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Refined Muscle Recruitment and Self-Fascia Release: A Study on the Effects of a New Protocol for Dance Training and Injury Prevention

THESIS

submitted in partial satisfaction of the requirements
for the degree of

MASTER OF FINE ARTS

in Dance

by

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DEDICATION

TO:

The LORD Jesus Christ

"In **HIM** are hid all of the treasures of wisdom and knowledge." **Colossians 2:3**

and

Michael Richard Blackwell
&
Christy Lee Blackwell

"A person standing alone can be attacked and defeated, but two can stand back-to-back and conquer. Three are even better, for a triple-braided cord is not easily broken." **Ecclesiastes 4:12**

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ABSTRACT OF THESIS

Refined Muscle Recruitment and Self-Fascia Release: A Study on the Effects of a New Protocol for Dance Training and Injury Prevention

by

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Master of Fine Arts in Dance

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Dr. Kelli Sharp, Chair

High injury incidence is an epidemic among the dance population. Dance science literature targets chronic pain and dynamic balance deficits as key dance-injury etiologies. An intervention protocol copulated by the lead researcher aimed to address these etiologies utilizing two components: 1. self-myofascial release (SMR) utilizing foam rollers and soft balls and 2. exercises designed to economize dance-specific movement. Larger implications embedded in this research warrant practical solutions to the dance injury epidemic, suggesting injury prevention techniques as a means in performance enhancement.

Changes in dynamic balance and subjects' pain experience in dance class were assessed in a 5-week intervention; collegiate dancers met for 55 minutes, twice a week and partook in a pre-and post-test series. Balance was measured using the Star Excursion Balance Test, pain experience was measured using the VAS Numeric Pain Scale. Repeated measures T-test in statistical analysis revealed a post-test decrease in bilateral leg-reach asymmetry. No changes were observed in SEBT leg-reach distances or experiences of pain. Asymmetry decreases on the SEBT test suggest intervention efficacy for injury prevention—unilateral dominance is clinically

evaluative for the identification of individuals at-risk of injury. No effect can be stated on intervention efficacy to increase postural control or decrease pain. No significance was observed statistically in leg reach distance or pain scores. Lead researcher suggests further studies with larger sample sizes and stricter controls to further assess intervention effect on pain and dynamic balance.

INTRODUCTION

Anecdotal Curiosity

My life as a dancer is interwoven with biomechanical study and injury prevention. Congenital deformities such as severe scoliosis, the absence of a right hip socket, deformed bones on the *demi-pointes* of my feet (metatarsal bones), and jaw abnormalities affecting the neck and skull, were among the challenges I attempted to overcome as a young woman. Ballet was suggested as a form of therapeutic exercise by an orthopedic surgeon who also performed my first hip construction when I was 2 ½ years old. Standing at the barre over a year later in ballet class, I started on a journey that would help me to not only increase functionality in my hip, but also to bring order and control to my limbs and torso, organizing them in a way that facilitates their obedience to willful movement. Unexpectedly, I fell deeply and shamelessly in love with the art form.

Thirty years later, serious study in ballet and professional work in other dance forms had taken toll on my body, leading to some invasive restorative efforts via orthopedic surgery. Perioacetabular Osteotomy, a procedure designed to reconstruct the dysplastic hip was my third and most invasive adult procedure. Post-operation, I questioned the success of the surgery. Doctors were pleased with my post-operative x-rays but my pain level was unbearable. Unable to walk unassisted, I limped through my daily routine with a cane and crutches and in need of constant pain medication. Other patients fully recovered after undergoing the identical procedure, however my most tenacious efforts in physical therapy proved arduous and unproductive.

Uncontrollable crying spells, cold sweats from the pain, chills and nausea became increasingly regular in their occurrence over the course of six months. Sleep was frequently interrupted by unyielding, high-level pain all throughout my body, exhausting my nervous system and leading to a compromised immune response. Autoimmune disease, as well as chronic fatigue and digestive infections arose. Planning for long term disability in terms of my vocation, living environment, and relationships consumed my time, finances, and energy and I began a plan of career change outside of the field of dance in humble acceptance of my new "normal".

Empathetic to my situation because of her own physical adversities, a colleague in the physical sciences suggested I try a manual therapy called myofascial release (tactile release of musculoskeletal connective tissue). Myofascial release paved a road to recovery for her after two years of relentless pain and total bed-rest following an acute back injury. Twenty-one visits with spine specialists led only to agnostic prognoses, though it was in her twenty-first visit that myofascial release was proposed as an alternative solution by the doctor. Upon completion of three (3) manual sessions with a myofascial release practitioner, she sat upright for the first time in two years. My first session working with a myofascial specialist is also a riveting story. After one appointment with an experienced *Rolfer* (myofascial release specialist that emphasizes skeletal alignment), my walking improved by about sixty percent. I thought I was dreaming when I stepped off the table and felt my right leg bear weight during the post-session gait test. Two more appointments with the same *Rolfer*, and I was walking completely unassisted, and with my pain cut in half, and my hope multiplied exponentially.

What exactly was this Rolfer attuned to? And why hadn't it been made available to me as part of my treatment working with doctors practicing western medicine? It became so important to me to research this topic, that I left a full-time paid position as director of a high school dance program to study under the direction of Dr. Kelli Sharp, investigating formally the myofascial system and its relationship to movement and the physical body. Preservation and protection of the physical instrument (that is also the artistic medium in dance) is part of what I consider my life's work—a key component to assisting performers in the pursuit of lasting, prosperous careers. Visions of dancers experiencing the freedom of dynamism and healthy, free-moving bodies, responsive to their will to move to a degree they never thought possible, is the inspiration that inspires me to conduct this research.

CHAPTER ONE

Injury Prevalence and Causation

Dance as an art form represents extremely high rates of injury (Russel, 2013, Baker et al., 2010, Ojofeitimi and Bronner, 2011, Noon et al., 2010, Allen et. al, 2013). Allen et al. published a study that assessed injury prevalence in a professional ballet company over the course of 1 year, and recorded 355 injuries in 52 dancers (a mean of nearly seven injuries per dancer in a single year)[1] (Allen et al., 2013). Another study published by Robert et al. searched 17 years-worth of data published by the National Electronic Injury Surveillance System (United States) for reports that fit criterion of dance-related injuries among individuals ages 3 to 19 (Roberts et al. 1991-2007). The study found 113,084 injuries in this age and activity group during the span of the study (Roberts et al., 1991-2007). Researchers Luke et al., Thomas and Tarr, and Bowling investigated injuries among working dancers, and observed 84% to 95% of people from the professional dance populous incur injury during the span of a dance career (Luke et al., 2002, Thomas and Tarr, 2009, Bowling, 1989).

While a diverse range of injuries can be linked to the dance profession, the most prominent are overuse injuries (Caine et al. 2015). Dance classes can last up to 1.5 hours, followed by rehearsals that can last up to 5 hours. Exposure to highly demanding physical activity for greater than six (6) hours a day is commonplace for the dance professional and a sufficiently ripe condition for the development of chronic injury (Miller, 2006). Unspoken expectations in dance culture to "dance through" micro-injuries was of topical importance in one article published by the *Journal of Dance Medicine and Science*, written to expose the tendency

[1] Russel, 2013, was first to make this inference.

of young artists to dance through pain in an attempt to avoid [most] teachers' misjudgment on physical or mental commitment (Murgia, 2013). Time needed for tissue repair and regeneration is compromised each time dancers concede to these implied expectations, ultimately leading to a progression of symptoms, which limits further their performance (Murgia, 2013; Jenkinson and Bolin, 2001).

Resting while injured and setting reasonable limits on dance training may seem like an obvious solution to the injury epidemic in the dance population. It fails however, to address dance injury etiology. Identification of dance injury causality, and inquiry into preventive measures for the identified etiological source is a primary goal of this research. Determining a "gold standard" for injury prevention warrants closer observation of the practices of high-level professionals who manage to sustain long careers with minimal time off.

International ballet star Sylvie Guillem, for example, an exceptional example that warrants observation, didn't incur her first injury until age 36 (Lister, 2013). Some may claim Guillem was genetically predisposed to dance, rising above the highly populated gene pool of mediocrity with exceptional dance-DNA. From this perspective, Guillem's robust career as a dance artist could be compared to winning a 'straight up' bet in roulette. However, it is important to point out that hypermobility of the foot, a visually observable trait of Guillem, predisposes dancers to injury (Steinberg et al., 2016) as does knee hyperextension, another of Guillem's observable traits (Scheper et al. 2012; Fornalski et al., 2008, Noyes et al., 1996). With more than genetic luck at play, a substantial portion of Guillem's success in dance can be attributed to her training and technical expertise. If an average of 59.5% of pre-professional ballet dancers may be incurring an injury, then 40.5% are not, though the training is virtually

identical among both populations (Caine et al., 2015). To direct forward this research, it is necessary to determine whether significant physical differences exist among populations having similar or identical dance training programs.

Dancers and Training Deficits

Dancers are subject to the same physical demands as athletes, and dance injuries have been linked to poor levels of physical and cardiovascular fitness, which often resemble those found in sedentary individuals (Koutedakis and Janurtas, 2004). Researchers Koutedakis and Janurtas link dance injuries to poor levels of individual physical fitness, claiming that physical fitness among dancers is the "Achilles heel" of dance training; i.e.: the vulnerable aspect of an otherwise strong operation[2] (2004). Aerobic power, muscular strength, muscular balance, and bone and joint integrity that make up this proverbial 'heel', become compromised areas of the dancers' physical composition because of an unfounded view in the dance world—that participating in exercise training that is not directly related to dance will bear nocuous consequences on a dance-specific physical aesthetic (Koutedakis and Janurtas, 2004).

One component of the 'Achilles Heel' theory, (or poor physical fitness attributes among dancers) requires specificity and clarification in the practical consideration of dance training—the term "muscular strength". Australian researcher Phillips wrote an article that critiqued muscular strength programs, specifying their difference in implementation and effect from muscle stability programs (Phillips, 2004). In this article, Phillips, contests a popular belief in the world of sport and athletic training: increase in power and strength of various muscles will inevitably enhance athletic performance (Phillips, 2004). Phillips offers an evidence-based

[2] 'Achilles heel' is a Greek Literature reference from Homer's *Iliad* where the protagonist, Achilles, a soldier in the Trojan War, becomes susceptible to mortality because of a peculiarly vulnerable body region: his Achilles heel (Burgess, 1995).

counter-argument, pointing out that an increase in muscle mass and torque production aren't always directly correlated to an increase in physical performance[3] (Phillips, 2004). Though muscle strengthening regimes can be of value, Phillips urges dancers to use motor learning strategies in the employment of muscle stability techniques (Phillips, 2004). Efficient recruitment of muscle activity is important, and stability training, i.e.: well integrated innervation of local and global muscles to control movement against gravity[4], is vital to increasing muscle efficiency (Phillips, 2004). Phillips does not stand alone in the assertion of motor recruitment as a key component for movement efficiency, one that is foundationally relevant to dance training. Researchers Nemececk and Chatfield's authored a publication urging dance instructors to acquire proficient cognition of motor learning principles due to their proven ability to maximize and expedite learning for the student dancer (2007). Another article surveying literature on biomechanical research in dance (from year 1970 to 2009), observed a coherent, prevailing theme in the studies on dance and motor control: elite dancers demonstrate different and superior motor strategies than novices or non-dancers (Wilmerding and Krasnow, 2011). Researcher Leiderbach utilized principles of motor control to explain the assessment of healthy movement in the context of dance science rehabilitation (2000). Leiderbach asserts reliable dance clinicians must possess 'expert' knowledge of the neuromuscular system, carrying out their [clinician/practitioner] work from a solid foundation of basic exercise and sport science (2000).

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[3] The reference supporting this claim: Clarkson PM, Thompson HS: *Drugs and Sport*: Research findings and limitations. Sports Med 24(6) :366- 384, 1997.

[4] Phillips references (Hodges and Richardson 1999, and Bergmark, 1989).

Dance science literature is unanimous in the notion that advanced, refined utilization of motor control systems is observably present in advanced dancers (Calvo-Merino 2005, Cross, 2006, Blasing et al., 2012, Hanggi. 2010). Motor control strategies have been proposed as one of the means to solve an epidemic of dance injuries, and suggested as a performance enhancement strategy for dance movement execution (Liederbach, 2010, Calvo-Merino et al., 2005). Simply defined, motor control is a set of internal processes associated with practice or experience that changes one's competency to [voluntarily] respond [in movement] (Schmidt, 1988). Chapter 3 below addresses principles of motor control in depth.

CHAPTER TWO

Fascia Defined

Muscles and their role in moving the dancing body are well understood by dance trainees and dance clinicians. Integral to kinetic function, muscle anatomy, and the internal and external architecture of the muscle, is a less prevalent mechanism called fasciae: connective tissue throughout the body that forms a web from head to foot without interruption (Barnes, 1990). Anatomical models of the muscle identify muscle fascia under the following three muscle structure components: 1. *Perimysium*, fascia that separates muscle fascicles (bundles of nerve or muscle fibers), 2. *Endomysium*, fascia that separates individual muscle or nerve fibers and operates as a continuous network of connective tissue, and 3. *Epimysium,* fascia that surrounds each individual muscle that is continuous with tendons that attach muscle to bones (Purslow and Delage, 2002). Fasciae are composed of collagen fibers (and occasionally also elastin fibers) in a matrix of hydrated proteoglycans[6] (PGs), which link together the collagen fiber networks in these structures (Purslow and Delage, 2002). Between the connective tissue layers is a cellular layer identified by fascia researchers as ground substance, a viscous medium with a jelly-like property (Barnes, 1990). In the last decade of research, it was discovered that fascia is mechanically active (contractible) with proprioceptive and nociceptive functions, two

[6] Proteins with long chains of sugars attached in a covalent bond. Proteoglycan function within the fascia is mainly to provide hydration and swelling pressure to the tissue enabling it to withstand compressional forces (Yanagishita, 1993).

functions relevant to dance training that will be discussed further in subsequent chapters (Krause et al, 2016[7]).

Myofascial System and Myofascial Release

Fascia involved in contractibility and repair of skeletal muscle is schematically referred to as the *myofascial* system, or, a system made up of a network of connective tissue of the associated with skeletal muscle (*myo* is the Latin word for muscle) (Meyers, 2012). Malfunction of the myofascial system due to trauma, posture, or inflammation can create binding of the fascia, resulting in abnormal pressure on nerves, muscles, bones, or organs and pain or improper muscle response throughout the body[8] (Barnes 1990). Myofascial release is a manual technique that aims to release connective tissue and rehydrate the cellular ground substance within the myofascial system through touch (Barnes, 1990). Hands-on techniques are the most common practice for myofascial release (much like massage therapy), through which the musculoskeletal fascia is hydrated and elasticized, promoting healing throughout the musculoskeletal system (Paolini, 2009). Due to the high expense of hands-on techniques, self-administered myofascial release deserves investigation for benefits to the dance population, as it proposes a cost-effective alternative to hands-on fascial manipulation, with similar physiological benefits (Renan-Ordine et al. 2011; Healy et al. 2014; Schroeder and Best, 2015).

[7] Krause et al. credits the following researchers for contributing to this claim (Yahia et al. 1992; Schleip et al. 2005; Stecco et al. 2006, 2007, 2008, 2013; Bhattacharya et al. 2010; Tesarz et al. 2011).

[8] Barnes further suggests than an extremely high percentage of people suffering with pain and/or lack of motion may be having fascia problems; but most go undiagnosed. Standard tests, such as x-rays, mylelograms, CAT Scans, electromyography, etc. do not show fascial restrictions.

Self-Myofascial Release

A survey of the literature on Self-Myofascial Release (SMR)—release techniques that can be self-administered with the assistance of balls or foam rollers—suggests that SMR may offer a possible cost-effective solution for dancers to maintain wellness in the myofascial system. SMR techniques are designed to bring relief to the body by relaxing contracted muscles and improving blood and lymphatic flow through movement and hydration of the ground substance of the fascia[9]. Sue Hitzmann, M.S., N.M.T., creator of the MELT method: a codified self-myofascial release (SMR) method designed to rehydrate connective tissue and restore balance in the nervous system, believes her SMR program presents an independently sustainable solution to maintenance of the fascial system (Hitzmann, 2013). Clinical studies to test the efficacy of SMR are emerging slowly, however at the time of this authorship there are no studies using dancers as subjects.

Experimental investigations of the effectiveness of SMR on healthy, adult subjects show improvements in muscle recovery and range of motion, suggesting SMR as an effective therapeutic tool in fitness and the physiological sciences (MacDonald et al., 2013). Sanjana et el. conducted a study specifically testing the MELT Method and its effect on thoracolumbar connective tissue, and found subjects using MELT experienced a significant decrease in pain and connective tissue thickness in comparison to controls, and a simultaneous increase in flexibility (Sanjana et al. 2017). Healey et al. experimented with foam rolling SMR and evaluated its effect on three specific outcomes: performance, fatigue and soreness (2014). Foam roll SMR did not significantly improve physical performance in this study, however, subjects that used foam rolling found significantly less fatigue, soreness, and exertion post-exercise when

[9] Definition adapted from the MELT Method Blog (2013, Oct 21).

compared with controls (Healey et al. 2014). Consequently, Healy et al. predicted that over a longer extended period, acute workout time and volume would increase as a byproduct of decreased fatigue, soreness, and exertion (2014). Cheatham et al. 2015 systematically reviewed and summarized data concerning SMR from fourteen studies investigating the effects of a foam roller or roller massager on range of motion (ROM), muscle recovery, and performance (Cheatham et al., 2015). Data collection from fourteen studies showed increased ROM in subjects using SMR, with no decrease in muscle performance, as well as decrements of delayed-onset of muscle soreness (DOMS) in subjects using SMR (Cheatham et al., 2015). In a niche experiment designed by research team Grieve et al., SMR was utilized to investigate a specific theory about the organization of fascial tissue. "Anatomy Trains" proposed by myofascial expert Tom Meyers suggests that several fascial meridians exist in the body, one of them is a superficial back line (SBL) of fascia[10] (Meyers, 2013). Meyers' hypothesis was investigated by testing the immediate effect of bilateral self-myofascial release on the plantar surface of the feet on hamstring and lumbar spine stability (Grieve et al., 2015). Acute improvement was observed; hamstring flexibility (tested by use of the sit-and-reach test) increased significantly in the SMR group when compared with controls, validating the use of SMR for range of motion improvement of the hamstrings and lumbar spine, and, offering empirical evidence in of support of Tom Meyer's functional theory of fascial organization,[11] specifically, the superficial back fascial line (Grieve et al. 2015).

[10] The theorized Superficial Back Line (SBL) connects and protects the entire back surface of the body from the bottom of the foot to the top of the head in two pieces – toes to knees and knees to brow [forehead] (Meyers, 2013).

[11] *Anatomy Trains* is the name of Tom Meyers model of fascial organization and the name of a book he authored in 2013.

SMR techniques were sought out for intervention design in this research due to evidence in the literature that SMR decreases muscle soreness and increases range of motion (Cheathem et al. 2015, Grieve et al. 2015). SMR is indeed, relevant to the dance population as muscle soreness/muscle pain must be continually addressed and assessed by dancers. Furthermore, studies point to compromised sensory-motor control, a key mechanism of advanced dance execution (refer to the end of Chapter 1) when pain/delayed onset muscle soreness is present (Slater et al. 2016, Ervilha et al. 2005, O'Sullivan, 2005, Arendt-Nielsen et al. 2008). SMR's proven ability to restore range of motion (ROM) is especially necessary for dancers, as movement ranges facilitated by dance technique are far greater than ranges utilized by the average population. Additionally, ROM restoration has been inextricably linked to motor recovery, while measures of ROM are utilized by clinicians as an outcome measure for injury rehabilitation (Hogan, 2008, Chae, 2015). SMR, utilized in the intervention designed for this research, holds promise as an effective tool for dancers in the enterprise of injury prevention and performance enhancement (Schroeder and Best, 2015).

CHAPTER 3

MOTOR CONTROL MECHANISMS

Motor control is the study of how transposition of a thought about movement (how one predetermines their next movement in terms of speed, force, etc.) can be expressed in a physical manifestation of that thought. Neural control can be refined through the executive command of motor neurons, a vital to knowing how best to train dancers (refer to Chapter 1). Australian dance rehabilitation expert Lisa Howell asserts that dancers tend to "over-recruit" their muscles[12], i.e.: they recruit voluntary signals to action at unnecessary speads[13] from motor units for a given muscle use, thereby inducing fatigue and increasing the likelihood of injuries (Howell, 5). One primary objective in this research's intervention was design was the fine-tuning of contractions as the muscles engage in the execution of dance movement; research shows a strong correlation between motor control and quality of the movement from a dancer (Calvo-Merino 2005, Cross, 2006, Blasing et al., 2012, Hanggi. 2010).

Physiological processes of motor control emphasize three distinct areas of the brain : the primary motor cortex, the premotor cortex, and the supplementary motor area (SMA) (Knierim, 1997). The primary motor cortex is responsible for movement initiation and coordination of movements, as well as control and learning of postural coordination (Peterson et al. 2009, Anderson and Megill, 2011). The premotor cortex controls the organization of movement prior to initiation, involving rhythmic coordination of transitions between movements, as well as planning eye movements and orienting visual/spatial attention (Casarotti et. al, 2012,

[12] Paraphrased from Lisa Howell's *Perfect Form Physiotherapy* Teacher's Training Manual, pg. 5
[13] 'Rate Code' is the name of the motor unit signal that determines the amount of force to be exerted by a muscle. An increase in the rate [frequency] of action potentials fired by a motor neuron increases the force innervated by that motor unit (Knierim, 1998).

Anderson and Megill, 2011). The supplementary motor cortex (SMA) controls sequential movements and executes the preconceived planning and organization of movement. (Parsons, 2005, Anderson and Megill, 2011, Knierim, 1997).

Neurons, the basic component of the nervous system, receive and send information throughout the entire nervous system and provide the means for cortical programming and motor control programing. (Anderson and Megill, 2011). Neurons are classified by function: sensory neurons send information to the central nervous system (CNS), interneurons function within the CNS, and motor neurons send information **from** the CNS to muscle fibers (Anderson and Megill, 2011). Motor neurons are classified into two types:

1. Alpha motor neurons, significant to this chapter, exist predominantly in the spinal cord and have branching connections[14] with the skeletal muscle fibers. Alpha motor neurons make up the motor [output] component of motor control, innervating muscles via nerve impulses from the extrapyramidal and corticospinal tracts: neural tracts that relay information from different portions of the brain, through the spinal column, eventually branching out to transmit the nerve impulse to muscle fibers (Anderson and Magill, 2011).

2. Gamma motor neurons supply a portion of the skeletal muscle called intrafusal fibers discussed further below (Knerim, 1998).

Alpha motor neurons and the total number of muscle fibers they innervate are called motor units (Knerim, 1998)**.** Motor units can be defined simply as **f**unctional units of motor control for the innervation of the muscles (Anderson and Megil, 2011). Voluntary control or level of force generated by a muscle is a process known as motor recruitment**:** recruitment of a specific number of motor units to match the voluntary command of specific muscle force

[14] *Dendrites* is the biological term for the "branching connections" described here.

(Anderson and Megil, 2011). Alpha motor neurons can also be called efferent neurons or effector neurons, as they effect changes in muscle activity upon receipt of motor commands (Knerim, 1998). Alpha motor neurons that innervate skeletal muscle are directly related to motor control, thus relating directly to dance training. Though not directly relevant to this research, it is important to mention another grouping of alpha motor neurons exist, playing an important part in the autonomic nervous system with effector neurons that innervate glands and smooth muscle (Knerim, 1998).

Alpha motor neurons receive information about how to innervate a muscle in part, from the sensory component of the motor system (Anderson and Megill, 2011). Sensory receptors beneath the skin are called mechanoreceptors; they deliver sensory information from the skin to the central nervous system related to pain, temperature, and movement. (Anderson and Megill, 2011). One unique type of mechanoreceptor located within a muscle is the muscle spindle,[15] containing both intrafusal muscle fibers and sensory fibers (Knerim, 1998). Gamma motor neurons within the muscle spindle activate the intrafusal muscle fibers, keeping the muscle spindle taught, and therefore sensitive to stretch, over a wide range of muscle lengths (Knerim, 1998). Muscle spindles also contain stretch receptors (afferent neurons) that detect the amount of stretch of the muscle as well as the speed of the stretch of the muscle, information that is communicated along the dorsal root of the spinal cord to the brain to help orient the body spatially – a process known as proprioception (Anderson and Megill, 2011). In addition to muscle spindles, receptors called Golgi tendons, located inside muscle-tendon junctions, deliver specialized signals to the nervous system that make up a large part of

[15] Each muscle contains many muscle spindles; muscles that are necessary for fine movements contain more spindles than muscles that are used for coarse movements (Knerim, 1998).

proprioceptive input (Van der Wal, 2013). Golgi tendon organs are sack-like, made of numerous collagen fibers that signal information about the amount of force or load being applied to the muscle (Knerim, 1998).

Undoubtedly, movement implementation through motor control requires numerous neurophysiologic events that involve the cooperative interaction of several cortical structures that make up the central nervous system, in addition to the sensory and motor systems of the peripheral nervous system (Van der Wal, 2013). Motor control activity involved in the execution of dance movements, subsequently, synthesize a vastly complex array of neural activities that underlie voluntary processes of seemingly simple behavioral activities (Cross, 2006, Anderson and Megill, 2011).

Motor Control in Dance Technique

Evidenced in peer-reviewed literature is the strong correlation between motor control and the refined execution of dance technique (Cross, 2016, Liederback, 2010). One study that investigated muscle coordination during a ballet *jeté*[16] found that skilled ballet dancers selectively applied minimal muscle tension at the reversal point of ballistic (jumping) leg movements, even though torque was maximal in this position (Lepelley et. al 2006). Another study comparing postural control during an *arabesque développé*[17] in three [skill] levels of dancers discovered that postural control worked synergistically with segmental timing (limb extension timing) for dancers of the highest level (Bronner, 2012). Mastery of motor control was well illustrated in this example;

[16] Throwing step. A jump from one foot to the other in which the working leg is brushed into the air and appears to have been thrown. (Defined by *ABT* online dictionary; **terms**: *jeté*).
[17] Time-developed movement into a position of the body in profile, supported on one leg, which can be straight or bent with the other leg extended behind at right angles to it, and the arms held in various harmonious positions creating the longest possible line from fingertips to toes. Defined by *ABT* online dictionary; **terms**: *arabesque, devéloppé*).

the advanced dancers performing the *arabesque* demonstrated well-timed execution in the movement of the extremeties, executing the *arabesque* with timed extremities and controlled posture (Bronner,2012). Advanced dancers did not prioritize postural control or gestural control but rather, coordinated both posture and gesture limbs with timing that regulated inertial forces generated by large limb and trunk accelerations (Bronner, 2012). Hanggi et al. further investigated the sensorimotor network of advanced ballet dancers using magnetic resonance-based morphometry, and observed reduced neural activity in skilled compared with nonskilled subjects, pointing to efficient neural-motor activity in the professional network of ballet dancers (2010). Among several studies that involve dance technique and motor testing, refined postural control (core control) is emphasized continually for its necessity in dance execution; studies on motor control are unanimous in their observation of exceptional competency in the ability to make spontaneous postural adjustments in advanced dancers (Simmons, 2005, Bronner, 2012, Schmit et al, 2005, Kiefer et al. 2011). Accordingly, deficits in core stabilizing abilities have been utilized by clinicians to predict injuries (Rein, 2011, Lin, 2011, Baston, 2009). Forward progression in this research requires further investigation of postural control: specifically, how it can be evaluated and improved.

CHAPTER FOUR

DYNAMIC BALANCE

Dynamic Balance and Proprioception

Dynamic balance is a prominent topic in the disciplines of dance science and injury prevention. Human balance is achieved through several interactive systems in the body, specifically, the visual, vestibular, auditory, motor, and higher level premotor systems (Horak 1997). Of all the balance properties, the most salient in dance science is proprioception, the body's ability know and perceive itself accurately in terms of spatiality (Baston, 2009, Schmitt, 2005, Leanderson, 1996). Physiological processes involving proprioception occur when peripheral input from sensory nerve endings (including input from Golgi tendon organs and muscle spindles; refer to chapter 3) travel through the central and peripheral nervous systems communicate with the subcortical and cortical areas of the brain (Pearson, 2002). Co-laboring with Golgi tendon organs and muscle spindle receptors in proprioceptive specific tasks are joint receptors, located inside a joint and communicating changes in force, rotation, movement and angle applied to that joint, especially at the extreme limits of angular movement (Anderson and Megill, 2011).

Stated simply, proprioception is the body's integration of internal responses to an external environment enabling the body to achieve balance and postural control (Knerim, 1998). G. Batson, P.T. published an article on proprioception and dancers, stating that a healthy, responsive proprioceptive system appears integral to the way dancers monitor themselves, learn, and self-correct, implying a potential advantage in motor planning, motor control, and postural stability (2009). Proprioceptive mechanisms are used to ensure proper

orientation of bodies in space with joints that are well aligned in the postural relationship, ultimately improv dance performance (Baston, 2009, Jola et al. 2011). One study on dancers performing pirouettes showed that dancers optimize the relation of foot distance and weight distribution during their fourth position preparation (Sugano and Laws, 2002). This is because single leg turns require an aligned axial skeleton, an orientation made possible by proprioceptive mechanisms (Sugano and Laws, 2002). Moreover, professional ballet dancers performed better in comparison with controls when given a "position-matching" task for the hand in space, a study that revealed not only stronger spatial orientation in the dancers, but the utility of proprioception by the dancers more than vision to complete the task (Ramsay and Riddoch, 2001). In another study measuring vestibular perturbation (dancers executing consecutive pirouettes thereby rigorously stimulating the vestibular system) and fatiguing effects on postural stability, professional dancers remained unaffected when disturbed by external perturbations (Hopper et al., 2014). Conversely, pre-professional and recreational dancers under the same conditions failed to maintain their postural balance effectively, exposing a higher level of skill-specific motor training in dancers of the highest level (Hopper et al., 2014). Several studies using non-dancers as subjects illuminated the functional benefit of proprioception and postural orientation in space, revealing the benefit of strong proprioceptive properties for the larger population in addition to dancers (Edwards et al; Maritus 2014; Mancini 2010). Proprioception is essential to human beings for integration and functionally with the physical environment, while core control associated with postural orientation effects not only a dancers proficiency, it also has a large effect on a person's functional tasks, i.e.:

carrying loads of laundry, grocery sacks, and picking up a small child (Anderson and Megill, 2011).

Proprioceptive control testing through dynamic balance was chosen as an outcome measure in this research because of its proven efficacy to prevent injuries (Emery et al., 2005, Zech et al. 2010, Steffen et al. 2013, Meyer et al. 2006). One six-year prospective study on professional basketball players measured the effect of proprioceptive training interventions on injury incidence, with level of difficulty increases in proprioceptive protocol every two-years (Riva et al., 2015). Single leg balance was the main outcome measure of proprioceptive competency for this study (Riva et al., 2015). In the six-year research period, the basketball players improved proprioceptive control by 72%, and experienced an overall 81% decrease in ankle sprains, 78% decrease in low back pain, and 65% decrease in knee sprains (Riva et al. 2015). Literature points to more than one benefit of proprioceptive competency concerning dancers: integral to core control and the body's spatial orientation, it is also effective injury prevention strategy that has promise for the benefit of dance technique (Riva et al. 2015, Steffen et al. 2013).

Dynamic Balance and Proprioception

Fundamental components of dynamic balance and pain from the scientific perspective greatly influenced both components (muscle recruitment and SFR) of protocol development for this research. In addition to the somatosensory system, a focal point of this chapter, visual and vestibular systems are also necessary for maintaining balance in all conditions of stance and locomotion (refer to chapter six and the Myofascia Release addendum in the appendix to see how visual and vestibular components were considered in the intervention protocol)

(Wilmerding and Krasnow, 2009). In static and dynamic balance activities, the nervous system gives more attention to somatosensory input for adults than to visual or vestibular contributions, however the nature of dance causes frequent perturbations in visual stimuli, meaning that dancers also need excellent proprioceptive and visual responses (Wilmerding and Krasnow, 2009).

CHAPTER FIVE

ADDRESSING PAIN

Pain Defined

Pain is sensed frequently in the dancing body, especially in its moderate forms such as soreness, tightness, bruising, and blistering. Emphasis on the experience of pain as it limits tissue repair, motor control, mobility, and healthy movement is relevant to the objetives of this research (Baston, 2007, Ostwald et al. 2004, Roussel et al. 2013, Roussel et al., 2009). *International Association for the Study of Pain* defines pain as an unpleasant sensory and emotional experience associated with actual or potential tissue damage (2016). Pain perception, or nociception (from the Latin word for "hurt"), is the process by which a painful stimulus is relayed from the site of stimulation to the central nervous system (Freudenrich, 1). Pain neurons are sensory receptors called nociceptors and belong to the peripheral nervous system (PNS); they communicate sensory input to the executive control center of the brain (Freudenrich, 2). Freudenrich, Ph.D. lists the biological process called the reflex arc that takes place when a human experiences pain; for example, cutting their hand with a knife:

- Mechanical stimulation from the sharp object.
- Potassium released from the insides of the damaged cells.
- Prostaglandins, histamines and bradykinin from immune cells that invade the area during inflammation.
- Substance P from nearby nerve fibers (2).

Pain was chosen as an outcome measure for this study because of the mechanical, emotional and physiological implications that it pain can induce on the body, especially in its relationship to movement (Baston, 2007, Ostwald et al. 2004, Roussel et al. 2013). Step 4 of

the reflex arc confirms pain as a tall tale sign the presence of inflammation, and while inflammation can be temporarily helpful, prolonged inflammation can also be damaging to the function of kinetic mechanisms such as joints, muscles, tendons and ligaments, as well as proprioceptive control that supports healthy movement (Zuzman, 1994, Gill and Callaghan, 1998, Newcomer et al. 2000).

Pain and Movement

Researcher R.F. Loeser asserts inflammation can be the etiological source of prolonged mechanical pathologies and cartilage damage due to central nervous system plasticity (Loeser, 2006). The central nervous has the capacity to generate potentially misleading signals about the spatial and modal nature of sensory input, often causing referred pain, some motor abnormalities, and the characteristic of peripheral tissue damage and inflammation[18] (Zuzman, 1994). One study supporting this claim tested the response of muscle activity in the trapezius on normal subjects, after pain and neural tissue were provoked (Van der Heide et al., 2001). Muscle activity was recorded with surface electromyography, and right and left elbow angles recorded pre- and post-perturbation using a electrogoinometer (Van der Heide et al., 2001). Results showed that normal pain responses and muscle responses of the trapezius muscle were observed for most of the healthy subjects; the onset of pain was highly reliable and compared favorably with detection of muscle activity (Van der Heide et al., 2001). No significant changes occurred with the onset of pain in the elbow angle between arms, revealing that in patients with unilateral or upper neck limb pain a difference between sides might be indicative of a possible neural tissue involvement (Heide et al. 2001).

[18] Zuzman credits the following researchers with this assertion: (Bovie 1989, Mense 1991ab; 1993; Waddell et a11990, Woolf 1991).

The Visual Analog Scale for Pain (VAS Numeric Pain Scale) was chosen as an outcome measure in this research to measure the subject's experience of pain, due to its clear relevance to dancers: in addition to physical discomfort, cellular changes caused by edema and associated with damaged tissue hinders mechanical performance, and thereby increases the risk of further injury (D. Gould et al. 2001, Dauphin et al. 1999, Husskison, 1974, Zuzman, 1994). Research suggests a link between observed restoration of kinetic function and the decrease in pain after an injury (Zhou et al., 2008), and, suggests that proprioceptive training can help to reduce pain symptoms (Kofotolis, 2016, Kannus, 2000). Pain prevention in the service of dance wellness and performance enhancement strategy is deserving of attention and careful analysis in dance medicine, as it is a powerful effector in the somatosensory nervous system upon which dance movement is dependent (Zuzman, 1994).

CHAPTER SIX

METHODS

Consent for this research was granted from the Institutional Review Board. Flyers were posted in the dance studios, dance bulletin boards, on Facebook and on the Claire Trevor School of the Arts Communication boards. E-mails were sent to subject who mentioned interest via word of mouth or written communication with lead researcher.

Screening and Consent

Prior to the experiment, subjects were screened and consented subjects. Each subject had the option to review the consent at home and to schedule a time to consent participating in the study. Each subject also filled out a medical history form, as this research prohibited participants with acute injuries, and students that were non-dance majors. Inclusion criteria was defined as each participant was at least eighteen years of age, currently enrolled as a Dance Major and the University of California Irvine.

Overview of Experimental Plan

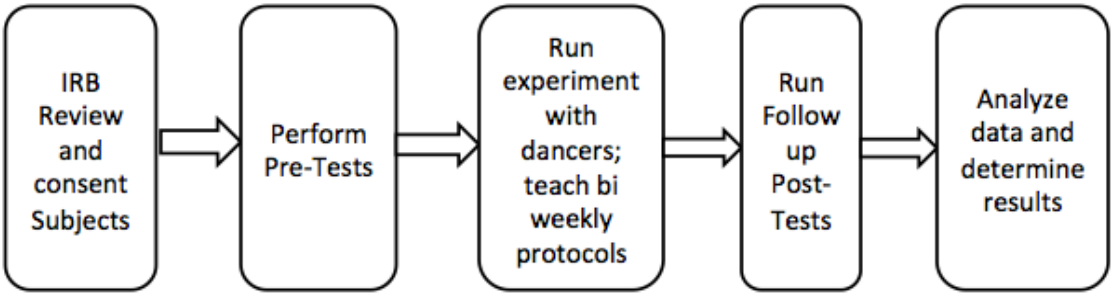


Figure 1: Overview of research chronology in five stages.

Hypothesis

Subjects that participate in muscle refinement and self-myofascial release intervention protocols designed for this research will incur an increase in dynamic balance competency and a decrease in pain experienced while dance training.

Experimental Design

Nine (9) undergraduate dance majors made up the sample group for this experiment. Prior to testing, subjects were assigned to Group 1 or Group 2, determined through process of randomization via an online randomizer[19]. Subjects were informed verbally of their group assignments prior to testing. After consenting the subjects, a pre-test evaluation was distributed for both outcome measures.

The experiment was held bi-weekly for both Group 1 and Group 2 in the spring quarter of 2016. Group 1 participated solely in the combined exercises that were compiled to the target refined motor control needed for dance. This protocol lasted approximately forty (40) minutes long. Group 2 participated in the identical program of Group A, but also participated in fifteen (15) additional minutes of combined self-fascia release techniques (also designed to accommodate the unique needs of a dancer in training), which took place after the strengthening. Once the workshop was completed, subjects participated in a post-test evaluation. The pre-test and post-test outcome measures were utilized to determine the protocol's effectiveness in improving dynamic balance and experience of pain (see Figure 1). Visual Analog [pain] Scale (VAS) and Star Excursion Balance Test (SEBT) were chosen as the evaluative methods for this research.

[19] Web address for online randomization tool (https://www.random.org/lists/).

Pre-and Post-Testing

Individual appointments were scheduled for pre- and post-test sessions, with each appointment lasting approximately 20 minutes. The Star Excursion Balance Test was administered first, followed by the VAS Numeric Pain Scale (see below for detailed descriptions of tests). Prior to formal administration of the tests, subjects were given an opportunity to ask questions. Readiness on the part of the subjects to begin the tests was verbally verified by the lead and faculty researchers. The formal beginning of the SEBT and VAS Pain Scale tests were also indicated verbally by the lead and faulty researcher. For the SEBT pre-and post-tests, subjects were told to, "go" or "begin," a command that also initiated the time record of each test. For the VAS Pain Scale tests, the verbal instruction, "Please be as honest as possible in your answers," was given to subjects by the lead researcher prior to the start of their VAS Pain Scale evaluation, which was also verbally indicated.

Each testing location was in a dance studio containing a hard floor and a mirror. Students were asked to remove their shoes for the SEBT, and all tests were conducted facing away from the mirror. No music was playing during pre- or post-test evaluations, and no persons were allowed in the studio that were not part of the research team or subjects participating in the experiment. Faculty researcher Kelli Sharp was present to supervise and aid lead researcher in the testing of subjects for the pre-test appointments.

Visual Analog Pain Scale

VAS Numeric Pain Scales rates experience of pain using an interval scale, ranging from levels one (1), to ten (10). Level one (1) indicates minor pain, level five (5) indicates moderate pain, and level ten (10) indicates maximum pain. The VAS pain scale is a one-dimensional

measure of the intensity of pain, utilized in this study to measure subjects' experience of pain while training in their dance classes (Huskisson, 1974). The VAS psychometric analysis was selected as means to the outcome measure of pain because of its prevalence as a viable method of investigation, utilized among a diverse range of disciplines such as mental health, dental health, orthopedics, oncology, and rheumatology (Hawker et al., 2011, Good et al, 2001). One-dimensional VAS scales have been found to be more sensitive to pain evaluation in comparison to other diagnostic methods such as the Numeric Rating Scale (Good et al., 2001)[20], as well a stronger detector of change between various treatments and intensities over diverse periods of time (Good et. al, 2001[21], Hawker et. al, 2011[22]).

Subjects were verbally instructed to account for kinesthetic and physical pain in their dance classes when scoring their pain experience per body region on the VAS Numeric Pain Scale tests. Although emotional pain/duress is often experienced as a co-symptom to physical pain, emotional health was not evaluated or measured in this investigation. Separate evaluations for the right and left sides of the body were marked for three physical regions: *Ankle/Foot, Knee,* and *Hip.* Neck and lumbar-thorax locations on the body were also evaluated under the following categories: *Lower Back, Upper Back* and *Neck/Shoulder*. Each physical location category listed above was assigned a pain scale for evaluation (*see Appendix C*).

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20 Good et al. in-text reference: (Huskisson, 1974) *Measurement of Pain*.

21 Good et al. in-text references: (Lee & Kieckhefer, 1989) Measuring Human Responses using Visual Analogue Scales; (Seymour, 1982) The use of pain scales in assessing the efficacy of analgesics in post-operative dental pain.

22 Hawker et al. in-text references: (Joyce et. al, 1975) Comparison of Fixed Interval and Visual Analogue Scales for Rating Chronic Pain; (Tashjian et. al, 2009) Minimal clinically important differences (MCID) and patient acceptable symptomatic state (PASS) for visual analog scales (VAS) measuring pain in patients treated for rotator cuff disease.

Procedures for administering the VAS scale for the pre-test and post-test were identical, with the only exception of time appointments of the testing sessions. Subjects for the pre-test came within a specified hour on "pre-test day", while subjects for the post-test were given the option of several testing sessions within three days and varying time blocks. Testing appointments were approximately 20 minutes in length. VAS Pain Scale tests for both pre-test and post-test provided a quiet area for testing with privacy

Star Excursion Balance Test

The Star Excursion Balance Test is the second evaluative method of choice in this experiment, and was selected for its validity in the sciences as a highly representative, non-instrumented dynamic balance test for physically active individuals (Gribble et al., 2012). It has been used to screen musculoskeletal impairments such as chronic ankle instability (Gribble et. al, 2012, Hertel et al. 2006; Delahunt et al. 2010; McKeon et al. 2008), static postural control (McKeon et. al, 2008; Nakagawa et al. 2004), and dynamic postural control (Gribble et. al, 2012; Hale et al.2007; Hoch et al. 2012). Importantly, SEBT has been used to assess the dance population, evaluating balance deficits in subjects with a history of lover extremity injury, as well as assessing dynamic balance of the dancer standing in one location [in space], such as replicated in center floor work (Batson, 2010).

Prior to conducting the SEBT, duct tape was used to create an eight-point star with the center point as the vertex. Each line was placed forty-five degrees away from the next, and each line measured 3ft. long from the vertex point. Modeled by Batson's screening test for dancers in 2010, this study labeled the directions of eight lines relative to the stance leg: anterolateral

(AL), anterior (A), anteromedial (AM), medial (M), posteromedial (PM), posterior (P), posterolateral (PL), and lateral (L) (Figure 2).

Subjects were first asked to stand with their hands either on their hips or down by their sides while taking the SEBT, eliminating the use of *port de bras:* carriage of the arms associated with dance and utilized commonly in balance and movement vocabulary in dance. Assuming the start position by standing in the middle of the eight-point star, subjects listened to a verbal explanation of the test and were given a chance to ask questions. Informed first on their start position, subjects began the test by assuming a static stance with a straight left support leg, and a right "gesture leg" curled in in a parallel "foot-hook" position with the foot off the floor. Subjects were then instructed to depart from the parallel "foot-hook" position with the right "gesture" leg, allowing it to stretch (support leg was permitted to bend or *plié)* while tapping toe of the free leg down each directional line. Subjects were told to reach the 'gesture' leg as far distance away from the center of the star as possible before returning to the beginning parallel "foot-hook" position. The beginning parallel "foot-hook" position would proceed each directional tap thereafter, creating a pattern of "tap leg, parallel "foot-hook", tap leg, parallel "foot-hook" and so on around the star for all directional points. Subjects were given the opportunity to "mark" the test (dance term used to let dancers learn movement cognitively, without using 100% of full effort/exertion) to ensure they felt comfortable with the test's operating procedures.

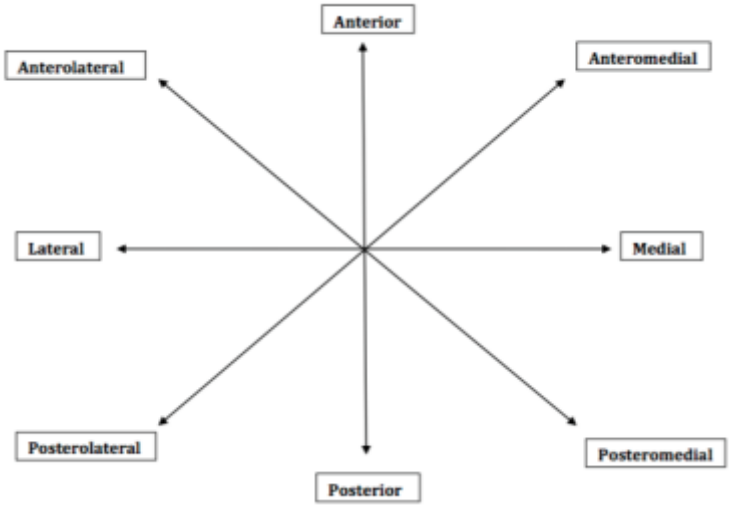


Figure 2: STAR Excursion Balance Test (adapted from Baston, 2010[23]).

Aiming to preserve accuracy for each measurement, the lead researcher and faculty researcher utilized small pieces of masking tape on the floor to mark the spatial location of the toe reach distances. Masking tape demarcations were made as the foot was tapped, prior to removal from the tap location. Time recording ceased directly after the last toe tap, which dictated the tests' completion of one side. Measurements were recorded in centimeters from the star's center-point (the vertex of each angle), to the tape that held the spatial location of each toe tap.

Failures were defined as moments when the subject was inaccurately tapping the toe outside of the directions marked by lines of tape, when the subject put down his or her foot to regain steadiness, or when the subject asked to stop and begin again because of a misjudgment of test "readiness". In the event of any of the procedure failures, subjects were paused and

[23]**Bronner reference for Figure 2**: (Olmstead et al., 2002) *Efficacy of the Star Excursion Balance Tests in Detecting Reach Deficits in Subjects with Chronic Ankle Instability*.

asked to begin again, and time was reset. See Appendix (C) for Standard Operating Procedures for the SEBT.

Intervention Protocol

Bi-weekly interventions were held in which subjects participated in protocol developed by the lead researcher. The self-fascia release component of the protocol (15 minutes) was administered to the experimental group only, while exercises designed to strengthen refined motor control for dance technique (40 minutes) was administered to both groups. Intervention sessions were 55 minutes long in total. (Refer to Appendices C and D for Self-Fascia Release and Muscle Recruitment Protocols, respectively).

Data Collection and Statistical Analysis

Control Data

The control and experimental groups utilize identical subjects in this research—this is a repeated measures research design. Scores on tests conducted prior to intervention participation serve as the control data in this experiment; post-test inferences will be drawn by comparison to the pre-test control.

Experimental Data

Experimental data for this study consists of the post-intervention data set, including scores on the VAS Numeric Pain Scale and Star Excursion balance tests. Basic statistics including mean and standard deviation of data sets will be used to compare the experimental data to control data. Post-test comparisons from the experimental data set will be made from the control data set made up of pre-intervention test scores for inferential analysis.

Statistical Analysis

Statistical analysis for asymmetry measurements began with organizing data tables for SEBT pre-and post-test scores, which recorded right and left leg-reach distances for all nine directions of the test: anterior, anteromedial, lateral, posterolateral, posterior, posteromedial, medial, mediolateral, and [back] anterior (see Tables 5A and 5B). Asymmetry scores for individual subjects were determined for by calculating the difference between right and left leg-reach distance scores for each SEBT direction on the pre-and-post-tests; asymmetry data was then organized in a separate table (See Table 6). Sample means for individual subjects' leg-reach asymmetry were calculated. Individual participants' asymmetry scores for each SEBT leg-reach direction were added together, and that sum was divided by nine, the total number of leg-reach directions in the SEBT, to determine individual asymmetry means (See Tables 6 and 7). Combined means of asymmetry for the sample population were calculated for both the pre-test and post-test by taking the sum of individual subject means, and dividing that score by 9, the total number of subjects in the sample.

Sample pre-test and post-teams means of asymmetric distances measured in the SEBT were tested for statistical significance using the Paired Samples T Test. Paired Sample T-Tests compare two data sets within the same sample population to determine if there is any statistical significance between the two sample means (pre-test and post-test) (Hahs-Vaughn and Lomax, 2012). Paired Sample T-Tests are hypothesis tests utilize a (*t*) statistic: a statistic that measures the size of the difference between two sample means, by comparing it to a critical statistic (*p*): a statistical measure that indicates two sample population means are equal (Hahs-Vaughn and Lomax, 2012). In other words, there is no statistically significant difference between pre-and post-test sample means, if the

calculated (*t*) statistic is examined to determine if it falls below the critical (*T*) value (Hans-Vaughn and Lomax, 2012). Conversely, if the calculated (t) statistic falls above the critical (*T*) value, there is significance statistically present in the results (Norušis, 2006). Paired Sample T-Tests have two assumptions prior to testing: the assumption of sample normality of variance (distribution outcomes fall symmetrically below and above the mean; distribution outcomes resemble a symmetrical bell-curve) and the assumption of no significant outliers in the data sets (Norušis, 2006).

Normality of variance was tested to meet assumptions of the Paired Sample T-Test and determined using the Shapiro-Wilk W test, as research suggests the Shapiro-Wilk W test is the best statistical tool to determine normality for small sample sizes (Ghasemi and Zahediasl, 2012). Following the determination of normality with Stat Plus statistical software (see appendix C), the Paired Samples T-Test commenced by calculating the difference between pre-test and post-test scores (Subject 1 pre-test score - Subject 2 post-test score) (Norušis, 2006). The sum of all difference scores was then divided by (*N*), the sample size, to determine the mean of all difference scores (Norušis, 2006). This score, i.e.: the mean of sample differences, was the number utilized in determining the (*t*) statistic: a statistic that measures the size of the difference between two means relative to the variation in the sample data (see appendix C) (Hans-Vaughn and Lomax, 2012).

Significance level for this research (α) was set to .05 *a-priori* to Paired Sample T-Test Calculations; (α) is the cut-off value at which statistical significance is claimed, ensuring approximately 95% confidence in the results of the analysis for statistical significance (Hahs-Vaughn and Lomax, 2012). A One-directional, or one-tailed t-test distribution was also set *a-*

priori to test the research hypothesis, as viable efficacy of the intervention can only be determined for the dance population if post-test asymmetry scores decrease (on a distribution graph, travel in one direction - in this case left – of the mean) (Hahs-Vaughn and Lomax, 2012).

Analysis for leg-reach distance scores of different individuals began with reach scores normalized to participants' leg length (Gribble et al., 2013, Gribble et al. 2012). Subjects' right and left leg length measurements were recorded from just above the greater trochanter (in line with the anterior superior iliac spine) to the medial malleolus for both the pre-test and post-test, based on research guidelines (Gribble et al., 2013). Normalization was performed by dividing each excursion distance by a participant's leg length, and then by multiplying by 100 (Gribble et al. 2003). Normalized values can thus be viewed as a percentage of excursions distance in relation to a participant's leg length (see Tables 8A and 8B) (Gribble et al., 2003).

VAS Numeric Pain Scale pre-and post- test sample means were calculated for each body region by adding each subject's pain scores per region, and diving that number by 8, the total number of subjects that participated in the VAS Numeric Pain Scale Test (see Figures 4A and 4B). Pre-and post-test sample means were calculated for each subject by adding together the scores of nine evaluated body regions: *right* and *left ankle/foot*, *right* and *left knee*, *right* and *left hip*, *lower back*, *upper back*, and *neck/shoulders*, and dividing the sum by 9, the number of categories of scores. Figure 5 represents mean pain scores categorized per subject for the pain scale pre-and post-tests. Pre-and post- test sample means were calculated for each body region by adding each subject's pain scores per region, and diving that number by 8, the total number of subjects that participated in the VAS Numeric Pain Scale Test (see Figures 4A and 4B). Pre-and post-test sample means were calculated for each subject by adding together the scores of nine evaluated

body regions: *right* and *left ankle/foot*, *right* and *left knee*, *right* and *left hip*, *lower back*, *upper back*, and *neck/shoulders,* and dividing the sum by 9, the number of categories of scores. Figure 5 represents mean pain scores categorized per subject for the pain scale pre-and post-tests.

VAS Numeric Pain Scale results were utilized to calculate combined means by determining the sum of each individual mean score of pain for the pre-test (the same procedure was carried out separately for the post-test), and diving the sum of those scores by eight, the total number of participants in the study.

Data Collection

Individual files were created for each participant. Data was collected and organized by lead researcher, and kept by faculty researcher in a private file cabinet in a locked room to comply with IRB protocol

The primary outcomes of this experiment were analyzing and comparing pre-and post-test results of dancer's experience of pain (VAS Numeric Pain Scale), and dynamic balance (Star Excursion Balance Test) using one-way analyses of variance. Pre-and post-data were compared and the delta change evaluated. Comparisons were made between control group and experimental group results. Pre-and post-data were compared and the delta change evaluated. ANOVA repeated measures and T-Test were utilized. *StatPlus* software for statistical data and analyses was utilized.

CHAPTER SEVEN

RESULTS

Demographics

Screened and consented participants included thirteen dance majors, ten of which completed the study. Overwork and inability to commit to a 7:00am meeting time was cited as the reason three participants dropped out. Eight females and two males participated in the study, and the median age of the participants was 20 +/-2 years of age. Of the ten subjects, there were three Caucasian participants, five Asian participants, and two Hispanic participants. Average number of years dancing among the subjects was 12 years. Most participants had primarily trained in ballet. The participants had additional training in the following dance forms: jazz, hip-hop, contemporary/lyrical, ballet, and modern, and participated in Pilates (see Table 1).

Table 1: Dance Training Experience (in years)

SUBJECT #	Pilates	Jazz	Hip-Hop	Contemp/ Lyrical	Ballet	Modern	Tap	Other
1	2	3	0.5	4	18	5	0	n/a
2	6	2	2	3	16	3	2	n/a
3	6	9	2	9	15	4	3	n/a
4	6	6	0	10	12	12	2	n/a
5	1	4	2	4	3	3	0	n/a
6	0	3	5	3	1	<1	0	2 - Latin
7	0	0	0	2	9	1	1	n/a
8	1	0	0	0	12	0	0	n/a
9	1	13	3	11	14	2	3	n/a
10	2	15	4	5	15	2	7	5- tumbling

One subject entered the study with a case of mild sesamoid inflammation under the first metatarsal of her right foot, daily treating it through natural remedies of ice and rest post-training in her daily classes. Half the participants (5/10) entered the study with a history of foot injuries and four subjects had previous ankle injuries. In addition to common ankle/foot

injures, subjects' reported three previous knee injuries and two participants had a history of injuries to their back prior to enrolling in the study.

Subjects with past injuries were asked how much the reported injury impeded their ability to dance. "Difficulty moving", "Minor Discomfort," and "No effect on dancing" were the three options given. Of the eight subjects that mentioned a history of injury, five reported that they experienced "difficulty moving" while training in technique class. Three indicated a current experience of discomfort while training in dance technique, a result of the reported injury (see Table 2).

Table 2A: Reported Injury History Prior to Enrollment in Study

Subject Number	Foot Injury	Ankle Injury	Knee Injury
1		X	
2	X	X	
3	X	X	
4	X		
5	X		
6			
7			
8	X		X
9			X
10		X	X

Table 2B: Reported Imposition on Dance Ability

Subject Number	Back Injury	Difficulty Moving	Minor Discomfort
1		X	
2	X	X	
3		X	
4	X	X	X
5			
6			
7			
8		X	
9			X
10			X

Participants were further provided space to indicate whether the reported injuries could be identified as "traumatic" (incurred in one event) or "stress-related" (incurred from use over time). "Traumatic" injuries were reported by three subjects, while two subjects reported "stress-related" injuries. Three students, all of whom reported more than one injury in their history profile, indicated both "traumatic" and "stress-related" causes for their injuries (see Table 3).

Table 3: Traumatic or Stress-Related Causes of Injury

Subject Number	Traumatic	Stress Related
1	X	
2	X	X
3	X	X
4		X
5	X	
6		
7		
8		X
9	X	X
10	X	

Attendance was impacted for one subject because of a case of mononucleosis. Sickness in the form of mental health or a cold, flu, or fever was not indicated in the injury history. Study participants were able, nonetheless, to give a concerted effort while participating in the intervention.

Dance Intervention

Overall attendance average for the dance intervention was 89%, averaging 400.50 minutes of total participation time for the control group and 489.5 minutes for the experimental group. Makeup sessions were offered to interested and available participants. Two subjects partook in a makeup session, participating in the identical protocol of session ten of the protocol. Attendance to regularly scheduled intervention meetings was averaged at 87% of total appointment time. Three subjects had a 100% attendance rate: subjects no. 3, 7, and 10. Subject no. 4 missed four full sessions of the intervention, due to over-commitment of activities in the quarter. Exhaustion, illness, and neck strain were other reasons noted for absences (see Table 4).

Table 4: Intervention Attendance for Scheduled Sessions and Make-up Sessions

Subject Number	Total # of Group Sessions (out of 10)	Session Attendance%	Total # of Make-UP Sessions
1	9	90%	1
2	7	70%	1
3	10	100%	0
4	9	90%	0
5	6	60%	0
6	8	80%	0
7	10	100%	0
8	9	90%	0
9	9	90%	0
10	10	100%	0
Subject Number	**Total # of Make-UP Sessions**	**Overall Attendance %**	**Reason for Absence**
1	1	100%	Performance the Prior Evening
2	1	80%	Illness
3	0	100%	N/A
4	0	90%	Exhaustion
5	0	60%	Overcommitment
6	0	80%	Epstein Barr Virus
7	0	100%	N/A
8	0	90%	Overcommitment/Exhaustion
9	0	90%	Neck Strain
10	0	100%	N/A

Dynamic Balance Assessment

Star Excursion Balance Test: Leg Reach Asymmetry

The SEBT test was modified in three ways from the standard procedures: 1. participants were not instructed to move as quickly as possible, 2. participants were given an opportunity to the "mark"[24] dynamic balance procedure prior to testing, and 3. A ninth direction was added by the lead researcher: a return to the anterior position. Improvement in dynamic postural control was measured by the reduction of asymmetry between the right and left leg reach scores, using the pre-test scores as a control for post-intervention score comparison. Symmetry was chosen as a postural control measure based on prior research in injury prevention, rehabilitation, and kinematic proficiency testing, all of which correlate de-normalized leg reach distances with postural control deficiencies and neuromuscular pathology (Sefton et al., 2009; Clagg et al., 2017; Logerstedt et al., 2013). Data records of asymmetry did not involve a delineation of the right or left leg achieving a further or lesser leg-reach distance, as the research question vested interest in one side only insofar as its comparative value (to the contralateral side) indicated the presence or absence of symmetry.

The pre-test sample mean of limb-reach asymmetry was 5.122 ± 1.115 (mean ± SD). The post-test sample mean of leg-reach asymmetry was 3.424± 0.735 (mean ± SD), revealing a 22% decrease in mean asymmetric leg-reach distances (where asymmetric leg-reach distance = highest unilateral leg reach score – lowest unilateral leg-reach score) when compared to pre-test asymmetry distances, and reduced standard deviation of scores around the mean. Sample scores suggest intervention protocol might improve core-control associated with symmetrical

[24] To "mark" movement is a term utilized in dance, meaning an execution of the movement without full effort for the sake of memory.

[right to left] single leg-reach distances while performing a dynamic balance-specific task (See Figure 1).

Dynamic Balance Assessment

Leg Asymmetry Scoring

The SEBT test was modified in three ways from the standard procedures: 1. participants were not instructed to move as quickly as possible, 2. participants were given an opportunity to "mark"[25] the dynamic balance procedure prior to testing, and 3. A ninth direction was added by the lead researcher: a return to the anterior position. Improvement in dynamic postural control was measured by the reduction of asymmetry between the right and left leg reach scores, using the pre-test scores as a control for post-intervention score comparison. Symmetry was chosen as a postural control measure based on prior research in injury prevention, rehabilitation, and kinematic proficiency testing, all of which correlate de-normalized leg reach distances with postural control deficiencies and neuromuscular pathology (Sefton et al., 2009; Clagg et al., 2017; Logerstedt et al., 2013). Data records of asymmetry did not involve a delineation of the right or left leg achieving a further or lesser leg-reach distance, as the research question vested interest in one side only insofar as its comparative value (to the contralateral side) indicated the presence or absence of symmetry.

Asymmetry scores for individual subjects were determined for by calculating the difference between right and left leg-reach distance scores for each SEBT direction on the pre-and-post-tests; asymmetry measurements were then organized in a separate table (See Tables 6 and 7). Combined means of asymmetry for the sample population were calculated for both the

[25] To "mark" movement is a term utilized in dance, meaning an execution of the movement without full effort for the sake of memory.

pre-test and post-test by calculating the sum of individual subject means, and dividing that score by 9, the total number of individual subjects who participated in the study.

Figure 3: Sample Results - Mean and *SD* of Asymmetry Distance Measurements (cm.)

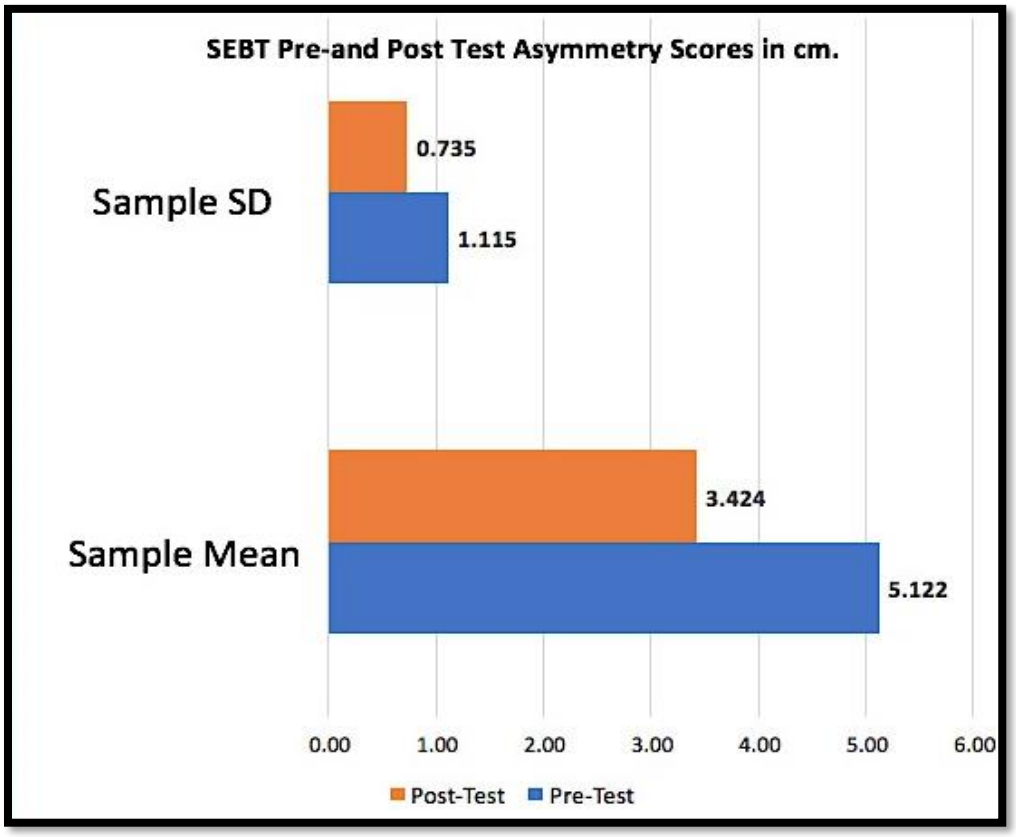


Figure 3: Sample statistics show a mean decrease in leg-reach asymmetry from pre-test to post-test and a decrease in standard deviation from pre-test to post-test, suggesting leg-reach symmetry improvement as a positive effect of intervention participation.

Table 5A: SEBT Pre-Test Leg Reach Scores Recorded in cm.

Subject	PRE-TEST LEG REACH SCORES: Right Leg								
1	55.88	55.88	50.8	40.64	35.56	43.18	43.18	55.88	58.42
2	71.12	73.66	63.5	58.42	58.42	55.88	55.88	60.96	67.31
3	86.36	78.74	76.2	69.85	68.58	68.58	48.26	73.66	86.36
4	63.5	68.58	60.96	63.5	59.69	60.96	48.26	63.5	71.12
5	68.58	63.5	59.69	59.69	53.34	50.8	57.17	55.88	62.23
6	55.88	60.96	58.42	58.42	45.72	45.72	40.64	58.42	55.88
7	63.754	63.5	50.07	50.8	45.72	53.34	48.26	53.34	62.23
8	63.5	68.58	58.42	58.42	50.8	48.26	48.26	50.8	63.5
9	71.12	78.74	71.12	63.5	66.04	63.5	60.96	60.96	73.66
Subject	PRE-TEST LEG REACH SCORES: Left Leg								
1	55.88	55.88	50.8	41.91	35.56	33.53	38.61	53.34	63.5
2	71.12	71.12	71.12	63.5	67.31	58.42	59.69	54.61	69.85
3	78.74	80.01	73.66	68.58	66.04	71.12	66.04	68.58	80.01
4	71.12	73.66	73.66	68.58	68.58	68.58	60.96	60.96	68.58
5	68.58	68.58	68.58	63.5	59.69	58.42	46.99	63.5	63.5
6	52.07	59.69	57.15	53.34	46.99	50.8	45.72	50.8	50.8
7	61.67	67.31	58.42	58.42	48.26	53.34	40.64	58.42	61.27
8	63.5	64.77	58.42	50.8	44.45	45.72	46.99	46.99	63.5
9	73.66	60.96	69.85	63.5	66.04	53.34	43.18	67.31	71.12

Table 5B: SEBT Post-Test Leg Reach Scores Measured in cm.

Subject	POST-TEST LEG REACH SCORES: Right Leg								
1	48.26	50.8	52.07	51.435	49.53	39.37	40.64	45.72	48.26
2	71.12	72.39	68.58	63.5	59.69	60.96	52.07	58.42	67.31
3	81.28	81.28	81.28	82.55	83.82	87.63	58.42	73.66	81.28
4	64.77	60.33	64.135	61.595	61.595	63.5	64.77	67.31	66.7004
5	64.77	66.04	65.405	71.755	72.39	66.04	50.165	53.975	53.34
6	55.88	55.88	59.69	62.23	58.42	57.785	50.8	54.61	55.88
7	63.5	62.23	64.77	68.58	63.5	73.66	48.26	54.61	63.5
8	55.88	59.45	63.5	63.5	60.96	54.61	46.99	48.26	53.34
9	74.93	72.39	66.04	69.85	69.85	71.12	55.88	64.77	74.168
Subject	POST-TEST LEG REACH SCORES: Left Leg								
1	48.26	52.07	49.53	43.18	48.26	49.53	40.005	46.99	48.26
2	60.96	68.58	64.135	67.31	63.5	60.96	46.99	53.34	66.04
3	78.74	77.47	82.55	88.9	78.74	95.23	58.42	71.12	76.2
4	62.23	50.8	50.8	66.675	64.77	63.5	64.135	67.31	61.595
5	61.595	66.04	66.675	69.85	71.12	68.58	63.5	55.88	61.595
6	55.88	58.42	59.69	63.5	62.23	63.5	53.34	52.07	55.88
7	60.96	60.96	63.5	64.77	63.5	59.69	50.8	53.34	59.69
8	55.88	68.58	64.77	67.31	61.595	58.42	54.61	53.34	55.88
9	72.39	71.12	68.58	69.85	67.31	73.66	48.26	63.5	71.755

Table 6: SEBT Pre- and Post-Test Scores: Difference between right and left leg-reach scores measured in distance (cm.)

	SEBT PRE-TEST: RIGHT to LEFT LEG-REACH ASSYMETRY MEASUREMENTS IN CM.								
Subject	Anterior	Anteriomedial	Medial	Postereomedial	Posterior	Posteriorlateral	Lateral	Antereolateral	Anteriomedial
1	0	0	0	1.27	0	9.653	4.572	2.54	5.08
2	0	5.08	8.89	3.81	6.35	5.08	10.16	6.35	1.27
3	0	3.556	0	7.62	6.35	7.62	10.16	3.81	0
4	0	2.54	7.62	5.08	8.89	2.54	3.81	12.7	1.27
5	5.08	1.27	2.54	1.27	2.54	2.54	17.78	5.08	6.35
6	7.62	5.08	12.7	5.08	8.89	7.62	12.7	2.54	2.54
7	3.81	1.27	1.27	5.08	1.27	5.08	5.08	7.62	5.08
8	2.286	3.81	3.81	7.62	2.54	0	7.62	5.08	0.762
9	2.54	17.78	1.27	0	0	10.16	17.78	6.35	2.54
	SEBT POST - TEST: RIGHT to LEFT LEG-REACH ASSYMETRY MEASUREMENTS IN CM.								
Subject	Anterior	Anteriomedial	Medial	Posteromedial	Posterior	Posterolateral	Lateral	Antereolateral	Anteriomedial
1	0	1.27	2.54	8.382	1.27	1.27	0.635	1.27	0
2	3.175	0	1.27	1.905	1.27	2.54	12.065	1.905	8.255
3	0	8.89	1.27	3.81	0.635	3.81	7.62	5.08	2.54
4	10.16	3.81	5.715	3.81	3.81	0	5.08	5.08	1.27
5	1.54	3.81	1.27	6.35	5.08	7.62	0	2.54	5.08
6	2.54	9.525	13.335	5.08	3.175	0	0.635	0	5.08
7	0	2.54	0	1.27	3.81	5.715	2.54	2.54	0
8	2.54	1.27	1.27	3.81	0	13.97	2.54	1.27	3.81
9	2.54	1.27	2.54	0	2.54	1.27	7.62	1.27	2.54

Table 6: Pre-test sample mean of limb-reach asymmetry was 5.122± 1.115 (mean ± SD). The post-test sample mean of leg-reach asymmetry was 3.424 ± 0.735 revealing a 22% decrease in mean leg-reach asymmetry scores when compared to pre-test asymmetry distances, and a narrower dispersion of scores around the mean.

Table 7: SEBT Pre- and Post-Test Scores: Mean of Total Asymmetry Measurements, Combined Mean of Asymmetry Measurements, Standard Deviation of Asymmetry Measurements

PRE-TEST			
Subject #	Mean of Total Asymmetry Measurements (cm.)	Combined Mean of Asymmetry Measurements in cm.	Standard Deviation of Asymmetry Measurements in cm.
1	5.289311111	5.122071605	1.114830354
2	5.221111111		
3	4.346222222		
4	4.938888889		
5	4.938888889		
6	7.196666667		
7	3.951111111		
8	3.725333333		
9	6.491111111		
	POST-TEST		
Subject #	Mean of Total Asymmetry Measurements (cm.)	Combined Mean of Asymmetry Measurements in cm.	Standard Deviation of Asymmetry Measurements in cm.
1	3.266135802	3.423644719	0.734752765
2	3.598333333		
3	3.739444444		
4	4.303888889		
5	3.698888889		
6	4.374444444		
7	2.046111111		
8	3.386666667		
9	2.398888889		

Paired Samples T-Test

Paired Samples T-Test results were determined with *StatPlus* statistical software. Sample mean of score differences (*M*) was 4.27 cm. with eight (8) degrees of freedom (*df*). The (*t*) statistic was 3.277, greater than the critical (*t*) value for this data, set at 1.895; in addition, the confidence (*p*) level associated with the critical (*t*) value was 0.005, resulting in 99.5% confidence level for this analysis, a statistically significant result in support of the research hypothesis (Norušis, 2006). This result suggests positive changes in a symmetrical dynamic balance performance and supports the claim that the implementation of the intervention

designed for this research may help improve postural control and prevent injury predisposition, evidenced by sample mean decreases in asymmetry pre-and post-test (see Appendix).

Comparing post-test asymmetry scores of "group 1" of the experiment sample (three subjects (n=3) that participated in the muscle recruitment protocol), to the scores of group 2 of the experiment sample consisted (seven subjects that participated in the muscle recruitment protocol and the SMR protocol of the intervention) shows a mean difference between groups of 1.06 cm., with group 2 scoring a slightly higher mean. Group 1 has a post-test asymmetry mean of 3.07 cm. and Group 2 has post-test asymmetry mean of 4.13. While the difference between scores is slightly higher than one standard deviation of the post-test data (*SD*= 0.735), no inference in this difference can be safely inferred due to the small sample sizes and the variance in sample size between group 1 and group 2. Further studies focused utilizing larger sample sizes and stricter controls are warranted to make inferences about the effect of the intervention protocol on dynamic balance improvements.

Table 8A: Pre-Test Normalized Leg Reach Scores Expressed as Percentage of Subjects' Leg Length

Subject	PRE-TEST LEG REACH SCORES: Right Leg								
1	55.88	55.88	50.8	40.64	35.56	43.18	43.18	55.88	58.42
2	71.12	73.66	63.5	58.42	58.42	55.88	55.88	60.96	67.31
3	86.36	78.74	76.2	69.85	68.58	68.58	48.26	73.66	86.36
4	63.5	68.58	60.96	63.5	59.69	60.96	48.26	63.5	71.12
5	68.58	63.5	59.69	59.69	53.34	50.8	57.17	55.88	62.23
6	55.88	60.96	58.42	58.42	45.72	45.72	40.64	58.42	55.88
7	63.754	63.5	50.07	50.8	45.72	53.34	48.26	53.34	62.23
8	63.5	68.58	58.42	58.42	50.8	48.26	48.26	50.8	63.5
9	71.12	78.74	71.12	63.5	66.04	63.5	60.96	60.96	73.66
Subject	PRE-TEST LEG REACH SCORES: Left Leg								
1	55.88	55.88	50.8	41.91	35.56	33.53	38.61	53.34	63.5
2	71.12	71.12	71.12	63.5	67.31	58.42	59.69	54.61	69.85
3	78.74	80.01	73.66	68.58	66.04	71.12	66.04	68.58	80.01
4	71.12	73.66	73.66	68.58	68.58	68.58	60.96	60.96	68.58
5	68.58	68.58	68.58	63.5	59.69	58.42	46.99	63.5	63.5
6	52.07	59.69	57.15	53.34	46.99	50.8	45.72	50.8	50.8
7	61.67	67.31	58.42	58.42	48.26	53.34	40.64	58.42	61.27
8	63.5	64.77	58.42	50.8	44.45	45.72	46.99	46.99	63.5
9	73.66	60.96	69.85	63.5	66.04	53.34	43.18	67.31	71.12

Table 8A: Pre-Test Normalized Scores were determined by dividing each excursion distance by the participants' leg length, and multiplying that number by 100 (Gribble et al., 2003). Normalized values can be viewed as a percentage of excursions distance in relation to leg length (Gribble et al., 2003)**.**

Table 8B: Post-Test Normalized Leg Reach Scores Expressed as Percentage of Subjects' Leg Length

Subject	POST-TEST LEG REACH SCORES: Right Leg								
1	48.26	50.8	52.07	51.435	49.53	39.37	40.64	45.72	48.26
2	71.12	72.39	68.58	63.5	59.69	60.96	52.07	58.42	67.31
3	81.28	81.28	81.28	82.55	83.82	87.63	58.42	73.66	81.28
4	64.77	60.33	64.135	61.595	61.595	63.5	64.77	67.31	66.7004
5	64.77	66.04	65.405	71.755	72.39	66.04	50.165	53.975	53.34
6	55.88	55.88	59.69	62.23	58.42	57.785	50.8	54.61	55.88
7	63.5	62.23	64.77	68.58	63.5	73.66	48.26	54.61	63.5
8	55.88	59.45	63.5	63.5	60.96	54.61	46.99	48.26	53.34
9	74.93	72.39	66.04	69.85	69.85	71.12	55.88	64.77	74.168
Subject	POST-TEST LEG REACH SCORES: Left Leg								
1	48.26	52.07	49.53	43.18	48.26	49.53	40.005	46.99	48.26
2	60.96	68.58	64.135	67.31	63.5	60.96	46.99	53.34	66.04
3	78.74	77.47	82.55	88.9	78.74	95.23	58.42	71.12	76.2
4	62.23	50.8	50.8	66.675	64.77	63.5	64.135	67.31	61.595
5	61.595	66.04	66.675	69.85	71.12	68.58	63.5	55.88	61.595
6	55.88	58.42	59.69	63.5	62.23	63.5	53.34	52.07	55.88
7	60.96	60.96	63.5	64.77	63.5	59.69	50.8	53.34	59.69
8	55.88	68.58	64.77	67.31	61.595	58.42	54.61	53.34	55.88
9	72.39	71.12	68.58	69.85	67.31	73.66	48.26	63.5	71.755

Table 8B: Post-Test Normalized Scores were determined by dividing each excursion distance by the participants' leg length, and multiplying that number by 100 (Gribble et al., 2003). Normalized values can be viewed as a percentage of excursions distance in relation to leg length (Gribble et al., 2003)**.**

Figure 4: Individual Subject Means of Leg-Reach Distance on Pre-and Post-Test, Measured as a Percentage of Leg Length

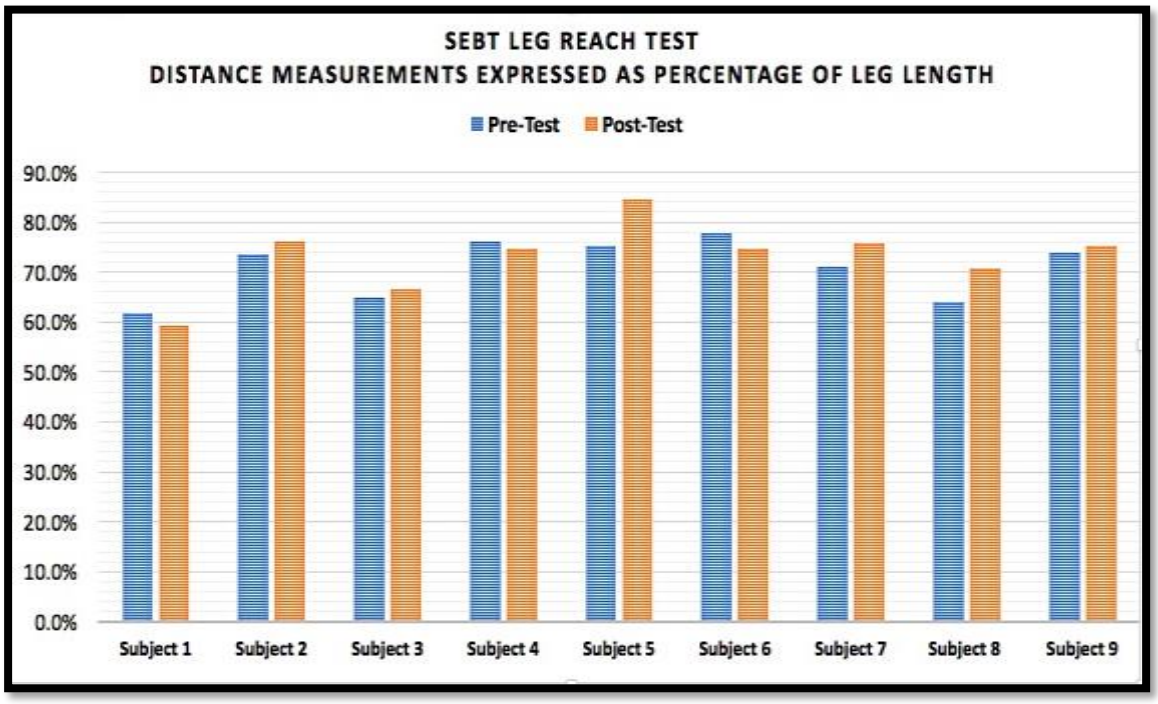


Figure 4: Mean of reach distance scores measured for each subject represent a pre-test range of 15.72% of leg length distance (77.47%, minimum value - 61.75%, maximum value) with a standard deviation of 5.54%. Results on the post-test indicate a larger range of leg-reach distance at 29.42% (55.19%, minimum value to 84.61% maximum value) with *SD* of 6.67%.

SEBT Leg-Reach Distances

SEBT Leg Reach distances were also calculated and compared (pre-test to post-test) to determine subject responsiveness to the intervention design of this research: an intervention built with the specific aim of refining neuromuscular control, necessitated for the task of dynamic balance (Sefton et al. 2011).

Pre-test sample mean of leg-reach distance for combined subjects was 70.9± 5.54 (mean ± SD. Post-test sample mean of leg-reach distance for combined subjects indicates a slight increase in combined scores, with 73.05 ± 6.67 (mean ± SD). Pre-to post-test increase in leg-reach percentages of distance is quite conservative, with a mere 2.15% increase of leg-reach distance. Standard deviation scores report a 20.4% increase from the pre-test to post-test. (See Figure 3). Therefore, the 2.15% increase of leg-reach distance observed in this sample could be the natural result of variance in the data set. Accurate determination of whether participation in the intervention protocol effects leg-reach distance performance on the SEBT warrants further research with larger sample sizes and stricter controls (see discussion for more information).

Figure 5: SEBT Leg Reach Distances: Combined Subjects Mean and Standard Deviation.

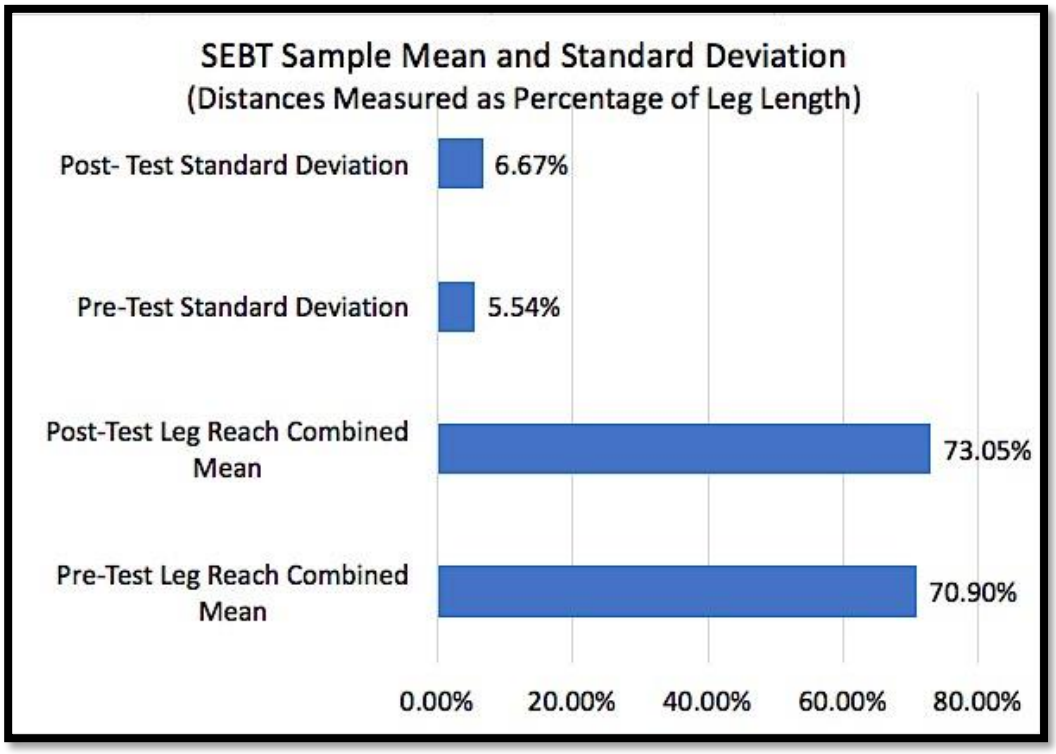


Figure 5: Post-Test leg reach results reveal an increase in standard deviation, and a slight increase in leg-reach distance by 2.15%**.**

VAS Numeric Pain Scale

VAS Numeric Pain Scale scores represent subjects' experience of pain while training and rehearsing as an undergraduate dance major. Pre-test scores represent subjects' levels of pain in dance class prior to participation in the six-week research intervention, while post-test scores represent post-intervention pain scores in subjects' collegiate training environment.

Analyzing results for combined means of all subjects indicate subjects incurred a minor increase in pain from pre-test to post-test pain scores. Pre-test numeric pain scores 1.04 ± 1.43 (mean and SD) reveal a slight mean increase when compared to post-rest scores 1.07 ± 1.54. Mean increase in combined subject scores could be a result of natural variance in the data, rather than an indication of intervention efficacy. Further studies with larger sample sizes and

stricter controls are warranted to determine the true effect of the intervention protocol on subjects' experience of pain.

Figure 6A. Pre-Test Sample Results on VAS Numeric Pain Scale: Mean Scores per Body Region.

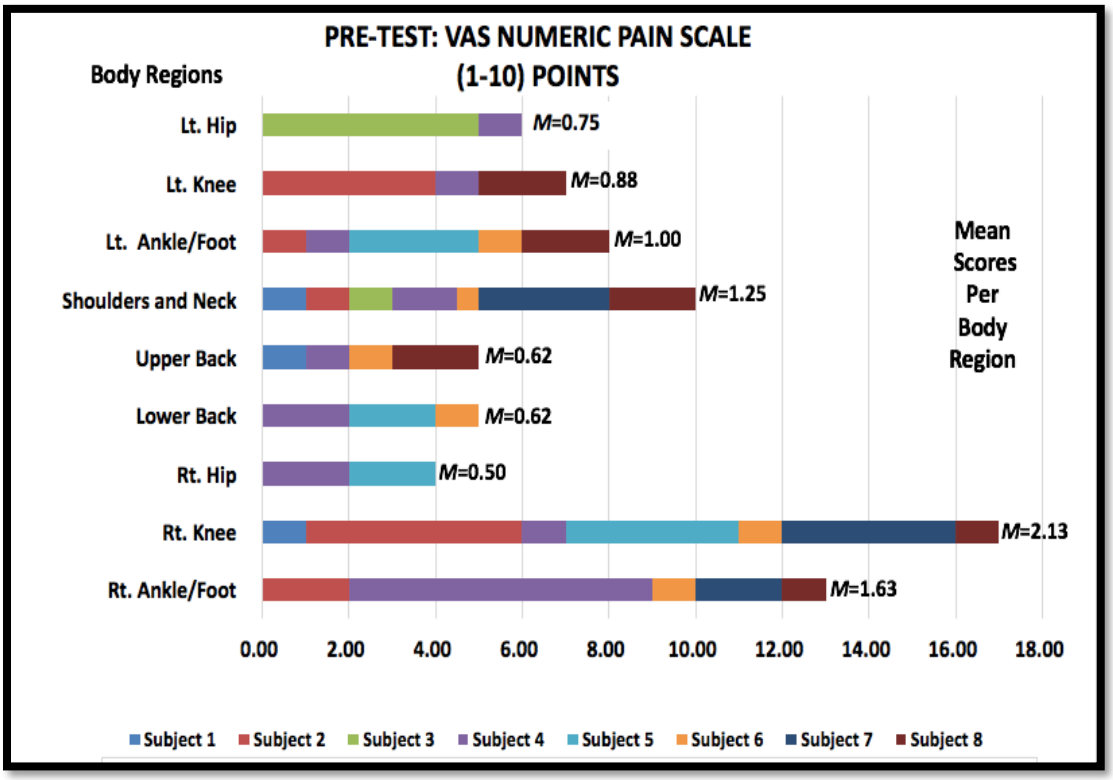


Figure 6A: VAS Numeric Pain Scale pre-test results—represented by mean score per body region—indicate the right knee as the most prominent region of localized pain, with a mean pain score of M=2.13 points, followed by the right ankle/foot with a mean of M=1.63 points. Pre-test scores provide evidence for a positive correlation between right knee and right ankle pain among subjects prior to intervention participation.[26]

[26] Tom Meyers presents evidence of physiological fascial trajectories in his book *Anatomy Trains*, and theorizes movement functionality occurring along these fascial trajectories. Knee and ankle pain occurring congruently and unilaterally may suggest pathological movement along a trajectory Tom Meyers identifies as 'lowest common myofascial tract of the Deep Front Line (DPL)'. Refer to page 185 of *Anatomy Trains,* Kindle Edition (Meyers, 2012).

Figure 6B. Post-Test Sample Results on VAS Numeric Pain Scale: Mean Scores per Body Region.

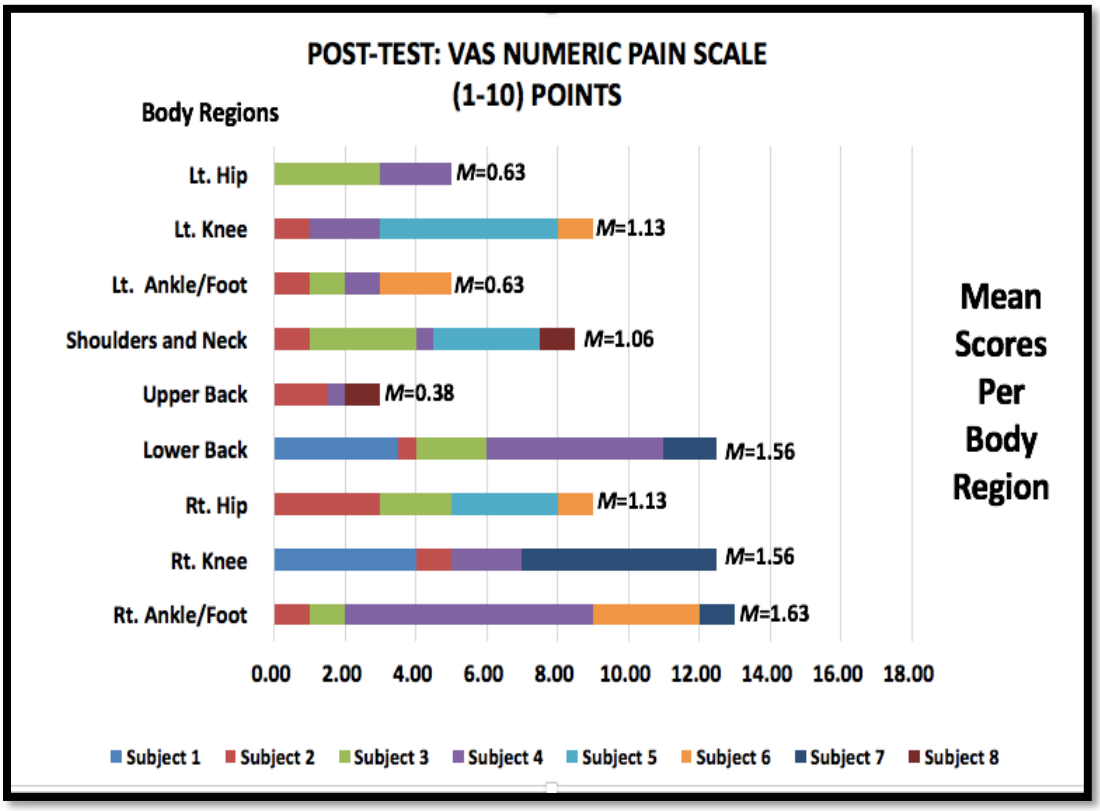


Figure 6B: Post-test scores reveal an identical dominant pain region as pre-test *right ankle/foot*, however it is the *right knee* and *lower back* categories on the post-test with the second-highest pain scores. Decrease in pain measurements per body region account for more than half of the evaluated body categories (66.67% of body regions reveal a slight mean decrease in pain).

Figure 7: VAS Numeric Scale: Mean Scores Categorized per Subject with Standard Deviation

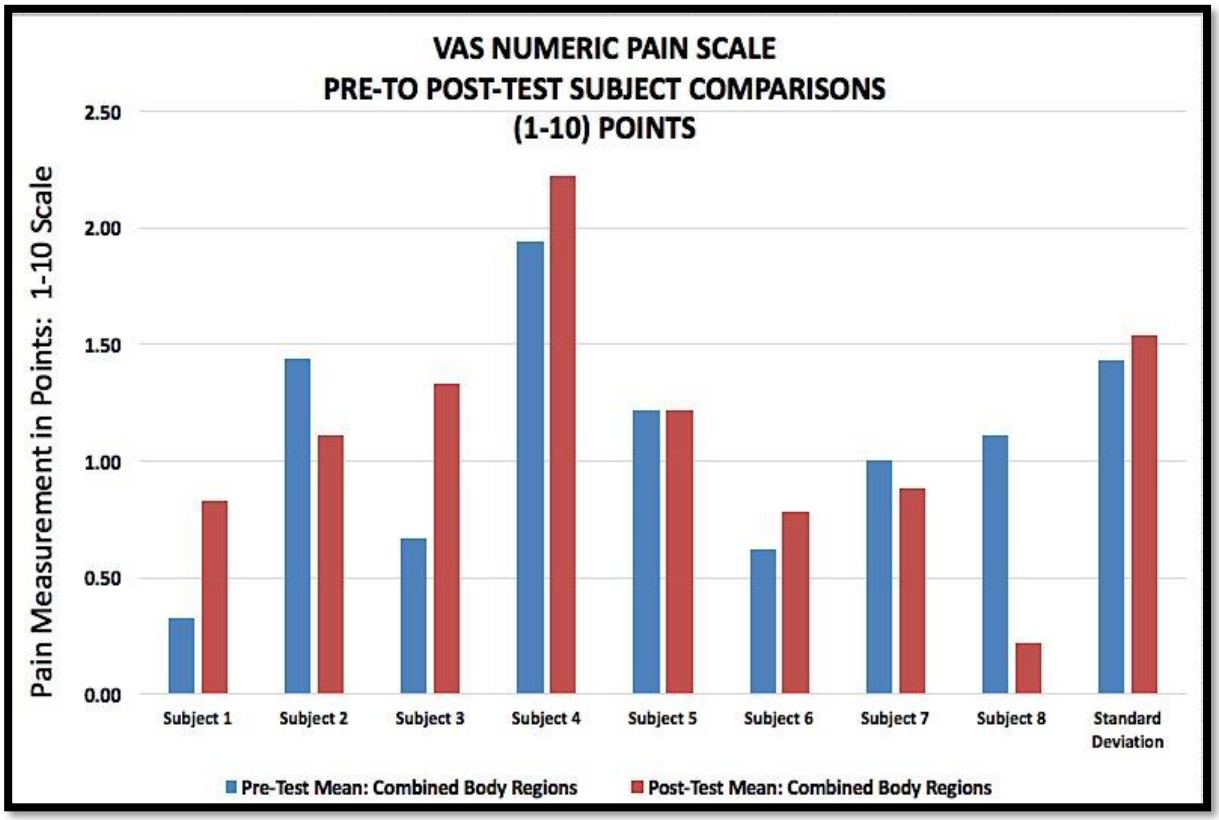


Figure 7: Pain Scores organized per subject. One subject, subject number five (#5), represents no change in pain experience from pre-test to post test. Mean increases and decreases in this data set reveal that increases or decreases in pain results could be a natural result of variance in the data sets**.**

Figure 8. VAS Numeric Pain Scores: Combined Subject Means and Standard Deviation

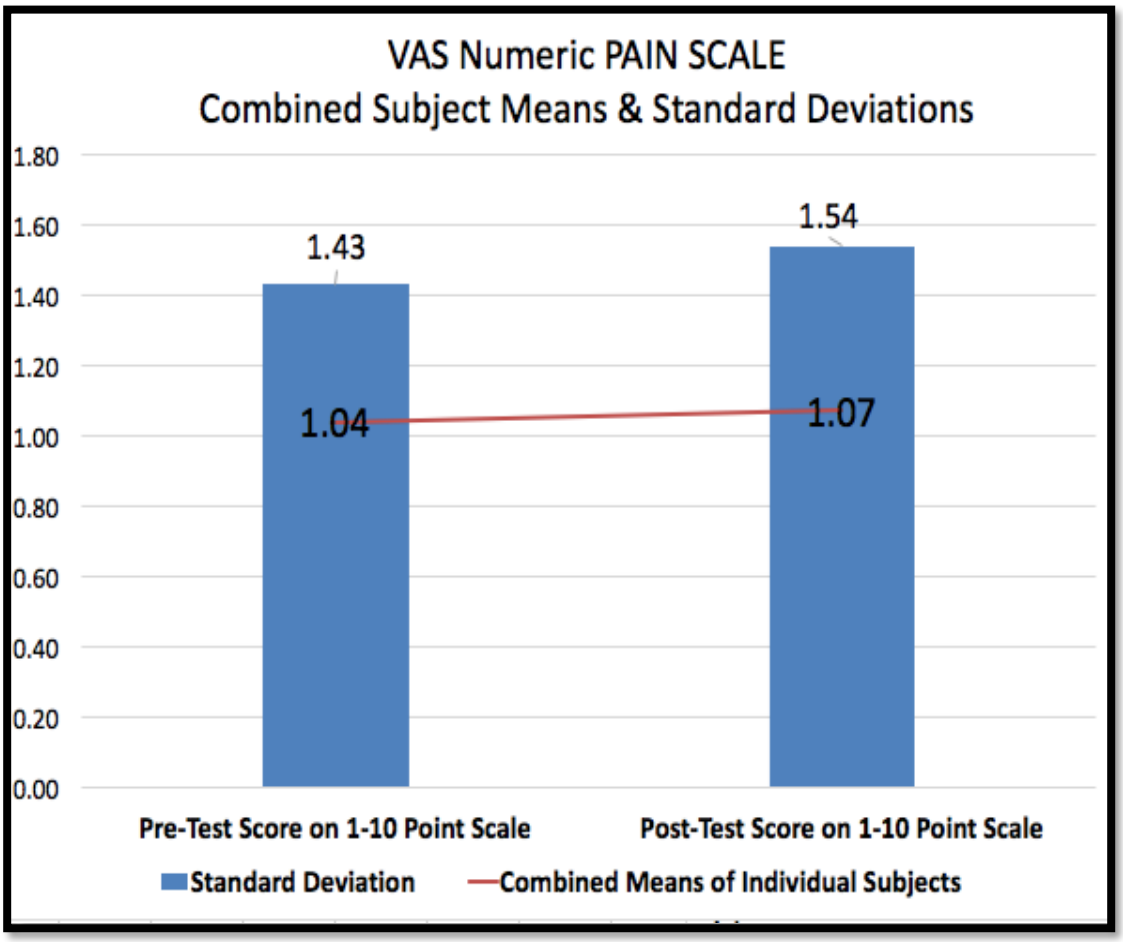


Figure 8: Combined subject mean of pre-test pain scores was 1.04 ± 1.43 points (mean ± SD). Combined subject mean of post-test pain scores was 1.07 ± 1.54 points (mean ± SD). Sample subjects underwent a mean increase of 0.03 points when comparing pre-to post-test pain scores, while the standard deviation of scores increased by 0.11 points. Thus, mean increase in combined subject scores could be a result of natural variance in the data, rather than an indication of intervention efficacy.

CHAPTER EIGHT

Discussion and Conclusion

Discussion

Star Excursion Balance Test and VAS Numeric Pain Scale pre-and post-test scores were used as primary outcome measures of the research hypotheses in this experiment:
Subjects that participate in muscle refinement and self-myofascial release intervention protocols designed for this research will incur an increase in dynamic balance competency and a decrease in pain experienced with dance training**.**

Decreased asymmetry scores (right and left side equivalency in kinetic execution) on the Analysis of SEBT post-tests scores begin with comparison of pre-test scores measuring leg-reach asymmetry by distance in cm. Scores affirm the first research hypothesis which stated that dynamic balance outcomes will improve as a result of intervention participation. Bilateral symmetry in kinetic performance is a clinical measure utilized by clinician and therapists, particularly when aiming to use preventative diagnostic testing to identify at-risk individuals susceptible to injury (Hubbard et. al, 2007; Gorman et. al. 2012). Experimental data from this study revealed a 22% decrease in bilateral asymmetry in post-intervention test scores when compared to pre-intervention bilateral asymmetry scores. Sample asymmetry scores from this experiment, coupled with research-based arguments from dance-specific literature suggest that the intervention protocol designed for this research might decrease the risk of injury among participants, as revealed by a statistically significant increase of dynamic-balance symmetry in post-intervention scores (Hubbard et. al, 2007; Gorman et. al. 2012).

No significant findings in asymmetry scores were found between individuals that participated in the muscle recruitment protocol solely when compared to individuals that participated in both the SMR and muscle recruitment protocols. In this study, acute effects of the SMR component when compared to the muscle recruitment component of the intervention were not significantly different due to a few key components.. Time allocated to the SMR component of the intervention (15 minutes) was brief in comparison to time allocated to the muscle recruitment component (40 minutes). Furthermore, the SMR component of the intervention were administered after the muscle recruitment protocol. . Temporal placement of the MFR component likely provoked some students to hasten their participation as mild stress response, induced to ensure timely arrival to the next course at 8:00am. Stress induced conditions are not conducive to productivity in restoring balance to the fascial system, and proven efficacy of myofascial release in restoring balance to the sympathetic and parasympathetic components of the autonomic nervous system is one of the strong appeals to the SMR component of a dance-specific intervention (Henley et al. 2008). Thus, further comparative studies with better design of time allocation is warranted to compare the effect of the SMR component to the muscle recruitment component, and again, to compare the hybrid of the two components to each individual component.

Leg-reach distances on the SEBT test were analyzed to determine the significant correlations between measures of functional stability (balance, strength) and mechanical instability (laxity, hypo-mobility); such measures were modeled previously in peer-reviewed experiments (Denegar et al., 2007). Leg reach distances testing with the SEBT points to proficiency in postural control and dynamic balance, two sensorimotor constructs (Wilmerding

and Krasnow, 2009). Researchers Sefton et al. utilized SEBT leg reach distances to test dynamic balance before and after an intervention training balance, and utilized static balance measures along with EMG signals to detect motor neuron excitability (Sefton et al. 2011). While Sefton et al. found no significant changes in static balance scores, significant changes in SEBT pre- and post-test leg reach scores were observed, along with prominent motor neuron pool excitability, suggesting that dynamic balance excites sensorimotor function (Sefton et al., 2011).

Leg-reach distance scores did not offer significant support of the research hypothesis, as the increase in mean leg reach, a mere 2.15% increase in distance from pre-to post-test, was smaller than standard deviation post-test scores, *SD*= 6.64%. An increase of leg reach distance could therefore be attributed to the natural variance in the distribution of scores. Standard deviation of post-test leg reach distance scores increased when compared to the pre-test standard deviation score, *SD*=5.54%. Increased standard deviation in the reach-distance post-test data set provides evidence in support of the largest internal threat to the study. Subjects participated in the intervention protocol in the spring quarter at the Claire Trevor School of Arts, a quarter is the most demanding for dancers and, a time-period where dancers' training and rehearsal schedules vary the most between individuals. Little internal control ensuring homogeneous training and rehearsing schedules among subjects was possible outside of the intervention participation, represented by the larger distribution of scores. In addition to a recommendation that future studies use larger sample sizes of the target population, it is recommended to administer the intervention in stricter conditions, ensuring stronger external controls thereby reducing variability of the research.

VAS Numeric Pain Scale pre-tests and post-tests administered to subjects were given the numeric markers from 1-10 to enhance validity through misinterpreted data (Hawker et al., 2011). VAS Numeric Pain Scale results varied considerably among participants, a reasonably predictable outcome based on literature reviewing the reliability of the VAS Numeric Pain Scale. Hawker et al. determines the VAS Numeric Pain Scale to be a reliable pain measure, though the absence of "a gold standard for pain" is mentioned. Individuals have different tolerances for pain and maximum pain thresholds, which might account for the pain score variance among the sample population (Hawker et al., 2011). Furthermore, subjects in this experiment indicated chronic injuries incurred in the past on their injury history forms. Training among subjects prior to UCI has an element of diversity even among similar styles, as training protocols and strengthening methods can vary considerably between schools.

Sample VAS Scores report a small mean increase of 0.03 points in overall experience of pain among the subjects, however, this increase could be attributed to natural variance in the dispersion of data, as it is lower than the standard deviation of 1.54 points on post-test VAS pain scores *SD*=1.54. Subjects' work load in the spring quarter as mentioned above is impacted in the spring quarter with commitments that impact physical demand on undergraduate. Further research under the controls of identical daily training schedules is again recommended by the lead researcher to determine a more accurate analysis of the efficacy of the research intervention on pain level experienced by subjects.

Conclusion

Intervention methods created by the lead researcher effected changes on postural control associated with dynamic balance, shown by a decrease in the distances of leg-reach asymmetry from pre-test to post-test. Asymmetry decreases evidenced by SEBT scores suggest intervention efficacy in injury prevention, as unilateral dominance in balance tasks identifies at-risk individuals for injury in clinical settings. Asymmetry distance scores decreased considerably in the comparison of pre-to post-test data. No effect can be stated on intervention efficacy to increase postural control or decrease pain, as no significance was observed statistically in leg reach distance or pain scores from pre-to post-test. Due to high variance in subjects' training schedules outside of the intervention, lead researcher suggests further studies with stricter controls to assess intervention effect on pain and dynamic balance. Future studies warrant larger sample sizes in experimental design from which more inferences can be drawn about the larger target population

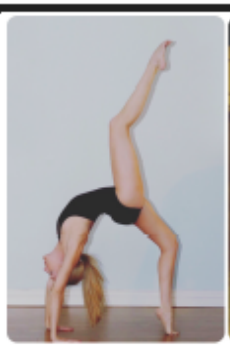
APPENDIX A: SUBJECT RECRUITMENT FLIER

DANCE SCIENCE RESEARCH

CAN I RELIEVE PAIN IN MY BODY?

CAN I MAKE IMPROVEMENTS IN MY TECHNIQUE OUTSIDE OF CLASS?

WITH MICHELLE





"I'D LIKE TO DECREASE MY DAILY LEVEL OF PAIN AND SORENESS"...

"I'D LIKE TO IMPROVE MY CORE CONTROL"..

"ID LIKE TO KNOW IF I'M USING THE CORRECT MUSCLES"..

"I'D LIKE TO LEARN HOW TO IMPROVE SINGLE LEG BALANCE"...

!

Michelle Blackwell, Lead researcher and 2nd year MFA candidate, designed a protocol she believes will be helpful to dancers for her thesis research.

Her experiment is inspired by her rehabilitation journey; born with a deformed skeleton, she has been through four major surgery recoveries.

Michelle will be conducting a 6 week experiment at UCI during Spring Quarter, 2016. The sessions will include two (2)1 hour sessions per week for some participants and two (2) thirty minute sessions per week for other participants. The sessions entail one or both of the following: 1) 30 minutes of combined exercises for the ankle/foot, upper legs, hips, back and core; 2) 30 minutes of self administered myo-fascial release (release of connective tissue of the muscle with specialized tools - similar to massage). The first and last sessions of the experiment will be used for testing days. Participants will receive a Starbucks gift card,

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APPENDIX B

Muscle Recruitment Intervention Protocol

SESSION 1[27].

EXPERIMENTAL GROUPS 1 and 2

Protocol 1: Core Control

Exercise 1: "Table-Top Leg raises" with Foam Roller[28]

Objectives: 1) Achieve bilateral *perilymph* symmetry to increase proprioceptive capabilities utilized in dynamic balance.

2) Place global abdominal muscles in an "actively insufficient" condition so that pelvic floor core stabilizers, particularly *coccygeal* and *iliococcygeal* muscles get recruited [by default] to maintain neutrality in the pelvis.

Description: Placing foam roller along spine while lying supine with neutral pelvis (NP) and arms extended on sagittal plane toward the ceiling, float one leg at a time up into table top position.

Contraindication: Exercise is contraindicated for deaf persons.

Progression 1: Simultaneously take contralateral arm overhead as leg lifts to tabletop.

Progression 2: Perform the with eyes closed.

[27] Lisa Howell, founder of *Perfect Form Physical Therapy*, Australia, and creator of *The Ballet Blog,* is the mastermind of these exercises as she invented them. Her work in creating optimal muscle recruitment strategies for dance training is the inspiration of this component of the intervention protocol. Lisa Howell can be credit to most of the ideas/exercises presented in this section.

[28] Originated by Sue Hitzmann, creator of the MELT® Method.

Exercise 2: "Three-Dimensional Breath" with Foam Roller [29]

Contraindication: Asthmatic symptoms/bronchial asthma.

Objective: To maximally depress diaphragm – aiming [low and deep] for the 9th and 10th rib [anterior] and 11th and 12th rib [posterior] (located right and left of the zyphoid process attachment) while expanding intercostal muscles bilaterally, and strengthening the diaphragm to assist deep core stabilization. Diaphragmatic breathing is targeted to "awaken" key core stabilizers necessary for core control during dynamic balance tests and to assist homeostatic balance between sympathetic/parasympathetic nervous system[30].

Description: Begin lying supine on a [vertically placed] foam roller, then cue the lungs to expand spatially in the sagittal plane (ceiling to floor/foam roller). Second, cue the lungs to expand spatially in the horizontal/transverse plane (laterally to the right and left sides of the room) and to expand spatially in the frontal/coronal plane (increasing space between the heart and the belly button, and the space between each vertebrae). Next, cue the inhalation in all three planes to occur simultaneously, and in the exhalation, cue an observance of three-dimensional deflation[31].

Contraindication: Exercise would be contraindicated for persons with asthmatic symptoms/bronchial asthma.

---

[29] Originated by Sue Hitzmann, creator of the MELT® method. Progressions developed by Lead Researcher.

[30] Autonomic homeostasis increases executive function in CNS, a central component to proprioceptive mechanisms used for functional dynamic balance as well as of the mechanism [CNS], the deliverer of pain messages to the dancer.

[31] Breath utilized in the Pilates technique emphasizes full, percussive breath with exhalations that make an audible "shh" sound, created by shaping the mouth shape and outward exertion of air, was been correlated through research with the facilitation of carbon monoxide bulk flow delivery from the environment to the lung airways and alveolar spaces (MacIntyre, 2005).

Progression 1: Breathe to maximum capacity and hold breath in for 5 seconds, exhale through the mouth.

Progression 2: Perform an audible "hah" sound upon exhalation[32].

Exercise 3: "Specialized Swimming" with Foam Roller[33]

Contraindication: Pain associated with SI joint/low back region.

Objectives:

1. To recruit spinal stabilizers: semi spinales and multifidus of the erector spinae (a postural stabilizer necessary for dynamic balance) as well as the smaller postural muscles of the spine: Interspinales, Rotatores, Intertranversrii Lateralis and Mediales (these commonly get inhibited in the case of back soreness or non-specific back pain).
2. To prevent global muscles, such as the quadratis lomborum and romboids from assuming stabilizing tasks for the spine. Recruitment of postural muscles of the spine for stabilization (designed for longevity, postural muscles can be described as "marathon runners") instead of superficial global muscles (designed for energetic brevity, these can

[32] Breath performed by inhalation through the nostrils and exhalation with an audible "hah" is characteristic of Pranayama breathing characteristic of some forms of yoga. Pranayama breathing has been shown to lower sympathetic activity of the autonomic nervous system (Bhargava et al. 1988).

[33] *Specialized Swimming* is an adaption by Lisa Howell, B. Phty, of a classical Pilates exercise. Lisa Howell is founder and creator of *Perfect Form Physical Therapy,* a clinic with dance specialization in Sydney, Australia, and a world-renowned educator in dance teacher training. *Specialized Swimming,* is a name given in this research to represent Lisa Howell's curtailment of the classical version of *Swimming,* a Pilates exercise, to the dancer. *Swimming* in its classical form belongs to the original mat series of Pilates work, developed by Joseph Pilates in method he called "Contrology," known today as Pilates. It is important to credit Joseph Pilates as the fundamental originator of this exercise and other exercises found in this intervention.

be thought of as "sprinters"), as the spine is a key player in achieving kinetic stability required in dynamic balance-specific tasks[34].

Description: No foam roller is used for the first iteration of *Specialized Swimming*. Lying prone with arms out in front of the body, a few feet forward of the head (palms down and head facing down to maintain long cervical spine), keeping all gluteal muscles completely **deactivated** [extremely important], lift one leg off the ground, head off the ground and contralateral arm off the ground in the same height as the leg. Reverse.

Progression 1: Perform the with a foam roller underneath the forearms. As the back is extended, allow the arms to roll back along the roller, but do not bear weight through the arms. Once the spine has reached extension, bring the contralateral arm to high fifth while maintaining spinal extension/bringing the spine into hyperextension with the support of the abdominal wall.

Progression 2: Perform the with rotation of the trunk, with precaution to rotate without fabricated of the arm and head as a lever. Arm and head are used by simply come "along for the ride" as an extension of the back and upper torso, and their movement is a bi-product of a torso that is rotating and extending.

Exercise Four: "Melted Roll Ups" with Foam Roller

Objectives:

1. Dynamic Core recruitment and refinement:

[34] In the case of non-specific back pain, global muscles and their attempt to compensate for weak or dormant postural muscles of the spine must be considered as a pathological source, as structures of the spine, rather than spinal musculature, are limited in nerve supply. Global muscles designed to aid dynamic, short-lived movement that utilized by the body to upright position of the torso (due to weakness in the spinal stabilizers) often become fatigued, dehydrated, and strained by the overwork – in some cases leading to soreness and non-specific, chronic discomfort in the back.

2. Turning **off** the larger superficial muscles; mainly, the rectus abdominis and prevention of a "bound" torso with "gripping" abdominal muscles.
3. Turning **on** the pelvic floor and transverse abdominis, recruiting both as dynamic stabilizers while the rectus abdominis relaxes so that the spine can be supple as it flexes and extends, indicating the yield of the superficial abdominal muscles to deeper

innervation of deep-core stabilizers that aid in dynamic balance and postural control.

Description: Placing the foam roller underneath the inferior ridge of the scapulae (observable height will vary depending of the length of the torso of the subject), begin lying supine with arms to the ceiling on the sagittal place. Inhale with the arms staying in place, exhale and "melt the ribs" beneath the pectoral muscles and roll up with **no** recruitment of the legs or pelvis, and **no** hoisting of the movement by utilizing momentum or the head as a lever. Keep the core alive with continual activity in dynamic movement while keeping soft the more superficial abdominal wall.

Progression 1: Cross Lateral Reach

Progression 2: Cross Lateral Reach with Core Stabilization

SESSION 2.

EXPERIMENTAL GROUPS 1 and 2

Protocol 1: Core Control Progressions and Preparation for Dynamic Stabilization

Exercise 1: "Table top with Leg Raises" with Foam Roller (see above)

Exercise 2: "Three-Dimensional Breath" with Foam Roller and Progression 1. (see above)

Exercise 3: "Melted Roll Ups" with Foam Roller and Progression 1 and 2.

Exercise 4: "Second Position Butterflies" against Mirror.

Objectives:

1. To isolate of the adductor region of the upper legs while maintaining a neutral pelvis/neutral spine and harmony of the torso.
2. To create balance for both the support leg and gesture leg by balancing adductor strength with that of quadriceps and glutes, as stabilization is achieved by

synchronous synergy maintained by the inner and outer muscles of the leg, the gluteus muscles and the deep core stabilizers, both in internal and external rotation.

Description: Begin by lying supine with legs open in a wide second position against a wall or the mirror. Use the pelvic floor to ensure grounding of the sacrum and neutrality of the pelvis. Recruit the uppermost portion of the adductor region, namely the gracilis, to begin the legs' journey up the wall, arriving into first position. Cue the "inseam of the pants" toward one another at every point along the path to first position, where the heals, calves and adductors will meet, with the VMO (vastus medialis oblique) slightly engaged. Keep the pinky toes as close as possible to the mirror throughout. Lower slowly in external rotation back to the beginning position.

Progression 1: Perform "Second Position Butterflies" using one's optimum ROM.

Exercise 5: "MTP Isolation" with ¾ inflated ball.

Objectives:

To eliminate toe (phalangeal) gripping, a compensatory response to a lack of dynamic and static control:

1. Activating isolating and strengthening the lumbricals, plantar arch muscles essential to mechanical health in a dancer's ankle/foot complex.
2. Ensuring all phalangeal pads of one or two support leg are "feeling" the floor balance so that all proprioceptive input can be received from foot mechanoreceptors.
3. Introducing a foundation for a subsequent training on ankle/foot pronation and supination and their compromising interference with ankle stability in double and single leg balance.

Description: Place the ball beneath metatarsal 1-5, and observe the protrusion/visibility of the MTP joint. Keep the inter-metatarsal joins in extension with little to no activation of the flexor-hallucis longus and do not flex the phalangeal joints.

Progression 1: Perform the same exercise with a Theraband; tension looped around the outside of the foot for added resistance and activation of the peroneus longus/brevis.

SESSION 3.

EXPERIMENTAL GROUPS 1 and 2

Protocol 3: External Rotator Isolation and Preparation for Dynamic Stabilization

Exercise 1: "Table-Top Leg raises" with foam roller and Progression 1.

Exercise 2: "Three-Dimensional Breath" with foam roller and Progression 1 and 2

Exercise 3: "Melted Roll Ups" with Foam Roller and Progression 1 and 2

Exercise 4: "Specialized Swimming" with Foam Roller and Progression 1 and 2

Exercise 5: "Lying Rotation for Standing" with Foam Roller[35].

Objectives:

[35] Adapted from Lisa Howell's exercise, *Running Man*.

1. To activate and isolate standing external rotation muscles (especially *obturator internus*) without innervation of the *gluteus minimus* and *gluteus medius,* as over-recruitment of the glutes in external rotation is a common pathology associated with inflammation of the SI joint and surrounding structures.
2. To isolate the external rotators from the pelvis and prevent compensatory pelvic tilts, both posterior and anterior, that take the pelvis out of neutral and the dancer's spine out of alignment.

Description: Begin lying on one side in neutral pelvis with the ASIS (anterior superior iliac spine, or 'hip bones') "stacked" on top of one another and pelvic floor engaged. Place the inner thigh of the top (anterior) leg on to the foam roller and bend the knee to form a 90-degree angle. Form a 90-degree angle with the bottom leg as well, with the thigh portion of the leg forming a vertical extension of the torso, and tibia portion of the back leg positioned in a 90-degree angle perpendicular to the torso. Stabilize the body in space and lift the inside of the heel toward the wall facing **your** front, and hold for three seconds at the maximum range of the motion in this direction. Return to starting position and resolve to a fully relaxed back leg, and repeat. Keep the large gluteus muscles relaxed, and keep the hip bones stacked to ensure pelvic neutrality.

SESSION 4.

EXPERIMENTAL GROUPS 1 and 2

Protocol 4: Gluteus Medius Activation and External Rotation Isolation

Exercise 1: "Three-Dimensional Breath" with foam roller and Progression 1 and 2

Exercise 2: "Melted Roll Ups" with Foam Roller and Progression 1 and 2

Exercise 3: "Lying Rotation for Standing" with Foam Roller.

Exercise 4: "Side-Lying Rotation" with Theraband.

Objectives:

1. To activate external rotation muscles that are used by the gesture leg of a dancer in an open chain environment, with focus on the quadratus femoris.
2. To refine the recruitment of the external rotators.
3. To activate the pelvic stabilizers such as the gluteus medius and gluteus minimus without tension or "gripping" in the lateral hip, which can lead to irritation around the bursa proximal to the greater trochanter.

Description: Tie a Theraband to a barre, choosing a fixed end that is perpendicular to the thigh bone of the subject while lying in a prone position with feet together. Attach the distal end of the theraband to the upper arch of the foot and lye prone. Bring the leg with the theraband attached to retire, the beginning position. Slowly draw the foot down toward the opposite knee of the vertical, resting leg, focusing on rotating the femur externally in the hip socket. Make sure the upper gluteals stay relaxed and the pelvis is maintained in a square position facing the floor.

Progression 1: This exercise can also be performed on a stability ball if there is enough rotation in the hips.

Progression 2: This exercise can be performed with the femur of the gesture leg placed in varying degrees in relationship to the body, from 10-degrees minimum to 90-degrees maximum.

SESSION 5.

EXPERIMENTAL GROUPS 1 and 2

Protocol 5: External Rotator Isolation and Preparation for Dynamic Stabilization

Exercise 1: "Three-Dimensional Breath" with foam roller and Progression 1.

Exercise 2: "Melted Roll Ups" with Foam Roller and Progression 1 and 2.

Exercise 3: "Corrected First Position".

Objectives:

1. To remove common pathologies associated with forced turnout in standing positions in ballet.
2. To remove common pathologies associated with compensation for a weak core in standing positions in ballet.

Description: Stand in first position with the pelvic floor and abdominals active. Place pelvis in neutral, avoiding any posterior or anterior tilts. Keep thighs continually active in turnout, sense a "spiral" activation of the legs: dual activation of the deep outward rotators and abductors, gently pulling up the VMO (vastus medialis oblique). Distribute even pressure between the borders of the foot by placing the weight on the first, second and third metatarsal, while keeping the lumbrical muscles of the feet active by maintaining a lift in the foot's arch.

Progression 1: *Plié* (French word for bend) with no tension at the Sub-Talar Joint; i.e.: relax the Anterior Talofibular Ligament.

Progression 2: Elevé ensuring that the "toepads" of the phalangeal joints can lift off the floor, to ensure there is no toe "clawing present". Maintain the arch of the foot as the elevé is lowered onto the flat

Progression 3: Complete postural assessment with turnout activation, plié, and elevé in all relevant ballet positions: 1st, 2nd, 4th and 5th position.

Exercise Four: "Corrected Supporting Leg"

Objectives:

1. To "stack" the joints of the support leg, achieving postural functionality in the legs.
2. To avoid balancing off hyperextension/balancing by resting into hip *joint* (*greater* trochanter) or the ankle (sub-talar) joint.

Exercise: Place the gesture leg on the barre in side attitude, and focus on keeping the hip joint of the open chain relaxed. Cue the greater trochanter to drop toward the sitz bone (ischial tuberosity) of the gesture leg, as the fold of the hip flexor maintains a relaxed state. Correct the support leg per the following postural organization: "sitz bone, over knee, over heel; weight on the 1st and 2nd metatarsal.[36]" Feel the continuity of the spiral of external rotation as it travels from the adductor, down the tibia and underneath the arch of the foot.

Progression 1: *Plié* with the knee tracking over the 2nd toe, thinking of external rotation at the support leg and how a "spiral" of maximal external rotation traveling down the leg assists a soft yielding at the sub-talar point to deepen the *plié*, as well as the soft yielding of *the Achilles tendon at* the back of the ankle in *plié*.

Progression 2: *Elevé*, maintaining the staked position of the leg and feeling the spiral of external rotation travel underneath the heel of the foot in *elevé*. Ensure the sitz bone is

[36] Many dancers with hyperextended knees need to be instructed to keep a "micro bend" in their knee, to ensure VMO activation and authentic external rotation, without "sinking" or "jamming" the knee joint by resting weight into it, by way of hyperextension.

maintained in line with the knee, in line with the heel. Rise onto the first, second and third metatarsal with toes spread and no toe gripping, maintaining a soft hip flexor and external rotation of the gesture leg.

SESSION 6.
EXPERIMENTAL GROUPS 1 and 2

Protocol 6: Standing Placement Overview

Exercise 1: "Three-Dimensional Breath" with foam roller and Progression 1 and 2.

Exercise 2: "Melted Roll Ups" with Foam Roller and Progression 1 and 2.

Exercise 3: "Corrected First Position".

Exercise Four: "Corrected Supporting Leg" (adding Progression 3).

Progression 3: Practice the same exercise with the support leg in parallel. Note that students with a valgus knee ("knock-knees") predisposition will need to be instructed to externally rotate to achieve a 'pure' parallel stance, with the patella tracking over the second toe. These same students, predisposed to knee valgus, will likely be fighting ankle/foot pronation that is commonly associated with internal tibia torsion. Conversely, students with a knee Varus ("bow-legged") predisposition will likely be fighting ankle/foot supination that is commonly associated with external tibia torsion. Verbal cues will be given to individual students based on their genetic predisposition/alignment, and strength competency on the support leg.

Exercise Five: "Passive Release of *Psoas Major*"

Objectives:

1. To release unnecessary tension or "gripping" of the psoas major while flexing the hip. Unnecessary gripping of the hip flexor is indicative of poor control of the core and/or poor pelvic/lumbar stabilization.

2. To activate the pelvic floor and the transverse abdominis to such an extent, Psoas Major muscle that attaches to the Lumbar Spine and stabilizes the back when the deep core stabilizers are not strong enough to take over postural control), frees itself to work **solely** as a hip flexor, rather than hip flexor **and** back stabilizer.

Description: Lye supine with legs supported by a chair or bench, bending the knees to a 90-degree angle so the forelegs can rest on the support. Ensuring there is NO tightening of the psoas major. Actively cue psoas major to release if it is "gripping". Actively deepen pelvic floor innervation and cue psoas major to completely release all activation.

Progression 1: Tuck and tilt the pelvis into an anterior and posterior tilt while keeping psoas major inactive as a back stabilizer. Psoas Major will need to feel soft and relaxed as the posterior and anterior movement of the pelvis is initiated and sustained by the pelvic floor muscles.

Progression 2: "Float" the legs of the chair and up into space without recruiting psoas major as a back stabilizer.

SESSION 7.

EXPERIMENTAL GROUPS 1 and 2

Protocol 7: Refining Floor Contact

Exercise 1: "Three-Dimensional Breath" with foam roller and Progression 1 and 2.

Exercise 2: "Melted Roll Ups" with Foam Roller and Progression 1 and 2.

Exercise 3: "Lying Rotation for Standing" with Foam Roller.

Exercise 4: "The Adagio Tendu".

Objectives:

1. To refine the recruitment of ankle/foot mechanics in single-leg work.

2. To refine the simultaneous activity of the support leg as the pelvis maintains neutrality. Correct common pelvic imbalances/shifting of the ASIS on the transverse and or coronal plane reduce stability of the support leg and core stabilizing integration.

Description: Stand in external rotation and think of sweeping dust off the floor as every bone of the foot on the floor is articulated to the pointe, with fully stretched phalangeal joints and no weight bearing on the gesture leg. Aim to truly sense the of the floor with the bottom of the gesture foot as the arch of the foot is maintained in a forward position, preventing the beginning of a "*sickled*" foot (ankle/foot supination and forefoot adduction). Cue the support leg to maintain a continual "spiral" of external rotation on the support leg, with the support foot distributing weight evenly between the medial and lateral borders. "Feel" the surface of the floor beneath the first second and third metatarsal of the support foot and lift the arches with activation of the lumbrical muscles of the foot. Inform subjects that proprioceptive

information will be delivered to the brain via sensors that feel the floor through the skin on the soles of the feet (more on this in session eight). Remind students of the standing leg alignment instructed in session six.

Exercise Five: "The Adagio Battement Fondu".

Objectives:

1. To build endurance of the mind/body collaboration involved in using only the muscles necessary (no more, no less) for a given movement or exercise.
2. To build physical strength of deep muscles that might have been previously under-recruited,
3. To integrate refinement introduced thus far in the intervention: ankle/foot mechanics, deep core activation, isolating external rotation, pelvic/lumbar stabilization, balanced use of the upper leg muscles, receipt of proprioceptive information via the foot's relationship to the floor.

Description: Stand in first position and review proper mechanics of the *fondu*. Articulate the support foot in each relevé maintaining a controlled plié. Control the arch, as activation of the lumbricals must be observable, and phalangeal joints must be lengthened on the floor in the *relevé* position. In the concentric ("up") phase of the *relevé* (rise) into *fondu* (melt step with *plié* in synchronous time with gesture limb), straighten the knee slightly prior to the lift off the heel; in the eccentric ("down") phase of the *relevé*, do the opposite: the arch of the foot must control the landing by using the lumbrical muscles to roll through the metatarsal (returning the foot to a flat position) slightly **prior** to the knee bending to absorb the impact of the lower from *relevé*. Activate the deep core so that the shoulder complex can maintain a relaxed openness. Widen and separate the scapulae from one another to allow the latissimus dorsi and serratus anterior

to recruit synergistically. Maintain alignment of the knee over the second toe on the support leg when descending into *plié*. Cue the working leg to pass through the *attitude* (ballet position of the gesture leg: 90 degree or greater bend in external rotation) position on the way in and out of leg extension, and maintain the femoral head inside the acetabulum (hip socket); cue the gesture leg to lengthen from the sitz bone to the heal, rather that directing traction in the hip socket via the reach of the femoral head at the hip crease.

Progression 1: Perform "The Adagio Battement Fondu" with circular resistance bands around both legs.

Progression 2: Perform "The Adagio Battement Fondu" with the support leg on an inflated disk.

SESSION 8.

EXPERIMENTAL GROUPS 1 and 2

Protocol 8: Refining Floor Contact

Objective: To increase mechanoreceptor activity involved with floor contact of the feet (can also apply to the hands for inversions).

Exercise 1: "Three-Dimensional Breath" with foam roller and Progression 1 and 2

Exercise Two: "Melted Roll Ups" with Foam Roller and Progression 1 and 2

Exercise Three: "Lying Rotation for Standing" with Foam Roller.

Exercise Four: "Parallel Tendu" (see session seven for description).

Progression 1: "Parallel Tendu": exercise done in internal rotation, bringing leg "*en lair*" (off the floor) in a "degagé" (disengaged from the floor) position with resistance band. Add side lifts in 2nd position for gluteus medius strengthening within the framework of dance technique.

Exercise Five: "The Adagio Battement Fondu": (see session seven for description; adding Progression 3).

Progression 3: Perform "The Adagio Fondu" with support leg on a rotating disk.

SESSION 9.

EXPERIMENTAL GROUPS 1 and 2

Protocol Nine: Proprioceptive Tools

Exercise 1: "Three-Dimensional Breath" with foam roller and Progression 1 and 2

Exercise 2: "Melted Roll Ups" with Foam Roller and Progression 1 and 2

Exercise 3: "Lying Rotation for Standing" with Foam Roller.

Exercise 4: "*Retiré* Balance on Half Disk" (*retiré*: rotated figure 4 position of the gesture leg)

Objectives:

1. To increase proprioceptive competence by compromising the stability of the supporting surface.
2. To increase plantar mechanoreceptor sensitivity by using the "spiked" side of a half disk, as the spikey protrusions on the surface of the half disk awaken dorsal balance receptors.

Description: Stand on the spiked surface of an inflated half disk, holding a parallel *retiré* position for 50 seconds. Review all cues for supporting leg and foot and gesture leg and foot mechanics. Review pelvic and core stabilizing principles that were introduced in prior sessions and apply them comprehensively to the perturbation of balance created by interference between the plantar side of the foot and its weight bearing surface (review sessions 1-8).

Progression 1: *Retiré* balance on half-disk while throwing subject a ball to catch and having them throw the ball back.

SESSION 10.
EXPERIMENTAL GROUPS 1 and 2

Protocol Ten: Proprioceptive Review and Introduction of Future Progressions

Exercise 1: "Three-Dimensional Breath" with foam roller and Progression 1 and 2

Exercise 2: "Melted Roll Ups" with Foam Roller and Progression 1 and 2

Exercise 3: "Lying Rotation for Standing" with Foam Roller.

Exercise 4: "*Retiré* Balance on Half Disk" (Adding Progressions 2, 3, 4, 5. And 6).

Progression 2: *Retiré* balance on rotating disk while throwing subject a ball to catch, and having them return the throw.

Progression 3: *Retiré* (rotated figure 4 position of the gesture leg) balance on half-disk with closed eyes. Removing sight as a variable that assists the body in dynamic balance.

Progression 4: *Retiré* balance on rotating disk with closed eyes. Removing sight as a variable that assists the body in dynamic balance.

Progression 5: Standing on the half disk, perform a *developé en croix* (*en croix*: shape of the cross; directional performance to the front, side, and back of the body, finishing with a return to the side) with the gesture leg.

Progression 6: On the rotating disk, perform a *developé en croix* with the gesture leg.

APPENDIX C
MFR Intervention Protocol

SESSION 1.

Self-Fascia Release to enhance core exercises.

GROUP 2: EXPERIMENTAL GROUP

- **Release 1: "Abdominal and Spinal Teeter" with foam roller.**

Contraindication: Exercise is contraindicated for expectant mothers.

Objective: To open and hydrate connective tissue that may need releasing for maximum dynamism in the core; to open the solar plexus/foramen openings to support sufficient nerve gliding - necessary for all voluntary movement including dynamic balance.

Description: Lying prone with the foam roller vertical, "shear" the tissue of the abdominal aponeurosis. Then "melt" all the soft tissue of the thorax around the roller. Lying supine with the foam roller vertical, rock back and forth gently on the roller, allowing the roller to "shear" the tissue on the right and left sides of the vertebral column.

- **Release 2: "S.I. (Sacroiliac) Release" with foam roller.**

Objective: To hydrate connective tissue around the sacroiliac joints to ensure a well-balanced pelvis – which leads to better core stabilization.

Description: Lye supine with the roller splitting the difference between the SI joint and the upper gluteal muscles. "Shear" the tissue side to side (right SI, left SI).

Perform the "Melted Roll Ups" again to observe changes.

SESSION 2.

Session 1 repeat: Abdominal releases to enhance core exercises.

GROUP 2: EXPERIMENTAL GROUP

- **Release 1**: **"Abdominal and Spinal Teeter" with foam roller.**
- **Release 2: "S.I. (Sacroiliac) Release" with foam roller.**
- **Progression 1**: "Shearing" the SI tissue with the legs off the floor in the happy baby position.

SESSION 3.

Self-Fascia Release for the intrinsic muscles of the foot.

GROUP 2: EXPERIMENTAL GROUP

- **Release 1**: **"Penta-Point Releases - Right and Left Foot" with soft ball[37].**

Objective: Hydrate connective tissue in the foot to increase ROM and yield more refined root control needed to stabilize on a supporting leg for dynamic balance.

Description: Cue the tissue to "Melt" around the soft ball using Sue Hitzmann's foot positions 1-5.

- **Release 2**: **"MTP (Metatarsophalangeal) Release" on the right and left foot with soft ball.**

Objective: Assist subjects in understanding of MTP joint location and ensure mobility to activate lumbrical muscles in the sole of the foot during plantar flexion, with phalangeal joints in extension rather than flexion.

- **Release 3**: **"Skin Receptor Scribble" on the right and left foot with spikey ball.**

[37] Sue Hitzmann, creator of the SMR method known as MELT® originated this myofascial foot release technique and the five position points of the feet. The same five position points apply to the hands. See **Chapter 9** in **Part Two** of her book *The Melt Method*, 2013).

Objective: Increase the sensitivity of mechanoreceptors of the sole of the foot so that proprioceptive input coming from the skin's 'intake' of information from the floor can be maximized.

Description: "Scribble" – fast and small movements define the 'scribble'- the spikey ball beneath all portions of the bottom of the foot.

Experimental Group Performed "MTP Isolation" again to observe changes.

SESSION 4.

Repeat of Session 3: Self-Fascia Release for the intrinsic foot muscles.

GROUP 2: EXPERIMENTAL GROUP

- **Release 1: "Penta-Point Releases" on the right and left foot with soft ball[38].**

Addendum 1: Apply the same pressure that was used in the Penta-Point releases in the foot to all 5 position points in the hand. Try executing a hand-supported inversion afterward and observe any acute changes resulting from release of the fascia in the palm.

- **Release 2: "MTP (Metatarsophalangeal) Release" on the right and left foot with soft ball.**
- **Release 3: "Skin Receptor Scribble" on the right and left foot with spikey ball.**

SESSION 5

Self -Fascia Release at the Ischial Tuberosity (IT) attachments.

GROUP 2: EXPERIMENTAL GROUP

- **Release 1: "Position Four (4) Piriformis Release" with foam roller.**

[38] Sue Hitzmann, creator of the SMR method known as MELT® originated this myofascial foot release technique and the five position points of the feet. The same five position points apply to the hands. See **Chapter 9** in **Part Two** of her book *The Melt Method*, 2013).

Objective: Release any connective tissue that may be inhibiting refined recruitment of the "deep six" outward rotators. Release fascia strain that may be occurring around the SI joint.

Description: Sit with hips square, one leg in a square front attitude position (90 degrees) with the foam roller beneath the ischial tuberosity bones, and the opposite leg directly behind, aiming to keep the front of the hips as vertical as possible. "Sheer" the tissue beneath the ischial tuberosity bones to address the connections that attach at those points, and reach forward to expand the fascia sheaths that run along the SI joint on the posterior side of the pelvis.

Optional: Perform "Side Lying for Standing" from muscle recruitment protocol once again to observe changes.

SESSION 6.

Self-fascial release for the outside of the hip.

GROUP 2: EXPERIMENTAL GROUP

- **Release 1: "Lying Hip Release" with Medium Yoga Ball.**

Objective: Releasing fascial tissue in the in the gluteal region below the iliac crest, preventing binding of the connective tissue on the posterior side of the pelvic complex; preventing SI dysfunction, piriformis syndrome, and releasing bound connective tissue surrounding the hip capsule. This release can be experienced as an 'unwinding' that takes place all the way down the leg, into the knee and ankle.

Description: Lying supine or one side, palpate with the ball an area beneath the iliac crest that needs a releasing. Hold one point of pressure until it consciously releases, rather than thinking

of "massaging" the area out. See if you can observe fascial unwinding or de-spiraling occurring down the leg, at the knee or even at the ankle.

Progressions: Perform the same hip release along the outer ridge of the iliac crest, where the bone meets the flesh. Remain in areas that are tight or stuck and administer light pressure, envisioning a release or unbinding of the tissues that lay below the ball.

Optional: Observe changes in range of motion immediately following the release(s).

SESSION 7.

Self-Fascial releases of the medial and lateral leg.

GROUP 2: EXPERIMENTAL GROUP

- **Release 1**: **"Lateral Leg Release/IT Band Release" with foam roller**.

Objective: To release the connective tissue on the lateral region of the upper femur.

Lying on one side, place the foam roller underneath the lateral side of the leg from the hip flexor down to the ankle, "shearing" the tissue in areas that feel exceptionally tight. Shear the tissue with "front to back" motions as well as "side to side" motions, and experiment with the length of these motions. Alternate from very small, incremental shears to longer shears.

- **Release 2**: **"Adductor Abrade" with foam roller**.

Description: Lying on one side, place the top leg in front of you on the floor at a 90-degree angle with the foam roller beneath the adductor region of the top leg. Release from the upper adductor region down to the ankle, shearing the tissue when tight regions arise.

SESSION 8.

Hip flexor release with Session 5 repeat: Self-fascia releases of the medial and lateral leg.

GROUP 2. EXPERIMENTAL GROUP

- **One: "Lateral Leg Release/IT Band Release" with foam roller.**
- **Release Two: "Adductor Abrade" with foam roller.**
- **Release Three: "Hip Flexor Halve" with foam roller**.

Objective: To eliminate fascial binding that inhibits freedom of the iliacus or psoas major.

Description: Lying Prone, shear the tissue directly above and directly below the hip flexor area. Remain steady on the point of tension(s) that seem tight and rigid, inhibiting the movement of femur within the acetabular (hip socket) cavity, but allowing circumduction within the socket as necessary to accommodate the shearing motion.

SESSION 9.

Self-fascia release for ankle and foot mobilization.

GROUP 2: EXPERIMENTAL GROUP

- **Release 1: "Malleable Mid-Foot" hand massage with emollient.**

Objective: To release connective tissue that sticks to the metatarsal bones.

Begin by sitting on the floor with the feet out in front of you. Grasp under the bottom of the foot with one hand, and with the other hand massage the fascia in between each metatarsal bone. If soreness is experienced, remember that the intrinsic muscles of the feet are richly innervated and nerves in between the metatarsal bones may need release.

- **Release 2: "Malleable Ankle Movement[39]".**

Objective: To increase range of motion in the talocrural joint.

Description: Bring your foot toward you via the front attitude position. Support around the talus with one hand and grasp the heel with the other. To create space in the joint, glide the calcaneus bone down in a scooping motion as you glide the talus up, simultaneously pointing the ankle joint.

Progression: Once the talo-crural joint is properly distracted, point and relax the ankle joint repeatedly and in small ranges. Observe any ankle joint adjustments or soft tissue releases that might ensue.

SESSION 10

Self-fascia release to enhance hamstring flexibility.

- **Release 1: "Sub Occipital Release" with foam roller[40].**

Objective: To release interconnected fascia along Tom Meyers' theorized superficial back line (SBL).

Description: Palpate the occipital bones on the posterior surface of the skull. Lying supine, place the foam roller below the occipital protrusions and rest the neck only on the soft surface of the roller. Shear the tissue of the neck by nodding "yes" and shaking the head "no" with the foam roller in position.

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[39] Lisa Howell originated this technique, designed for dancers to create space/distraction in the talocrural joint. Lisa Howell calls it "Mid-Foot Mobilization". I created the progression through experimentation with Howell's description of her mobilization technique.

[40] Sue Hitzmann, creator of the MELT® method is the true originator of the self-fascia release design described here. Small adjustments to the classical sub occipital release designed by Sue Hitzmann were made by the lead researcher to further access the superficial back line and affect the fascia of the hamstring, a specific objective for the dance population.

- **Release 2: Gastrocnemius Release with foam roller.**

Objective: To release interconnected fascia along Tom Meyers' theorized superficial back line (SBL).

Description: Sitting on the floor, position the foam roller perpendicular to your foreleg, and rest your calf on the top of the roller's surface. Addressing the posterior aspect of foreleg, begin to "shear" the fascial tissue in two directions: laterally, by moving your foreleg back and forth in a horizontal direction, and vertically, by moving your foreleg up and down in a vertical direction, allowing the foam roller to roll along the ground and the calf accordingly. Begin the "shearing" up by the knee, working down toward the bottom of the Achilles tendon.

APPENDIX D

STAR EXCURSION BALANCE TEST (S.E.B.T.)

Standard Operation of Procedures

- MATERIALS
  - 2-inch wide tape
  - Goniometer

- CONSTRUCT THE STAR
  - Make a 6.0 x 6.0 foot square.
  - Create 8 lines that start from the center and reach to the edge, in a star shape. Using the goniometer, the angle between each line should measure 45 degrees.

- PROCEDURES:
  - Only verbal instruction will be given, and the subject will not be given a practice round.
  - The subject will stand in the center of the grid, with hands on hips, and one foot off the ground with toes at the ankle (coupe).
  - The subject will be instructed to lightly tap the toe of the raised foot at each point, extending first to the front, then opening laterally, then extending medially.
  - The subject will perform first on the right leg, then on the left.
  - The subject should aim to complete the test as quickly as possible.

Sources:

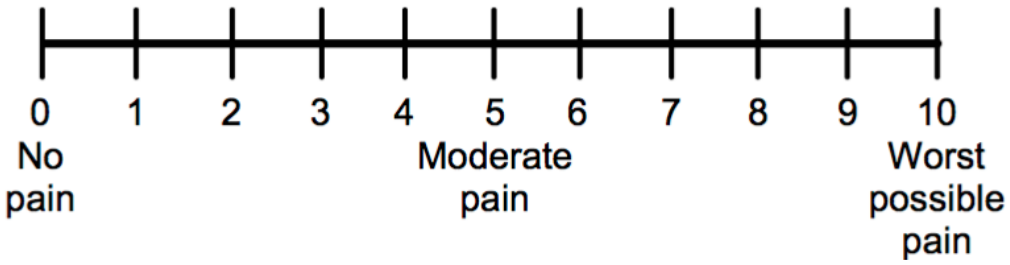
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APPENDIX E

VAS NUMERIC PAIN SCALE

with 0-10 Number Scale Intervals



Sources:

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