.

**How many people will be studied?**

We expect to enroll about 15 people in this research study at this site.

**What happens if I say "Yes, I want to be in this research"?**

The total duration of the study will be 10 weeks. Subjects will be asked to fill out physical activity and injury history questionnaire prior to Week 1.

Week 1:

- Pre Testing - There will be one 35 minute testing session where the subject will do a warm up, perform The Plank Hold Test, and execute a dance.

Weeks 2-9:

- Intervention - All intervention will be taught through Zoom Video Conferencing.
- Intervention will consist of Pilates at sessions 2X a week for 45 minutes each session.

Week 10:

- Post Testing - There will be one 35 minute testing session where the subject will do a warm up, perform The Plank Hold Test, and perform a dance

**What happens if I do not want to be in this research?**

You can leave the research at any time and it will not be held against you.

**What happens if I say "Yes", but I change my mind later?**

You can leave the research at any time and it will not be held against you.

**Is there any way being in this study could be bad for me?**

Pilates classes can lead to minor strains and other muscular injuries. Participants would be incurring no additional risk based on their current dance technique activities.

**Will being in this study help me in any way?**

We cannot promise any benefits to you or others from your taking part in this research. However, possible benefits as a dancer include more awareness of core engagement and possibly will increase your overall core strength.

**What happens to the information collected for the research?**

Efforts will be made to limit the use and disclosure of your personal information, including research study records, to people who have a need to review this information. We cannot promise complete privacy. Organizations that may inspect and copy your information include the TAMU HRPP/IRB and other representatives of this organization. The monitors, auditors, the TAMU HRPP, and the US Office for the Protection of Human Research Protections (OHRP) may be granted direct access to your records to conduct and oversee the research.

By signing this document you are authorizing this access. We may publish the results of this research. Confidentiality will be maintained to the extent permitted by law. Your full face image may be used in the publication of this research.

**Can I be removed from the research without giving my OK?**

The person in charge of the research study can remove you from the research study without your approval. Possible reasons for removal include back, hip, ankle, and knee musculoskeletal injuries, pregnancy or missing either pre or post testing or missing an intervention session.

We will tell you about any new information that may affect your health, welfare, or choice to stay in the research.

I agree _______

I disagree _______

The researcher may use video record me to aid with data analysis. Video recordings may be used in the presentation of this research.

The researcher may use video record me for use in scholarly presentations or publications. My identity may be shared as part of this activity, although the researcher will attempt to limit such identification. I understand the risks associated with such identification.

The researcher may contact me in the future to see whether I am interested in participating in other research studies by the principal investigator of this study.

I give permission for (photographs/video recordings) to be made of my during my participation of this study.

Signature Block for Capable Adult

| |
|---|
| Your signature documents your permission to take part in this research. |
| Signature of subject Date |
| Printed name of subject |

Signature of person obtaining consent Date: ______________________________________

Printed name of person obtaining consent: _______________________________________

IRB NUMBER: IRB2020-0993
IRB APPROVAL DATE: 09/22/2020

### 11.4 Injury History form for Study #2

**The Effectiveness of Pilates Mat Classes on Core Strength and Dance Performance**
**Injury History Inventory**

Directions. The purpose of this questionnaire is to enable the staff of the Exercise and Sport Sciences Laboratory to evaluate your health and fitness status. Please answer the following questions to the best of your knowledge. All information given is CONFIDENTIAL as described in the Informed Consent Statement.

Participant Number: ____________________ Age: _____ Date of Birth: ____________________ Height: __________ Weight: _________ Dance Technique Level at TAMU: __________________ Email: ____________________________________________

INJURY HISTORY

Have you had any injuries in the past 6 months? If so, please list the injury, date of the injury and recovery protocol.

Are you currently pregnant? ____________________

Do you know of any medical problem that might make it dangerous or unwise for you to participate in this study? ____ If yes, please explain:
_______________________________________________________________

Recommendation for Participation

- ____ No exclusion criteria presented. Subject is cleared to participate in the study.
- ____ Exclusion criteria is/are present. Subject is not cleared to participate in the study.

Signed: _____________________________________ Date: ________________________

IRB NUMBER: IRB2020-0993
IRB APPROVAL DATE: 09/22/2020

## 11.5 Consent form for Study #3

**TEXAS A&M UNIVERSITY HUMAN RESEARCH PROTECTION PROGRAM**
**INFORMED CONSENT DOCUMENT**

Title of Research Study: The Effectiveness of Pilates Wall Unit Training on Core Stability

Investigator: Christine Bergeron
Funded/Supported By: This research is not funded.

**Why are you being invited to take part in a research study?**

You are being asked to participate because you are enrolled in the Texas A&M University Dance Program as a dance minor, University Studies: Dance concentration student, a BS in Kinesiology: Dance Science track student.

What should you know about a research study?

- Someone will explain this research study to you.
- Whether or not you take part is up to you.
- You can choose not to take part.
- You can agree to take part and later change your mind.
- Your decision will not be held against you.
- You can ask all the questions you want before you decide. Who can I talk to?

If you have questions, concerns, or complaints, or think the research has hurt you, talk Carisa Armstrong at [e-mail address redacted]

This research has been reviewed and approved by the Texas A&M Institutional Review Board (IRB). You may talk to them at at 1-979-458-4067, toll free at 1-855-795-8636, or by email at irb@tamu.edu., if

- You cannot reach the research team.
- Your questions, concerns, or complaints are not being answered by the research team.
- You want to talk to someone besides the research team.
- You have questions about your rights as a research participant.
- You want to get information or provide input about this research.

**Why is this research being done?**

The purpose of this study is to determine the effectiveness of Pilates Cadillac/wall unit on dancer's training and performance.

**How long will the research last?**

We expect that you will be in this research study for 7 weeks.

**How many people will be part of the study?**

We expect to enroll about 100 people in this research study at this site.

**What happens if I say "Yes, I want to be in this research"?**

The total duration of the study will be 7 weeks. Subjects will be asked to fill out an injury questionnaire prior to Week 1.

Week 1:
● Pre Testing - There will be two 20 minute testing sessions where the subject will perform the plank test, assisted abdominal test, lower abdominal test, and a movement phrase.

Weeks 2-6:
● Intervention - two 45 minute intervention sessions for 5 weeks.
  - Exercises on the Pilates cadillac will be taught and led by the researcher and you will be observed for proper alignment
- The Control Group will not receive any intervention and will continue their regular routine.

Week 7:
● Post Testing - There will be two 20 minute testing sessions where the subject will perform the plank test, assisted abdominal test, lower abdominal test, and a movement phrase.

**What happens if I do not want to be in this research?**

You can leave the research at any time and it will not be held against you.

**What happens if I say "Yes", but I change my mind later?**

You can leave the research at any time and it will not be held against you.

**Is there any way being in this study could be bad for me?**

Exercise can lead to minor strains and other muscular injuries. Participants would be incurring no additional risk based on their current dance technique activities.

**Will being in this study help me in any way?**

We cannot promise any benefits to you or others from your taking part in this research. However, possible benefits as a dancer include improved muscular strength.

**What happens to the information collected for the research?**

Efforts will be made to limit the use and disclosure of your personal information, including research study records, to people who have a need to review this information. We cannot promise complete privacy. Organizations that may inspect and copy your information include the TAMU HRPP/IRB and other representatives of this organization. The sponsor, monitors, auditors, the TAMU HRPP, the US Office for the Protection of Human Research Protections (OHRP) and the Food and Drug Administration (FDA) may be granted direct access to your records to conduct and oversee the research.

By signing this document you are authorizing this access. We may publish the results of this research. However, we will keep your name and other identifying information confidential.

**Can I be removed from the research without giving my OK?**

The person in charge of the research study or the sponsor can remove you from the research study without your approval. Possible reasons for removal include musculoskeletal injuries, missing a pre or post testing session, or missing an intervention session.

We will tell you about any new information that may affect your health, welfare, or choice to stay in the research.

I agree _______ I disagree _______

The researcher will video record me to aid with data analysis. The researcher will not share these recordings with anyone outside of the immediate study team or TAMU Compliance.

The researcher will photograph or video record me for use in scholarly presentations or publications. My identity may be shared as part of this activity, although the researcher will attempt to limit such identification. I understand the risks associated with such identification.

The researcher may contact me in the future to see whether I am interested in participating in other research studies by the principal investigator of this study. Your signature documents your permission to take part in this research.

Signature of subject: ________________________________ Date: _____________

Printed name of subject:_________________________________________________________________

IRB NUMBER: IRB2021-1039D IRB APPROVAL DATE: 09/13/2021

## 11.6 Injury History form for Study #3

**The Effectiveness of Pilates Wall Unit Training on Core Stability**
**Injury History Inventory**

Directions. The purpose of this questionnaire is to enable the staff of this study to evaluate your injury status. Please answer the following questions to the best of your knowledge. All information given is CONFIDENTIAL as described in the Informed Consent Statement.

Name: ________________________________ Age: _____ Date of Birth: ____________________ Height: _______ Weight: ________ Dance Technique Level at TAMU: __________________ Email: __________________________________________

INJURY HISTORY

Please list any injuries. Please include type of injury, date of initial injury, date of return to dance from injury.

___________________________________________________________________________

___________________________________________________________________________

Do you have any current injuries? For the purposes of this study, an injury is defined as a medical condition (such as muscular strain, fracture, etc) that keeps you from participating in dance class or other physical activity.

If yes, please explain.

__________________________________________________________________________

Do you know of any other medical problem that might make it dangerous or unwise for you to participate in this study?

___________________________________________________________________________

___________________________________________________________________________

If yes, please explain.

___________________________________________________________________________

___________________________________________________________________________

Recommendation for Participation

- ____ No exclusion criteria presented. Subject is cleared to participate in the study.
- ____ Exclusion criteria is/are present. Subject is not cleared to participate in the study.

Signed: ________________________________ Date: _____________________

IRB NUMBER: IRB2021-1039D IRB APPROVAL DATE: 09/17/2021

## 12 Appendices – PEDro Scale

### 12.1 PEDro Scale

| Criteria | YES | NO |
|---|---|---|
| 1. Eligibility criteria were specified. | YES | NO |
| 2. Subjects were randomly allocated to groups (in a crossover study, subjects were randomly allocated an order in which treatments were received) | YES | NO |
| 3. Allocation was concealed | YES | NO |
| 4. The groups were similar at baseline regarding the most important prognostic indicators | YES | NO |
| 5. There was blinding of all subjects | YES | NO |
| 6. There was blinding of all therapists who administered the therapy | YES | NO |
| 7. There was blinding of all assessors who measured at least one key outcome | YES | NO |
| 8. Measures of at least one key outcome were obtained from more than 85% of the subjects initially allocated to groups | YES | NO |
| 9. All subjects for whom outcome measures were available received the treatment or control condition as allocated | YES | NO |
| 10. The results of between-group statistical comparisons are reported for at least one key outcome | YES | NO |

| | | |
|---|---|---|
| 11. The study provides both point measures and measures of variability for at least one key outcome | YES | NO |

# 13 Appendices – Questionnaires

## 13.1 Pre-test Questionnaire for Study #2

**The Effectiveness of Pilates Mat Classes on Core Stability and Dance Performance**
**Pre-Test Questionnaire**

Participant Number: ____________________ Date: ____________________

Please answer the following questions as honest as possible. This will help us determine, from the dancer's perspective, if this training method is effective.

1. How would you rate your current core strength? (circle one)

   Excellent Good Average Below Average Poor

2. Do you think core strength has a direct correlation to how well you perform in a dance class? (circle one)

   YES NO

3. What activity(s) do you do to improve your core strength?

4. What dance classes and rehearsals are you currently participating in? How often do they meet and how long are your rehearsals? (Example, Rehearsal 1 meets MW from 3-5pm; ballet meets 3X a week 9:30-10:45am, etc)

5. What do you perceive will happen in the next eight weeks?  Do you think this training method will help with core strength?  Do you think it will have an impact on your overall dance training?

IRB NUMBER: IRB2020-0993
IRB APPROVAL DATE: 09/22/2020

## 13.2 Post-test Questionnaire for Study #2

**The Effectiveness of Pilates Mat Classes on Core Stability and Dance Performance**
**Post-Test Questionnaire**

Participant Number: ____________________ Date: ____________________

Please answer the following questions as honest as possible. This will help us determine, from the dancer's perspective, if this training method is effective.

1. How would you rate your current core strength? (circle one)

   Excellent Good Average Below Average Poor

2. What dance classes and rehearsals are you currently participating in? How often do they meet and how long are your rehearsals? (Example, Rehearsal 1 meets MW from 3-5pm; ballet meets 3X a week 9:30-10:45am, etc)

3. Do you have any comments you would like to share about the improvements or lack of improvements you have made with this training method?

IRB NUMBER: IRB2020-0993
IRB APPROVAL DATE: 09/22/2020

## 13.3 Pre-test Questionnaire for Study #3

**Effectiveness of Pilates Wall Unit on Core Stability**
**Pre-Test Questionnaire**

Participant Number: ____________________ Date: ____________________

Please answer the following questions. These questions are from your perspective on your current abilities.

1. How would you rate your current abdominal strength? (circle one)

Excellent Good Average Below Average Poor

2. How would you rate your pelvic placement? Pelvic placement in this context is defined as the ability to maintain proper placement during dance movements. (circle one)

Excellent Good Average Below Average Poor

3. How would you rate your core stability? Core stability in this context is defined as the ability to maintain proper placement and control of the whole core during dance movements. Core is defined as abdominal strength, pelvic placement, spinal stability, and shoulder engagement. (circle one)

Excellent Good Average Below Average Poor

4. Do you think abdominal strength has a direct correlation to how well you perform in a dance class? (circle one)

YES NO

5. Do you think pelvic placement has a direct correlation to how well you perform in a dance class? (circle one)

YES NO

6. Do you think core stability has a direct correlation to how well you perform in a dance class? (circle one)

YES NO

7. What activity(s) do you do to improve your abdominal strength?

8. What activity(s) do you do to improve your pelvic placement?

9. What activity(s) do you do to improve your core stability?

10. What dance classes and rehearsals are you currently participating in? How often do they meet and how long are your rehearsals? (Example, Rehearsal 1 meets MW for 2 hrs each day; ballet meets 3X a week for 1:20min. each time, etc)

11. What do you perceive will happen in the next five weeks?

IRB NUMBER: IRB2021-1039D IRB APPROVAL DATE: 09/13/2021

### 13.4 Post-test Questionnaire for Study #3

**Effectiveness of Pilates Wall Unit on Core Stability**
**Post-Test Questionnaire**

Participant Number: ____________________ Date: ____________________

Please answer the following questions. These questions are from your perspective on your current abilities.

1. How would you rate your current abdominal strength? (circle one)

   Excellent Good Average Below Average Poor

2. How would you rate your pelvic placement? Pelvic placement in this context is defined as the ability to maintain proper placement during dance movements. (circle one)

   Excellent Good Average Below Average Poor

3. How would you rate your core stability? Core stability in this context is defined as the ability to maintain proper placement and control of the whole core during dance movements. Core is defined as abdominal strength, pelvic placement, spinal stability, and shoulder engagement. (circle one)

   Excellent Good Average Below Average Poor

4. Do you have any comments you would like to share about your participation in this research study or the impact this training had on you?

IRB NUMBER: IRB2021-1039D IRB APPROVAL DATE: 09/13/2021

# 14 Appendices – Study Instruction, Observation, and Teacher Rubric Sheets

## 14.1 Instruction and Observation Sheet for Study #1

**Physiological Impact of the Fitness Gram vs. Pilates-based Abdominal Curl Test**
**Observations and Instruction for Abdominal Testing**

Metronome Review:
Before any of the exercises are done, the examiner should go over the metronome with the participant making sure they understand the timing of when the curl up and down should occur. The metronome setting is set to 35 beats per minute and be used with each of the following tests.

FITNESSGRAM Test:

Verbal Instruction: Lay down (supine) on the mat with your knees bent and feet flat on the floor. Line your fingertips on the tip of the yellow strip. Curl up until your fingertips reach the second yellow strip on the mat. Keep your fingertips on the mat and make sure your head returns to the mat each time. Listen to the metronome and make sure you are curling up and down on the beat.

The examiner should make sure the participant to doing the following during testing:

- Feet flat on the floor with knees bent
- Feet stay connected to the floor throughout
- Head returns to the mat between each curl
- Fingertips reach 4.5” from starting point to the second tape line

Pilates-based Abdominal Curl (without biofeedback pressure cuff) Test:

Verbal Instruction: Lay down (supine) on the mat with your knees bent and your arms by your side. Now find your neutral pelvis. Bring one leg up to tabletop, maintaining a neutral pelvis. Now bring up the other. Now, while maintaining a neutral pelvis extend the legs fully. Following the beat of the metronome, curl up to your shoulder blades and at the same time, while maintaining a neutral pelvis, lower the legs as far as you can while maintaining the placement of the pelvis. As you lower down make sure your legs return to 90 degrees and your head returns to the mat. Your arms will stay on the mat throughout the exercise. Listen to the metronome and make sure you are curling up and down on the beat.

The examiner should make sure the participant to doing the following during testing:

- Head returns to the mat between each curl
- Participant rounds up to the tip of the shoulder blades
- Pelvis stays in neutral position
- Legs stay straight, at specified angle and feet remain pointed
- Legs move and return to 90 degrees at the end of each curl (in double leg lower version)

Pilates-based Abdominal Curl (with sphygmomanometer) Test:

Verbal Instruction: This is the same as the exercise you just did but with the cuff under your low back. When you curl up and down you want to keep the numbers in the dial between 40 and 60. Lay down (supine) on the mat with your knees bent and your arms by your side. (Examiner places the sphygmomanometer under the low back). Now find your neutral pelvis. Bring one leg up to tabletop, maintaining a neutral pelvis. Now bring up the other. Now, while maintaining a neutral pelvis extend the legs fully. (examiner adjust the inflation on the sphygmomanometer) Following the beat of the metronome, curl up to your shoulder blades and at the same time, while maintaining a neutral pelvis, lower the legs as far as you can while maintaining the placement of the pelvis. As you lower down make sure your legs return to 90 degrees and your head returns to the mat. Your arms will stay on the mat throughout the exercise. Listen to the metronome and make sure you are curling up and down on the beat.

The examiner should make sure the participant to doing the following during testing:

- Head returns to the mat between each curl
- Participant rounds up to the tip of the shoulder blades
- Pelvis stays in neutral position
- Legs stay straight, at specified angle and feet remain pointed
- Legs move and return to 90 degrees at the end of each curl (in double leg lower version)
- Pressure on cuff stays between 80 and 120 throughout the testing protocol

## 14.2 Instruction and Observation Sheet for Tests for Study #2

### 14.2.1. Impact of Pilates Mat on Core Stability and Dance

**Performance Observations and Instruction for Abdominal Testing**

<u>Plank Test</u>

<u>Verbal Instruction</u>: We will be doing a plank on your forearms. Remember while in the plank you want to keep the head aligned, the hips inline with the shoulders, the legs straight, and don't collapse in the shoulders. Come to all fours, now lower to your forearms, extend one leg and then the other. Now hold this with correct form as long as you can.

The examiner should make sure the participant to doing the following during testing:

- Maintain the head in line with the shoulders
- Legs should stay straight throughout
- Pelvis should not be arched
- Pelvis should not drop
- Pelvis should not be higher than the height of the shoulder blades
- Shoulders should not collapse

### 14.2.2. Pilates Mat on Core Stability and Dance Performance Instructions for Movement Phrase

Instruction:
You will learn a movement phrase and then you will do it on the right and the left sides four times. We will record you from the front and the side so be prepared to stop after you complete the right and left sides. I will let you know when to begin each time.

*Examiner will teach the phrase below but will only give instructions of sequence or clarification on how to do a movement (if needed).

**NO INFORMATION SHOULD BE PROVIDED ON CORRECT ALIGNMENT unless it relates to the mechanics of how to complete a step. Examiner should limit information about proper alignment during the movements; some verbiage to avoid "pull in your abdominals (or the like)," "keep your shoulders down (or the like)," or similar cues as it relates to alignment.

| Begin in a large 2nd position (hips externally rotated & abducted) | |
|---|---|
| Counts | Movement |
| 1-4 | • Lateral curve left |
| 5-8 | • Circle through the center in plié to tilt on the right leg (left leg in tilt) |
| 1-4 | • Pique to left leg (right leg in passé) |
| 5-8 | • Step out right to side lunge |
| 1-4 | • Tuck and roll to the floor |
| 5-8 | • Roll to stand and step to second to repeat to the other side |

## 14.3 Instruction and Observation Sheet for Tests for Study #3

### 14.3.1 Impact of Pilates Wall Unit on Core Stability Observations and Instruction for Inactive/Active Neutral Pelvis

Inactive neutral pelvis test

Verbal Instruction: Lay down (supine) on the mat with your knees bent and your arms by your side. I want you to align the pelvis to a neutral pelvis, maintaining the ASIS and the pubis on the same plane. You can get into the position any way you need to including using your hands to on your hips. Let me know when you feel you are in a neutral pelvis.

*(Once the participant informs the examiner, the examiner will make sure the arms are down by their side and the feet are still in the bent position).

Active neutral pelvis test

Verbal Instruction: Stand in first position with your left hand on the barre. Align your body in a proper 1$^{st}$ position including finding your neutral pelvis. Bring your right arm to 5$^{th}$ en haut and cambré back. As you cambré focus on your pelvis and make sure you keep it in neutral throughout the cambré. When you feel you are in your full cambré let me know and stay there for one moment until I tell you to stop.

### 14.3.2 Impact of Pilates Wall Unit on Core Stability Observations and Instruction for Inactive/Active Neutral Pelvis

Pilates-based Abdominal Curl (with sphygmomanometer) Test:

*Examiner sets the metronome to 35 beats per minute.

Verbal Instruction: When you curl up and down you want to keep the numbers in the dial between 40 and 60 and follow the metronome – up on the beat and down on the beat. Lay down (supine) on the mat with your knees bent and your arms by your side.
*(Examiner places the sphygmomanometer under the low back )

Now find your neutral pelvis. Bring one leg up to tabletop, maintaining a neutral pelvis. Now bring up the other. Now, while maintaining a neutral pelvis extend the legs fully.
*(Examiner adjust the inflation on the sphygmomanometer)

Following the beat of the metronome, curl up to your shoulder blades and at the same time, while maintaining a neutral pelvis, lower the legs as far as you can while maintaining the placement of the pelvis. As you lower down make sure your legs return to 90 degrees and your head returns to the mat. Your arms will stay on the mat throughout the exercise. Listen to the metronome and make sure you are curling up and down on the beat.

The examiner should make sure the participant to doing the following during testing:

- Head returns to the mat between each curl
- Participant rounds up to the tip of the shoulder blade
- Pelvis stays in neutral position
- Legs stay straight, at specified angle and feet remain pointed
- Legs move and return to 90 degrees at the end of each curl (in double leg lower version)
- Pressure on cuff stays between 80 and 120 throughout the testing protocol

### 14.3.3 Impact of Pilates Wall Unit on Core Stability Observations and Instruction for Lower Abdominal Strength Test

Lower Abdominal Strength Test

Verbal Instruction: Lay down (supine) on the mat with your knees bent and your arms by your side. *(Examiner places the sphygmomanometer under the low back).

Now bring your legs up to 90 degrees with the legs straight.
* (Examiner makes sure the legs are aligned with the 90 degree marker on the protractor.)

You want to keep the dial between 80 and 120 throughout the exercise. Now while maintaining the pressure lower your legs as far as you can. When you deviate from the 80-120 range, I will ask you to stop. We will repeat the test 3x.

### 14.3.4 Impact of Pilates Wall Unit on Core Stability Observations and Instruction for Plank Test

Plank Test

Verbal Instruction: We will be doing a plank on your forearms. Remember while in the plank you want to keep the head aligned, the hips inline with the shoulders, the legs straight, and don't collapse in the shoulders. Come to all fours, now lower to your forearms, extend one leg and then the other. Now hold this with correct form as long as you can.

The examiner should make sure the participant to doing the following during testing:

- Maintain the head in line with the shoulders
- Legs should stay straight throughout
- Pelvis should not be arched
- Pelvis should not drop
- Pelvis should not be higher than the height of the shoulder blades
- Shoulders should not collapse

### 14.4 Teacher Observation and Score Rubric for Movement Test for Study #2

**Impact of Pilates Mat on Core Stability and Dance Performance**
**Movement Phrase**
**Teacher Analysis and Score Rubric**

Visual Cues to analyze:

| Movement | Cues |
|---|---|
| Circle through a la seconde | ▪ Proper pelvic placement<br>o vertical plane and alignment of ASIS and pubis<br>o lateral sides of the body are even and one hip is not elevated more than the other<br>▪ Engage muscular of abdominals<br>o Dancer is actively drawing in the abdominals throughout the movement<br>▪ Scapulae engagement<br>o no elevation of the scapulae is seen |
| Tilt | ▪ Proper pelvic placement<br>o vertical plane and alignment of ASIS and pubis<br>o lateral sides of the body are even<br>▪ Torso is in proper placement in relation to the pelvis and leg<br>o Dancer has the correct proportion of tilt of the torso in relation to hip placement and leg height<br>▪ Engaged muscular of abdominals<br>o Dancer is actively drawing in the abdominals throughout the movement<br>▪ Scapulae engagement<br>o no elevation of the scapulae is seen |
| Handstand | ▪ Proper pelvic placement<br>o Proper alignment of ASIS and pubis<br>o lateral sides of the body are even<br>▪ Engage muscular of abdominals |

| | |
|---|---|
| | ◦ Dancer is actively drawing in the abdominals throughout the movement<br>▪ Scapulae engagement<br>◦ no elevation of the scapulae is seen during the inversion |

Rating Scale 0-2

0 = no core engagement seen throughout movements

1 = some core engagement but not consistent through all movements

2 = core engagement throughout all movements

**RIGHT SIDE MOVEMENTS**

| RIGHT SIDE - Circle through a la seconde | | | | |
|---|---|---|---|---|
| Testing Date | Evaluator 1 | Evaluator 2 | Evaluator 3 | Average |
| Pretest | | | | |
| End of Wk 2 | | | | |
| End of Wk 4 | | | | |
| End of Wk 6 | | | | |
| Post Test | | | | |

| RIGHT SIDE - Tilt | | | | |
|---|---|---|---|---|
| Testing Date | Evaluator 1 | Evaluator 2 | Evaluator 3 | Average |
| Pretest | | | | |
| End of Wk 2 | | | | |
| End of Wk 4 | | | | |
| End of Wk 6 | | | | |
| Post Test | | | | |

| RIGHT SIDE - Handstand | | | | |
|---|---|---|---|---|
| Testing Date | Evaluator 1 | Evaluator 2 | Evaluator 3 | Average |
| Pretest | | | | |
| End of Wk 2 | | | | |
| End of Wk 4 | | | | |
| End of Wk 6 | | | | |
| Post Test | | | | |

**LEFT SIDE MOVEMENTS**

| LEFT SIDE - Circle through a la seconde | | | | |
|---|---|---|---|---|
| Testing Date | Evaluator 1 | Evaluator 2 | Evaluator 3 | Average |
| Pretest | | | | |
| End of Wk 2 | | | | |
| End of Wk 4 | | | | |
| End of Wk 6 | | | | |
| Post Test | | | | |

| LEFT SIDE - Tilt | | | | |
|---|---|---|---|---|
| Testing Date | Evaluator 1 | Evaluator 2 | Evaluator 3 | Average |
| Pretest | | | | |
| End of Wk 2 | | | | |
| End of Wk 4 | | | | |
| End of Wk 6 | | | | |
| Post Test | | | | |

| LEFT SIDE - Handstand | | | | |
|---|---|---|---|---|
| Testing Date | Evaluator 1 | Evaluator 2 | Evaluator 3 | Average |
| Pretest | | | | |
| End of Wk 2 | | | | |
| End of Wk 4 | | | | |
| End of Wk 6 | | | | |
| Post Test | | | | |

# 15 Appendices – Data Collection Forms

## 15.1 Data Collection Form for Study #2

**The Effectiveness of Pilates Mat on Core Stability and Dance Performance**
**Data Collection Sheets**

*NOTE: Use this data collection sheet in tandem with the Observations and Instruction Sheets

PLANK TEST

| Participant # | Plank<br><br>REPS in seconds | Reasoning Comment |
|---|---|---|
| | | |
| | | |
| | | |

## 15.2 Data Collection Form for Study #3

**The Effectiveness of Pilates Wall Unit on Core Stability**
**Data Collection Sheets**

*NOTE: Use this data collection sheet in tandem with the Observations and Instruction Sheets

**NEUTRAL PELVIS – INACTIVE AND ACTIVE TEST**

| Participant # | Inactive Neutral Pelvis | If no, reasoning | Active Neutral Pelvis | If no, reasoning |
|---|---|---|---|---|
| | YES or NO | | YES or NO | |
| | YES or NO | | YES or NO | |
| | YES or NO | | YES or NO | |
| | YES or NO | | YES or NO | |

**ABDOMINAL TESTS – UPPER AND LOWER**

| Participant # | Pilates-based Abdominal Curl REPS | Reasoning Comment | Lower Abdominal REPS | Reasoning Comment |
|---|---|---|---|---|
| | | | | |
| | | | | |
| | | | | |

**PLANK TEST**

| Participant # | Plank REPS in seconds | Reasoning Comment |
|---|---|---|
| | | |
| | | |
| | | |

## 16 Publications

Bergeron, C. S., Greenwood, M., Smith, T., & Wyon, M. (2017). Pilates Training for Dancers: A Systematic Review. National Dance Society Journal, 2.

Bergeron, C. S., Smith, T., Welsh, T., and Wyon, M. (2024). The Effects of Pilates Mat Classes on Abdominal Core Control and Dance Performance: A Pilot Study. Journal of Dance Education. https://doi.org/10.1080/15290824.2024.2348466

Bergeron, C. S., Smith, T., Greenwood, M., and Wyon, M. (2024). The efficacy of Pilates-based Exercises on Rectus Abdominis engagement in comparison with the FITNESSGRAM in Collegiate Dancers. Journal of Bodywork and Movement Therapies. https://doi.org/10.1016/j.jbmt.2024.03.071

Bergeron, C. S., Smith, T., Welsh, T., and Wyon, M. (2024). Journal of Theatre, Dance, and Performance Training. Submitted, waiting for response