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Short- Term Pilates Exercise Intervention and Its Impact on Functional Movement in Healthy Middle-Aged Adults

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Abstract

This study aimed to examine a short- term Pilates exercise intervention and its impact on functional movement in healthy middle-aged adults. The research included 24 healthy, middle-aged adults from 40-59 years. Participants were divided into an experimental group (Pilates Group= PG, n=17) to perform Pilates exercise four days a week and control group (CG, n=7). The video-based, 6-week Pilates intervention evaluated fundamental movement patterns using the Functional Movement Screen (FMS) which is comprised of seven separate tests. Total FMS scores and scores of the seven tests were analyzed pre and post-intervention. Statistical analyses used the SPSS program. P values of less than 0.05 were considered statistically significant.

A mixed model ANOVA was selected to examine pre and post-FMS total scores between and within the PG and CG groups, and to evaluate between and within group differences in the seven FMS tests. The total FMS scores improved significantly for the PG group (mean: 12.12 to 15.71) and did not improve in the CG group (mean: 16.00 to 15.57). The seven tests for the PG group pre to post-test: Deep squat (mean: 1.65 to 2.12), hurdle step (mean: 1.47 to 2.06), inline lunge (mean: 1.94 to 2.47), shoulder mobility (mean: 1.29 to 1.88), active straight-leg raise (mean: 2.59 to 2.82), trunk stability push-up (mean: 1.88 to 2.47), and rotary stability (mean: 1.29 to 1.88). The present findings suggest that Pilates exercise is effective in improving fundamental movement patterns in healthy middle-aged adults.

Keywords: Pilates, functional movement, middle-aged, mobility, trunk stability, functional movement screen

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Chapter 1: Introduction

Background Information

Functional Movement

Functional movement plays an important role in activities of daily living and overall health. It allows an individual to move freely through a specific range of motion utilizing balance, core control, postural stability, muscular control, and strength. Movement health, competency, and capacity are fundamental aspects of human movement (Benoît-Piau et al., 2021; Cook et al., 2014a; Cook et al., 2014b; Lim & Park, 2019). Fundamental movement patterns include upper body and lower body movements targeting balance, stability, and mobility to enhance dynamic movement health.

Efficient movement patterns can improve transitional movements and range of motion in daily activities to enhance quality of life. Research has shown functional movement can improve overall balance, core control, postural stability, muscular control, and strength for daily activities (Cook et al., 2014a; Cook et al., 2014b; Koehle et al., 2016; Lim & Park, 2019; Segal et al., 2004). In addition to balance and muscular control, additional benefits include reducing the risk of injury and bodily pain. Daily activities such as walking, sitting, and standing can benefit from greater ease of movement.

Functional movement dysfunction can lead to poor biomechanics and minimize an individual's activities of daily living. Dysfunction increases the possibility of micro- or macro-traumatic musculoskeletal injury (Cook et al., 2014a; Mahdieh et al., 2020). In addition, movement dysfunction can lead to muscular imbalances and misaligned muscular movement patterns causing bodily discomfort, pain, and additional stress on the body (Comerford & Mottram, 2001; Cook et al., 2014a; Kim et al., 2020; Laws et al., 2017; Mahdieh et al., 2020). Inefficient movement patterns will further decrease range of motion, forcing an individual to adopt muscular compensation patterns over time, and increase risk of injury (Cook et al., 2014a). “A balance between mobility and stability in joints through the kinetic chain is a prerequisite for performing fundamental movement patterns, which, in turn, is a prerequisite for performing basic functional movements” (Mahdieh et al., 2020, p. 2). Movement dysfunction limits an individual's ability to efficiently perform activities of daily living.

The primary method researchers and practitioners utilize to assess functional movement is the Functional Movement Screen (FMS). The FMS is a dynamic screen to assess fundamental movement patterns, stability, mobility, neuromuscular control, and asymmetry of the human body (Akkoç & Kırandi, 2019; Beardsley & Contreras, 2014; Hatta et al., 2021; McNeill, 2014). The FMS is scored between 0 - 21 points, with higher scores indicating greater movement control and stability (Beardsley & Contreras, 2014; McNeill, 2014). The FMS results allow the researcher to identify movement efficiency strengths and weaknesses, limitations, compensations, and further develop a training program emphasizing movement pattern corrections to improve flexibility, mobility, and overall coordination (Cook et al., 2014a; Cook et al., 2014b; Mahdieh et al., 2020; McNeill, 2014; Perry & Koehle, 2013). The FMS is a portable, convenient, and widely used assessment for functional movement.

Pilates

Pilates is a form of exercise that has grown in popularity in the United States. Joseph Pilates created the Pilates method of training to emphasize exercise and movement (Cruz-Ferreira et al., 2011; Laws et al., 2017; Segal et al., 2004). The original Pilates program consisted of thirty-four original exercises and was referred to as Contrology (Isacowitz & Clippinger, 2020; Pilates & Miller, 1945). Contrology focused on balance and total coordination of body, mind, and spirit through combined elements of gymnastics, martial arts, yoga, and dance (Cruz-

Ferreira et al., 2011; Lange et al., 2000; Pilates & Miller, 1945; Tolnai et al., 2016). As noted previously, muscular imbalances, poor habitual movement patterns, and compensatory movements can increase an individual's risk of injury. In response to this, Pilates primary focus is on six key principles: Centering, concentration, control, precision, flow, and breath (Cruz-Ferreira et al., 2011; Eliks et al., 2019; Hatta et al., 2021; Hatta et al., 2018; Pilates & Miller, 1945; Tolnai et al., 2016; Yamato et al., 2015). These principles embody the Pilates practice and serve as the foundation for training (Cruz-Ferreira et al., 2011; Pilates & Miller, 1945). Centering and concentration are essential for stability and emphasize trunk and core strength, as well as awareness of active muscles within each movement (Eliks et al., 2019; Ispas & Macovei, 2016; Pilates & Miller, 1945; Yamato et al., 2015). Control and precision highlight muscle action, accuracy of muscle movement, alignment, and postural control (Ispas & Macovei, 2016; Pilates & Miller, 1945). Flow and breath principles focus on the importance of conscious breathing and exercise sequencing to practice flowing movement patterns (Ispas & Macovei, 2016; Pilates & Miller, 1945). Pilates classes emphasize the six key principles while offering exercises with fluid movements and smooth transitions.

Numerous general and specialized Pilates class options are available today in public and private studios. Classes are open to diverse populations of all ages and physical activity levels. Mats and Pilates apparatus, such as reformer body conditioning equipment, serve as the primary equipment for most classes (Cruz-Ferreira et al., 2011; Yamato et al., 2015). One-on-one training and large mat-based classes are readily available and taught by certified instructors. Pilates classes offer a systematically designed series of exercises promoting enhanced range of motion, balanced muscle development, body coordination, body awareness, and movement efficiency (Akkoç & Kırandi, 2019; Hatta et al., 2021; Hatta et al., 2018; Kim et al., 2020; Kofotolis et al., 2016; Lim & Park, 2019; Pilates & Miller, 1945; Segal et al., 2004; Tolnai et al., 2016). In addition, Pilates exercise programs support muscular strength, flexibility, postural alignment, core strength, and improved circulation (Akkoç & Kırandi, 2019; Cruz-Ferreira et al., 2011; Hatta et al., 2021; Hatta et al., 2018; Kloubec, 2011; Kofotolis et al., 2016; Lim & Park, 2019; Monger & Harrison, 2016; Pilates & Miller, 1945; Segal et al., 2004; Tolnai et al., 2016). In summary, Pilates has been proven to enhance daily movement patterns by way of the six key principles.

Pilates and Functional Movement

Pilates classes offer exercises to improve ease and efficiency of daily movement patterns. The individual Pilates exercises can enhance overall muscular strength, core control, and balance to diminish one's risk of movement deficiencies. Functional movements are observed in Pilates-based classes as the exercises engage specific activation patterns along the kinetic chain (Monger & Harrison, 2016; Segal et al., 2004). Closed kinetic-chain exercises can diminish degenerative risk by inducing compressive and decompressive forces to joints and cartilage (Segal et al., 2004). Some examples of closed kinetic chain Pilates exercises that utilize multiple joints and muscle groups include shoulder bridge, side-kick kneeling, and single and double leg stretches. The shoulder bridge exercise is performed supine with the knees bent and feet flat on the floor while raising one leg towards the ceiling and pointing the toes, then returning to starting position. Side-kick kneeling exercise is performed on both sides of the body. For example, leaning the body towards the right side with the right hand and right knee on the floor, the left leg is lifted upwards to align with the hips and the left arm is stretched towards the ceiling. Single and double leg stretches are performed supine, palms resting down by the sides of the body and lifting single or both legs up off the floor. Pilates systematic sequence of exercises highlights muscle recruitment and alignment throughout the full range of motion to improve movement efficiency (Hatta et al., 2018). Greater functional movement can reduce muscular imbalances, poor body alignment, and movement dysfunction.

Gaps in Research and Scholarship

The benefits of Pilates are well documented, and Pilates interventions can positively impact health and quality of life. Despite previous research detailing the benefits of Pilates, limited research has investigated the impact of Pilates on functional movement patterns in healthy populations (Tolnai et al., 2016). Functional movement patterns in older adults have been examined, but limited research is available among middle-aged adults. First, there is a need for further research on the impact of Pilates on muscles and joints, muscle mobilization, and postural alignment to examine the physical effects of sedentary behavior or physical inactivity throughout the lifespan (Lee et al., 2016; Lim & Park, 2019). Second, previous research has provided evidence-based need to analyze the effects of Pilates mat exercise on abdominal strength, back strength, and trunk flexibility (Sekendiz et al., 2007). Third, there is limited research identifying specific Pilates exercises that target lower back and abdominal muscles as well as the exercise prescription to produce flexibility outcomes (Sekendiz et al., 2007). Fourth, Kim et al. (2020) recommended further evaluating the effects of core stability exercise on quality of life and mild pain and discomfort. Fifth, there is limited research available on Pilates video interventions in healthy populations (Donahoe-Fillmore et al., 2007; Donahoe-Fillmore et al., 2015). Finally, there is a need to develop Pilates-based programs and examine the acute and chronic physical and psychological effects on healthy populations (Monger & Harrison, 2016; Tolnai et al., 2016). While all of the strategies are excellent approaches, there is limited information on the direct benefits of Pilates on functional movement in healthy middle-aged populations.

Problem Statement (Research Question)

The purpose of this study is to assess the impact of a short-term Pilates exercise intervention pre to post-test on functional movement patterns as measured by the FMS in healthy middle-aged adults.

Hypothesis

H_1- A short-term Pilates exercise intervention administered through a series of videos will improve functional movement patterns as tested by the total FMS scores in healthy middle-aged adults.

H_2- There will be significant group differences between experimental and control groups in functional movement patterns as tested by the seven FMS tests following a short-term Pilates exercise intervention administered through a series of videos.

H_0- A short-term Pilates exercise intervention administered through a series of videos will not improve functional movement patterns in healthy middle-aged adults.

Definitions

The following definitions help understand the terminology used in this study.

Functional Movement Patterns- Fundamental movements of the upper and lower body target balance, stability, and mobility to enhance dynamic movement health, competency, and capacity (Cook et al., 2014a; Cook et al., 2014b; Lim & Park, 2019). The goal is the absence of dysfunction, although functional movement can still exist even if there is dysfunction in the movement patterns.

Functional Movement Screen (FMS)- A dynamic screening tool which assesses fundamental movement patterns, stability, mobility, neuromuscular control, and asymmetry of the human body (Akkoç & Kırandi, 2019; Beardsley & Contreras, 2014; Hatta et al., 2021). This screening tool is comprised of seven tests including, active straight leg raises, trunk stability push-up, deep squat, shoulder mobility, rotary stability, hurdle step, and in-line lunge (Beardsley & Contreras, 2014). Each individual test is rated from 0 (pain occurs during a test), 1 (cannot perform the movement), 2 (able to complete the movement with slight modification), and 3 (performs the movement correctly) combined into a final score of twenty-one possible points (Beardsley & Contreras, 2014). The FMS is a valid test with high levels of inter-rater and intra-rater reliability used to identify movement pattern limitations and/or dysfunctions (Beardsley & Contreras, 2014).

Healthy Population- For the purposes of this study, this will be assessed by the absence of cardiovascular, metabolic, neuromuscular, pulmonary, and orthopedic pathology and/or dysfunctions (Monger & Harrison, 2016; Tolnai et al., 2016). Current pregnancy or childbirth within the past six months will also be excluded. The PAR-Q+ will assess each participant's readiness for physical activity and confirm participants do not have any major issues that would cause them not to be able to participate in the study (see Appendix C).

Intervention- A prescribed exercise program designed to improve fundamental movement patterns.

Middle-aged- Age 40-59 years

Movement capacity- Muscle performance based on functional movement tasks engaging single-joint or multi-joint muscular systems affecting force and velocity relationships and power output (Cook et al., 2014b; Zivkovic et al., 2017).

Movement competency- Fundamental movement patterns completed in the absence of pain and compensation to exhibit muscle proficiency (Benoît-Piau et al., 2021; Cook et al., 2014b).

Movement health- The ability of a muscle to move without structural changes, neurological disabilities, or permanent limitations to movement (Cook et al., 2014b).

Pilates- Mind-body mat-based exercise conditioning system developed by Joseph Pilates, systematically designed, and based on six key principles: Centering, concentration, control, precision, flow, and breath (Byrnes et al., 2017; Cruz-Ferreira et al., 2011; Eliks et al., 2019; Hatta et al., 2021; Hatta et al., 2018; Pilates & Miller, 1945; Yamato et al., 2015). Centering refers to the activation and stabilization of the 'powerhouse' core muscles (Eliks et al., 2019; Key, 2013; Pilates & Miller, 1945; Yamato et al., 2015). Joseph Pilates referred to the 'powerhouse' as the physical center of the body from the bottom of the rib cage to base of the glutes, anterior and posterior of the body (Isacowitz & Clippinger, 2020; Key, 2013; Pilates & Miller, 1945). Concentration emphasizes directed attention, control refers to intentional guided movements, and precision highlights exercise technique (Eliks et al., 2019; Pilates & Miller, 1945; Yamato et al., 2015). Flow brings attention to fluid and transitional movement patterns, while incorporating rhythmic breathwork (Eliks et al., 2019; Pilates & Miller, 1945; Yamato et al., 2015). The emphasis is on total coordination of body and mind awareness, enhancing daily movement patterns, postural stability and alignment, proprioception, dynamic balance, flexibility, and abdominal strength (Byrnes et al., 2017; Cruz-Ferreira et al., 2011; Eliks et al., 2019; Hatta et al., 2021; Hatta et al., 2018; Pilates & Miller, 1945;

Yamato et al., 2015). Pilates and Miller (1945) recommended four practice sessions per week to develop greater muscular strength, flexibility, and normal muscle function.

Short-term- 6-weeks

Assumptions and Limitations

There are several methodological assumptions present throughout the study. First, it was assumed the variables under investigation were measurable. Second, it was assumed the screening tools and exercise intervention were appropriate to the problem addressed and the purpose of the study. Third, a familiarization session was conducted pre-intervention to provide an opportunity for participants to preview the screening tools and to sample Pilates exercises. Fourth, the researcher divided participants into experimental and control groups and collected pre- and post-test measurements but could not verify that all would complete the study. Fifth, all participants were encouraged to work to the best of their abilities throughout all exercise sessions. Sixth, the experimental group only participated in Pilates exercise, no other form of training, during the intervention period. Then the control group was advised to continue with normal daily activities, but not participate in Pilates (mat or Reformer) for the duration of the study. Lastly, a major assumption was participant adherence would be met for the duration of the study.

There were several methodological limitations to the study. A major limiting factor was the age range, including only 40-59 years. By limiting the age range, younger and older adult populations were not examined. Several studies specifically examined younger and older adult populations, with a gap in existing research demonstrating the need for the middle-aged population. A second limitation was specific exercise selection and class design. Numerous Pilates exercises were considered, but a specific number were selected for each weekly session to be completed within a realistic time frame. The weekly class sessions were designed to focus on progressive full body exercises. A third limitation was Pilates exercise session duration and frequency. Exercise session duration and frequency were carefully considered to encourage participation within realistic time commitments, further potentially increasing adherence to the study. Accordingly, six weeks were selected to stay within research timelines and comparable to several studies which examined four-to-eight-week interventions. A fourth limitation was weekly video administration. Video administration did not allow the researcher to visually observe proper execution of all movements during weekly class sessions. A fifth limitation was the study took place in one central location, and the possibility of recruiting a small sample size existed and would not be representative of the population. To conclude, the study had been intentionally designed to minimize the impact of limitations and ensure quality data collection from participants.

Significance of Study

Pilates can improve core strength, balance, flexibility, muscle control, and improve postural awareness. The individual exercises induce muscle activity to mimic specific kinetic chain activation patterns in daily functional movements (Monger & Harrison, 2016). Efficient fundamental movement patterns influence an individual's dynamic movement health, competency, and capacity (Cook et al., 2014a; Cook et al., 2014b; Lim & Park, 2019). Functional movement deficiencies detected in middle-aged adults can minimize the risk of movement dysfunction and disability later in life. Fundamental movement patterns are vital for daily functioning throughout the lifespan. Previous studies have targeted young adult or older adult populations, and there is limited research exploring age-related progressive loss in functionality during middle-age. This low-cost and short-term intervention can provide an opportunity for middle aged adults to identify movement limitations, learn exercises to enhance fundamental movement patterns, and aid in future programming for this population.

Chapter 2: Literature Review

Introduction

The development of incorrect movement patterns and muscular imbalances over time creates muscle weakness and overcompensation in middle-aged adults. Early detection of movement deficiencies in middle-age can minimize loss of functionality, disability, and fall risk later in life. Progressive muscle loss, impaired balance control, and gait changes occur with aging and may be prevented by early detection as well. Greater mobility and stability in joints are critical to comfortably performing fundamental movements. “Decreases in muscle strength and mass in middle-aged adults may negatively affect the quality of daily activity applications (walking, sitting, climbing stairs) that are performed in the advanced ages” (Guler et al., 2021, p.1). With increasing age, physio motor abilities may decrease due to structural and functional changes within the neuromuscular system (Guler et al., 2021). Functional capacity, joint mobility, and aging effects on the neuromuscular system can be protected by building muscular strength.

Pilates exercise programs support enhanced functional health, muscular strength, and movement efficiency. A study by von Sperling de Souza and Brum Vieira (2006) reported the majority of individuals seeking Pilates training are middle-aged women in pursuit of improved posture and flexibility. Pilates-based classes embody a therapeutic role to reduce musculoskeletal discomfort and pain through a series of exercises designed to improve fundamental movement pattern efficiency (von Sperling de Souza & Brum Vieira, 2006). Pilates classes are offered in commercial and private studios, as well as electronic format. Videos can serve as a convenient, accessible, and cost-effective option permitting individuals to schedule practice within realistic time commitments. The mind-body connections, strength building exercises, and fluid transitions throughout a Pilates class generate increased awareness of bodily movements.

Pilates and Functional Movement

Functional Movement

Functional movement allows an individual to move freely through a specific range of motion utilizing balance, core control, postural stability, muscular control, and strength. Research has shown greater functional movement can reduce muscular imbalances, poor body alignment, and injury risk associated with movement dysfunction (Akkoç & Kırandi, 2019; Comerford & Mottram, 2001; Laws et al., 2017; Lim & Park, 2019). Movement dysfunction can limit movement through the body's anatomical planes, further reducing range of motion and leading to muscular imbalances (Comerford & Mottram, 2001). Greater movement efficiency can have a positive impact on activities of daily living.

Pilates interventions can offer individuals an opportunity to strengthen and retrain fundamental movement patterns for dynamic movement health. In addition, Pilates exercises are designed to help minimize functional deficits and promote functional capacity for greater functional movement. Laws et al. (2017) conducted a study with healthy recreational runners and used a modified FMS (MFMS) including deep squat, hurdle step, in-line lunge, trunk stability push-up, and rotary stability tests. Biomechanical imbalances, physical, and functional demands were assessed following six weeks of 60-minute weekly Pilates sessions. Laws et al. (2017) demonstrated a significant improvement in MFMS scores from 13.5 ± 2.5 to 17.0 ± 1.7 following Pilates. The authors reported biomechanical improvements in hip and knee control and lower limb alignment to enhance running economy following the Pilates intervention (Laws et al., 2017). The intervention successfully addressed the functional deficits, as demonstrated by the biomechanical improvements. The runners experienced greater dynamic hip and knee control to further reduce the risk of injury. The progressive Pilates classes also contributed to substantial strength and stability improvements.

Pilates can provide physical and mental health benefits throughout all stages of life. The six principles of Pilates may contribute to movement awareness and motor sense further developing functional movement (Lim & Park, 2019). Lim and Park (2019) and Akkoç and Kırandi (2019) recruited healthy middle-aged adults and examined the impact of an 8-week Pilates intervention on functional movement. Both studies included pre- and post- measurements for all seven FMS tests and displayed statistically significant results. Lim and Park (2019) reported FMS test results improving from 10.36 ± 2.27 to 12.43 ± 2.13 following Pilates. Akkoç and Kırandi (2019) reported similar improvements of 13.08 to 17.58. The authors suggested the dynamic movements in Pilates specifically designed to enhance balance, stability, and mobility attributed to the FMS test results. Several Pilates interventions ranging from three to twelve weeks showed improvement in FMS scores.

Flexibility

Flexibility is the ability of muscles and muscle joints to stretch temporarily, ultimately allowing the joint to move. Functional and neuromuscular efficiency, reduced muscular tension, and better muscle and tendon extensibility are benefits of whole-body flexibility (Ružić, 2020). Muscular imbalance corrections, increased joint range of motion, and reduced joint stiffness are additional benefits of greater flexibility (Ružić, 2020). The benefits of flexibility are well documented and have been documented in Pilates-based research as noted in the paragraphs to follow.

A study by Gladwell et al. (2006) examined a modified Pilates program with an emphasis on increasing flexibility and reducing functional disability in primarily middle-aged adults. The 6-week progressive intervention consisted of instructor-led 60-minute classes and home-based 30-minute classes (Gladwell et al., 2006). Functional flexibility-based assessments, including the stork stand test and sit and reach, showed enhanced functional performance ($p < 0.05$) and significant improvements in flexibility (cm; pre: 8.7 ± 7.7; post: 13.3 ± 7.7) following Pilates (Gladwell et al., 2006). Another study by Ružić (2020) also incorporated the sit and reach test to assess flexibility and recruited healthy college-aged students. Participants completed a 12-week Swiss ball Pilates intervention and similar to Gladwell et al. (2006), developed 60-minute sessions consisting of a dynamic warm-up and static cool-down. Significant improvements in the sit and reach test were evident post-intervention (cm; pre: 25.53 ± 9.93; post: 31.20 ± 8.01) particularly in the torso region, due to increased range of motion (Ružić, 2020). As noted in these studies, short-term Pilates interventions designed to incorporate functional movements specifically targeting core muscles can enhance flexibility.

Pilates has been shown to be an efficient training method to enhance trunk and hamstring flexibility. For example, Sekendiz et al. (2007) designed a 5-week Pilates mat exercise intervention targeting posterior trunk flexibility and consisted of 60-minute sessions. The authors reported significant improvements in the YMCA standard sit-and-reach test (cm; pre: 23.9 ± 7.5; post: 31.3 ± 6.8) post-Pilates (Sekendiz et al., 2007). This finding was further supported in a similar study by Kloubec (2010) who also incorporated a mat Pilates intervention for two 60-minute sessions per week. Following twelve weeks of Pilates, participants performed the sit and reach test and reported statistically significant improvements (cm; pre: 30.68; post: 33.41) (Kloubec, 2010). Pilates structured exercise sequence of dynamic stretching and repetitive movements contributed to flexibility improvements.

Mobility

Mobility is the ability of muscles and muscle joints to actively move through a full range of motion. Mobility impairments may lead to functional losses and impact fundamental movement patterns with increasing age (Grimmer et al., 2019). Functional Movement Screen assessments examining bilateral and symmetrical functional mobility were favorable following Pilates exercise training (Hatta et al., 2018; Hatta et al., 2021). Hatta et al. (2018) examined Pilates exercise and its effects on hip joint flexion mobility in healthy collegiate athletes. Three weeks of Pilates exercise and static stretching produced significant changes in the FMS overhead squat assessment, specifically hip-to-floor distance ($F = 130.897$, $p < 0.001$, $\eta p^2 = 0.867$) (Hatta et al., 2018). This finding was further supported by Hatta et al. (2021) who tested a similar hypothesis in college-aged students. The authors found hurdle step (pre: 2.2 ± 0.4, post: 2.7 ± 0.5), in-line lunge (pre: 2.2 ± 0.4, post: 2.6 ± 0.5, $p < 0.05$), and rotary stability (pre: 2.2 ± 0.4, post: 2.5 ± 0.5, $p < 0.05$) FMS measurements increased following 5-weeks of Pilates (Hatta et al., 2021). Total FMS scores increased from 15.9 ± 1.7 to 18.0 ± 1.6 ($p < 0.001$) following Pilates (Hatta et al., 2021). Pilate’s exercise enhanced bilateral hip joint flexion mobility, functional mobility of the hips, quadriceps flexibility, and hamstrings extensibility. Both studies demonstrated Pilates exercise diminished risk of musculoskeletal system dysfunction and enhanced fundamental movement patterns.

Stability

Stability is defined as muscle and surrounding tissue’s ability to support and control movement patterns. Core strengthening exercises engage the lumbar-pelvic-hip complex (transverse abdominis, diaphragm, pelvic floor muscles, deep fibers of the lumbar multifidus), and target specific activation patterns to improve functional movement performance (Kim et al., 2020; Monger & Harrison, 2016). Daily activities benefit from core stability exercises designed to target body stabilization, force, and power generation (Kim et al., 2020). Pilates exercises activate a broad range of core muscles and maximize core function, further strengthening abdominal and lumbar regions to support the spine and transfer during functional movements

(Lee et al., 2016). In addition, Pilates exercises emphasize rhythmic breathing patterns actively engaging abdominal muscles to stabilize the core musculature and enhance movement efficiency.

Pilates practice can increase awareness of postural misalignments and improve core strength and stability to minimize muscular imbalances. A study by Lee et al. (2016) examined the impact of a 12-week mat-based Pilates intervention on physical structures, muscle mobilization, and postural alignment in middle-aged adults. The progressive intervention emphasized an adaptive period (weeks 1–3), development period (weeks 4–10), and maintenance period (weeks 11–12). The authors reported Pilates exercise performed symmetrically strengthened deep trunk muscles and improved postural alignment in the sagittal and horizontal planes (Lee et al., 2016). Core stability generates force and power in three planes of movement to facilitate greater movement control in daily activities.

Pilates classes intentionally focus on body alignment to retrain dysfunctional movement patterns. Core stability exercise stems from Pilates exercise programs and the unique emphasis on inter-segmental coordination of bodily movement and body realignment (Kim et al., 2020). Kim et al. (2020) examined functional movement and balance following a 4-week Pilates video-based intervention emphasizing core stability. Participants were asked to complete the video-based intervention twice a day, three days per week with a goal of twenty sessions over the course of 4-weeks. The researchers requested participants complete weekly check-ins and track exercise sessions in a training log. The authors analyzed the seven FMS tests independently, as well as the total FMS score. Post- assessments showed improvements in all seven tests: deep squat (pre: 2.4 ± 0.5, post: 2.9 ± 0.3), hurdle step (pre: 2.0 ± 0.5, post: 2.5 ± 0.5), in-line lunge (pre: 2.2 ± 0.9, post: 2.7 ± 0.5), shoulder mobility (pre: 2.0 ± 0.8, post: 2.1 ± 0.7), active straight-leg raise (pre: 1.9 ± 0.9, post: 2.5 ± 0.5), trunk stability push-up (pre: 2.4 ± 1.1, post: 2.6 ± 0.7), and rotary stability (pre: 1.7 ± 0.7, post: 2.1 ± 0.3) (Kim et al., 2020). A significant increase in hurdle step ($p = 0.024$, group × time effect) and shoulder mobility ($p = 0.037$, group × time effect) were determined following a Pilates intervention (Kim et al., 2020). Further analysis demonstrated there was a significant main effect of time on active straight leg raise ($p = 0.037$) and trunk stability ($p = 0.023$) tests (Kim et al., 2020). Dynamic stability and segmental movement patterns increased by way of core strengthening exercises, further leading to greater functional movement.

Social Cognitive Theory and Physical Activity

The social cognitive theory (SCT) emphasizes personal, environmental, and behavioral interactions, perceived self-efficacy, knowledge, goal setting, outcome expectations, observational learning, reinforcement, and self-regulation. The theory is recognized as one of the most common health behavior change constructs to successfully promote positive improvement in a variety of physical activity interventions (Bandura, 2004; Poddar et al., 2012). Poddar et al. (2012) examined the self-regulation construct through an online health intervention. The authors found health education delivered via electronic mail including weekly behavior checklists and quizzes, supported participant’s use of self-regulation strategies. Weekly communication with participants increased awareness, tracking, planning, and significantly improved health behaviors throughout the 8-week intervention. Health interventions that include weekly checkpoints have the ability to increase adherence and self-monitoring skills to encourage and adopt positive behavior change in the long term.

Numerous studies have shown physical activity interventions based on SCT demonstrate more favorable results and positive relationships amongst the SCT components. Rovniak et al. (2002) acknowledged the significance of SCT-based interventions offering a unique framework to explain and predict physical activity outcomes when designing exercise interventions. Following an 8-week intervention, the authors reported physical activity levels improved and were greatly impacted by goal setting, self-regulation, and planning principles (Rovniak et al., 2002). Individuals with higher levels of exercise self-efficacy appeared to intentionally schedule exercise participation, commit to plan, and set goals, and face obstacles with positive problem-solving strategies (Rovniak et al., 2002). Exercise self-regulation involved skills for planning, organizing, self-monitoring, and managing exercise activities throughout the intervention. Physical activity interventions based on SCT can positively encourage long-term permanent changes.

SCT-based interventions have proven successful in young to middle-aged adults. For example, Rosenkranz et al. (2018) evaluated measures of self-efficacy and outcome expectations of two online physical activity interventions. Middle-aged adults (mean age = 50.8 ± 13.0 years) increased physical activity levels due to the theory-based behavior-change model. Similar studies by Easton et al. (2017) and Ehlers and Huberty (2014) examined the impact of environmental factors, social support, and emotional support from others ultimately affecting one's decision to become physically active (Easton et al., 2017; Ehlers and Huberty, 2014). Easton et al. (2017) recruited sixty-two women with ages ranging from 23-61 years (M= 35.66 years) to participate in a 6-week boot camp fitness intervention. The intervention encouraged women to follow a fitness program and focus on goal setting, problem solving strategies, and physical activity tracking (Easton et al., 2017). Five pre- and post-surveys were distributed to assess social physique anxiety, social support, exercise benefits, and barriers. Regardless of the number of exercise sessions attended, participants displayed significant differences in change scores for benefits to exercise ($p = .002$), but not in social physique anxiety (pre- 18.61; post- 18.49) and social support scales (pre- 18.61; post- 18.49) (Easton et al., 2017). Throughout the study, the group setting offered females an outlet to connect, enhance social support, communicate, set goals, self-regulate exercise activity, and train together while improving overall health.

A similar study by Ehlers and Huberty (2014) administered an SCT-based survey on health and fitness mobile application preferences to middle-aged women. Health/fitness preferences were favored by 63.8%, primarily for a desire to lose weight (63.4%), and physical activity tracking (54.5%) (Ehlers & Huberty, 2014). Most females expressed an interest in mobile apps to provide feedback (91.2%), track exercise progress (90.1%), goal setting (78.4%), offer music (92.2%), and track a variety of physical activities (91.0%) (Ehlers & Huberty, 2014). Middle-aged women appreciated the convenience, functionality, self-regulation (activity tracking and monitoring), and goal setting components and considered these as top priorities when selecting a mobile application (Ehlers & Huberty, 2014). When face-to-face interventions are not feasible, mobile health applications and online delivery appear to be a more accessible and convenient option.

Physical activity participation, motivation, commitment levels, and adherence can be explained by examining the influence of SCT components. White et al. (2012) evaluated the SCT in middle-aged and older adults and questionnaire data showed significant increases in physical, self-evaluative, and social outcome expectations (White et al., 2012). The authors demonstrated self-efficacy primarily influenced physical activity levels, both directly and indirectly via outcome expectations. Physical activity interventions specifically based on SCT are recommended for middle-aged adults to encourage positive behavior change, increase physical activity levels, and limit disability risk through self-regulation strategies.

Video Intervention

Video-based Pilates exercise programs offer individuals greater flexibility to practice at a convenient time and aim to increase comfort in a location of personal choice. Limited research is available on home-based video programs designed for healthy populations (Donahoe-Fillmore et al., 2015). Donahoe-Fillmore et al. (2007) and Donahoe-Fillmore et al. (2015) recruited healthy women ages 18-35 years and examined the impact of home-based 10-week Pilates video interventions. Both studies included pre- and post-measurements, a control group that was advised to not practice Pilates exercises, and explored core strength and endurance, flexibility, posture, and balance. Donahoe-Fillmore et al. (2007) led an information session on posture and gave all participants a brochure on principles of good posture. The experimental group received a mat Pilates video to practice three times per week, and the control group was advised to not perform any Pilates exercises. The authors observed improvements in trunk flexor endurance (Pilates: 45.5%; control: 12.5%) and trunk extensor endurance (Pilates: 57.4%; control: 20.5%) following the Pilates intervention (Donahoe-Fillmore et al., 2007). The video-based format did not require direct supervision of a qualified instructor,

A similar intervention was conducted by Donahoe-Fillmore et al. (2015) who instructed an experimental group to practice an 8-minute beginner video for three weeks, six sessions per week, and consisted of six Pilates exercises, diaphragmatic breathing, and abdominal exercises. The following seven weeks, the group practiced a 50-minute video, two sessions per week and consisted of thirty Pilates activities. Following the intervention, the authors noted statistically significant differences between the experimental and control groups in left and right hamstring flexibility (left: Pilates- 26.17cm, control- 28.19cm; right: Pilates- 26.47cm, control- 27.86cm) and trunk flexor endurance (Pilates- 205.00 sec, control- 195.93 sec) (Donahoe-Fillmore et al., 2015). The multi-directional reach test (MDRT) evaluated stability, and the Pilates group demonstrated greater improvements reaching right (pre: 26.17cm, post: 28.72cm) and left (25.85cm, post: 30.53cm) (Donahoe-Fillmore et al., 2015). The video intervention performed in the home environment showed improvements in flexibility and muscular endurance.

Another study by Kim et al. (2020) examined functional movement and balance following a 4-week Pilates video-based intervention emphasizing core stability. Participants were asked to complete the video-based intervention twice a day, three days per week with a goal of twenty sessions over the course of 4-weeks. The researchers requested participants complete weekly check-ins and track exercise sessions in a training log. The authors analyzed the seven FMS tests independently, as well as the total FMS score. The authors found total FMS scores (pre- 14.6 ± 3.9, post- 17.4 ± 1.9, $p < 0.05$) significantly improved post-intervention. Post-assessments showed improvements in all seven tests: deep squat (pre: 2.4 ± 0.5, post: 2.9 ± 0.3), hurdle step (pre: 2.0 ± 0.5, post: 2.5 ± 0.5), in-line lunge (pre: 2.2 ± 0.9, post: 2.7 ± 0.5), shoulder mobility (pre: 2.0 ± 0.8, post: 2.1 ± 0.7), active straight-leg raise (pre: 1.9 ± 0.9, post: 2.5 ± 0.5), trunk stability push-up (pre: 2.4 ± 1.1, post: 2.6 ± 0.7), and rotary stability (pre: 1.7 ± 0.7, post: 2.1 ± 0.3) (Kim et al., 2020). A significant increase in hurdle step ($p = 0.024$, group × time effect) and shoulder mobility ($p = 0.037$, group × time effect) were determined following a Pilates intervention (Kim et al., 2020). Further analysis demonstrated there was a significant main effect of time on active straight leg raise ($p = 0.037$) and trunk stability ($p = 0.023$) tests (Kim et al., 2020). The study demonstrated Pilates exercise had a positive impact on FMS scores and enhanced fundamental movement patterns. The video-based intervention offered a convenient plan for participants to perform Pilates at home and improve FMS test scores.

Conclusion

Pilates offers a series of dynamic movement patterns to enhance movement efficiency, postural alignment, core stability, and functional mobility. Pilates classes, offered by way of video, provide an opportunity for individuals to practice at a convenient time and place based on one's schedule. The series of exercises are purposefully designed to promote balanced muscle development and greater flexibility throughout the full range of motion to improve daily fundamental movement patterns (Akkoç & Kırandi, 2019; Hatta et al., 2018; Lim & Park, 2019; Sekendiz et al., 2007). Greater functional movement allows an individual to move freely and effectively through a full range of transitional movements in daily activities to enhance quality of life.

Chapter 3: Methodology

Introduction

The purpose of this study was to determine the impact of a short- term Pilates exercise intervention on functional movement in healthy middle-aged adults. Participants were required to follow study protocols for nine weeks consisting of familiarization sessions (one week), testing procedures (two weeks), and Pilates exercise intervention (six weeks). The intervention was followed for six weeks and included upper body, lower body and abdominal exercises specifically designed to target fundamental movement patterns. The intervention applied two social cognitive theory constructs including observational learning and self-regulation (see Appendix A). The principal investigator modeled all Pilates exercises delivered in weekly videos. In addition, the experimental group participants tracked weekly Pilates sessions in a log. The FMS evaluated functional movement patterns by way of pre and post-test measurements. Statistical analysis was performed to compare pre and post-FMS total scores for the experimental group (PG) and control group (CG). Additional statistical analyses were performed to examine the seven individual FMS test scores for the PG and CG groups.

Participants

Participant recruitment was conducted at a small local college and in the local community. A campus-wide email announcement was delivered to campus faculty and staff, as well as members of the community, approximately two months prior to the start of the study. The email served as a recruiting tool and explained study protocols and participant obligations.

Inclusion criteria included both genders between the ages of 40 and 59 years and classified as healthy per study definition. All participants completed a PAR-Q+ to determine study eligibility as well. Exclusion criteria included Pilates practice within the past six months, participants missing three or more days of the intervention, and missing both pre and post-testing. Participants were randomly allocated to experimental (Pilates group= PG) and control groups (CG). The control group was advised to continue with normal daily activities.

Instruments

Informed Consent-

The informed consent contained descriptions of all study protocols, risks, benefits, costs and compensation, participant rights, confidentiality statement, and participant signature (see Appendix B).

Demographic Survey-

The survey collected participant demographics including age, gender, past and current exercise experience (see Appendix C). Participant demographic characteristics were presented in Table 1.

PAR-Q+-

The PAR-Q+ assessed participant's readiness for physical activity and confirmed participants did not have any major issues that would cause them not to be able to participate in the study (see Appendix D).

Functional Movement Screen (FMS)-

The FMS measured fundamental movement patterns and the assessment included deep squat, hurdle step, inline lunge, shoulder mobility, active straight leg raises, trunk stability push-up, and rotary stability. The FMS took approximately 10-15 minutes to complete per participant. The deep squat assessed bilateral, symmetrical, functional mobility and stability of the hips, knees, and ankles. The hurdle step test assessed step and stride mechanics, stability, and control in a single-leg stance. The inline lunge required spine stabilization to test hip, knee, ankle, and foot mobility and stability. The shoulder mobility test evaluated the range of motion in the shoulder. The active straight leg raises evaluated the active mobility of the flexed hip and core stability. The trunk stability push-up test assessed reflex core stabilization. The rotary stability test examined pelvis, core, and shoulder girdle stability during a combined upper and lower body movement pattern. Raw scores for right leg and left leg were collected for five FMS tests, including the hurdle step, inline lunge, shoulder mobility, active straight leg raise, and rotary stability. The raw scores were converted to a final score for each test.

FMS is a valid test with high levels of interrater (0.81; 95% CI, 0.70-0.92) and intrarater (intraclass correlation coefficient-ICC= 0.81; 95% CI, 0.69-0.92) reliability used to identify movement pattern limitations and/or dysfunctions (Beardsley & Contreras, 2014; Bonazza et al., 2017; Minick et al., 2010; Moran et al., 2016; Shultz et al., 2013). Visuals of each FMS test can be found in Appendix E. Each individual test is rated as follows: 0 (pain occurs during a test), 1 (cannot perform the movement), 2 (able to complete the movement with slight modification), and 3 (performs the movement correctly). The individual scores for each of the seven tests were combined into a final score with twenty-one possible points (Beardsley & Contreras, 2014). Individual scoring sheets for the FMS can be found in Appendix F.

Familiarization Session-

Introductory video (unlisted YouTUBE video) delivered directly to personal email accounts. The video explained study protocols, participant screening process, pre and post-testing requirements, as well as visuals of the FMS assessments. The video also included an explanation of the six key principles of Pilates, spinal, core, and body alignment techniques, safety techniques, and a brief familiarization session of exercises (fundamental movements-chest lift, one leg and double leg stretches, and spine stretch).

Pilates Exercise Intervention-

Mat-based beginner to intermediate level Pilates exercises served as the foundation for the intervention. A series of weekly videos (unlisted YouTube videos) were released on six consecutive Sundays and delivered to personal email accounts. The researcher was a certified Pilates instructor and instructed all weekly videos. Videos were recorded in the researcher's home gym. The intervention included some of the original thirty-four Pilates exercises and variations were implemented throughout the course of the study. Individual exercises were instructed and cued step-by-step and progressively integrated to incorporate all limb movements and breathing techniques for a full-body workout. A complete list of Pilates exercises, target muscle groups, and accompanying muscles can be found in Appendix G. Pilates weekly exercise intervention can be found in Appendix H. Pilates log can be found in Appendix I.

Procedures

Participant Recruitment- Two months prior to the intervention an email explaining intervention protocols and participant obligations was delivered as a campus-wide announcement to a small local college and personal emails to other members of the known community. *Familiarization Session*- Two weeks prior to the intervention, the researcher shared an introductory video (unlisted YouTUBE video) with all participants delivered directly to personal email accounts. *Meeting #1 and FMS pre-testing*- One week prior to the intervention, study protocols were reviewed with each participant, participant screening conducted, informed consent, demographic survey, and PAR-Q+ were reviewed and signed prior to testing. Participants were randomly allocated to experimental (PG) and control (CG) groups. Baseline FMS measurements were administered by the researcher. *Intervention Weekly Schedule*- The PG group participants selected four days a week (one week runs from Sunday- Saturday) to perform the Pilates exercise intervention. Participants were encouraged to consistently schedule exercise days and rest days to recover over the course of the six weeks. One full day of recovery was recommended between sessions. Specific days were not assigned but selected by participants based on individual schedules and availability. Participants tracked individual sessions in a Pilates log. *Meeting #2 and FMS post-testing*- One week following the intervention, Pilates exercise logs were reviewed, and post-intervention FMS measurements were administered.

Design and Data Analysis

Statistical analyses performed with SPSS statistics 27.0.1.0 for MS-Windows (IBM Corp., Chicago, IL, USA). Statistical significance was set at $p < 0.05$. Descriptive statistics captured critical participant demographics. Individual functional movement screen tests were displayed as mean, standard deviation, minimum, and maximum for differences in pre and post-assessments. A mixed model ANOVA was selected to examine PG and CG between group differences, as well as pre and post-test within group differences. The test compared pre and post-FMS total scores between the PG and CG groups. Also, a mixed model ANOVA compared group differences between the PG and CG groups in functional movement patterns as tested by the seven FMS tests, as well as pre and post-test within group differences. The Shapiro-Wilk and Kolmogorov- Smirnov tests were used to determine if the PG and CG groups had normal distribution or not. Significant main effects and interactions were present; therefore, post-hoc testing was conducted with a Bonferroni adjustment. All data presented in tables showed mean and standard deviation.

Ethical Considerations

Participants signed an informed consent consisting of all testing procedures, risks, and benefits involved in the study. Participants completed a demographic survey and PAR-Q+, and all information collected throughout the study remained anonymous and strictly confidential. The study design and procedures were in full compliance with the experimental research protocols and approval was granted by Concordia University, St. Paul Kinesiology and Health Sciences Department and Concordia's Institutional Review Board (IRB).

Chapter 4: Results

Introduction

The purpose of this study was to assess the impact of a short-term Pilates exercise intervention pre to post-test on functional movement patterns as measured by the FMS in healthy middle-aged adults. The results of the analyses for the research question and three corresponding hypotheses are also provided in this chapter.

Upon completion of the Pilates intervention, statistical analyses were performed with SPSS statistics 27.0.1.0 for MS-Windows (IBM Corp., Chicago, IL, USA). Statistical significance was set at $p < 0.05$. Statistical analyses and findings are presented in this chapter. There were two hypotheses and one null hypothesis established for the Pilates exercise intervention. Two were supported and the null hypothesis was rejected after careful examination of statistical analysis. Specific tests were selected to assess the impact of a short-term Pilates exercise intervention pre to post-test on functional movement patterns as measured by the FMS total score and individual test scores in healthy middle-aged adults.

Findings

Descriptive statistics captured critical participant demographics. The PG group consisted of five males and twelve female participants (n= 17) to successfully complete the intervention. The CG group consisted of two males and five female participants (n= 7). Sixteen participants met exclusion criteria or left the study at different time points due to personal reasons. Twenty-four participants voluntarily completed the participant screening, informed consent, demographic survey, PAR-Q+, baseline measurements, and post-test measurements for the full 8-week intervention. Participant demographic characteristics are presented in Table 1.

Table 1

Participant Demographics

Demographic	Pilates Group	Control Group	Total Participants
	n	n	n
Gender			
Male	5	2	7
Female	12	5	17
Age (yrs)			
40- 44	9	5	14
45- 49	1	1	2
50- 54	4	0	4
55- 59	3	1	4

The first hypothesis stated that a short-term Pilates exercise intervention administered through a series of videos will improve functional movement patterns as tested by the total FMS scores in healthy middle-aged adults. The total FMS test scores were displayed as mean, standard deviation, minimum, and maximum for differences in pre and post-assessments and displayed in Table 2. Descriptive statistics captured total FMS scores in the PG and CG groups and displayed in Table 3. The data was determined to be normally distributed, and results are displayed in Table 4. A mixed model ANOVA was used to further analyze data. Mauchly's Test of Sphericity showed that due to the data violating assumptions of sphericity, ANOVA test statistics were estimated using the Greenhouse-Geisser method (1.000). The results can be found in Table 5.

Table 3

Descriptive Statistics for Total FMS Scores in the PG and CG groups

	Group	Mean	Std. Deviation	N
Pre-Total	Con	16.00	2.160	7
	Exp	12.12	2.547	17
	Total	13.25	2.996	24
Post-Total	Con	15.57	1.512	7
	Exp	15.71	1.724	17
	Total	15.67	1.633	24

The total FMS scores improved for the PG group ($p < .001$) and did not improve in the CG group ($p = .200$).

Main effects were reported by the mixed model ANOVA. There was a significant main effect of time from pre to post within- subjects $F(22) = 28.786$, $p <.001$, $\eta_p^2 = .567$ with a greater post-test total FMS score in the PG group (see Table 6). There was a significant main effect of time from pre to post between- subjects $F(22) = 4.401$, $p = .048$, $\eta_p^2 = .167$ with a greater post-test total FMS score in the PG group (see Table 7).

Interaction effects within and between groups were also determined by the mixed model ANOVA. There was a significant interaction effect of time within the PG and CG groups $F(22) = 46.522$, $p <.001$, $\eta_p^2 = .679$ (see Table 6). Planned comparisons using paired samples t-tests revealed that participants in the PG group significantly improved total FMS score compared to the CG group $t(16) = -10.132$, $p <.001$, $d = 1.460$ (see Tables 8 and 9). There was however no significant difference in total FMS score in the CG group $t(6) = 1.441$, $p = .200$, $d = .787$ (see Tables 8 and 9). Post-hoc testing revealed significance between the PG and CG groups in pairwise comparisons, $p= .048$ (see Table 10 and Figures 1 and 2).

Figure 1

Pre-Test and Post-Test Total FMS Scores for the PG and CG Groups

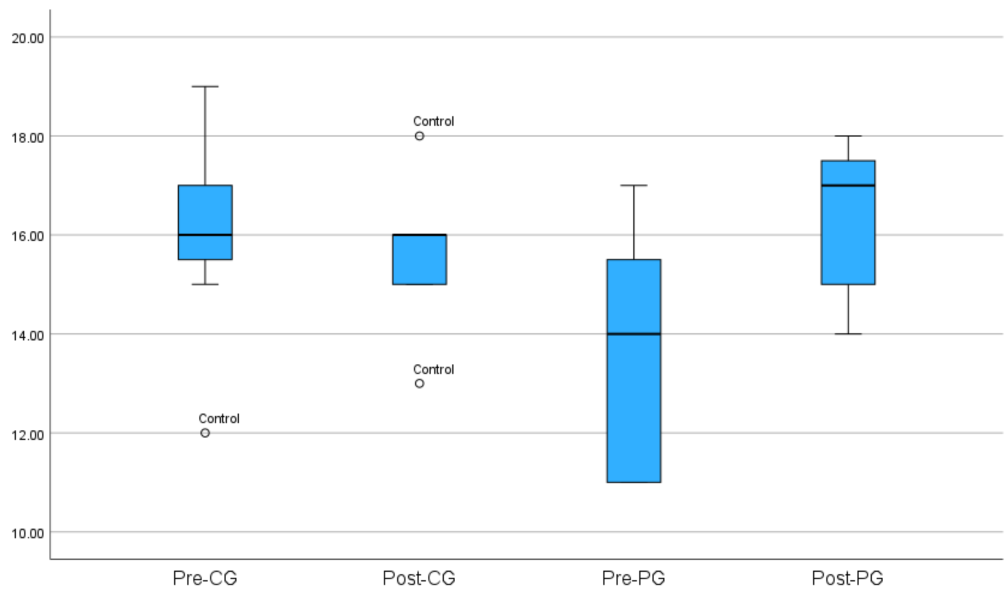
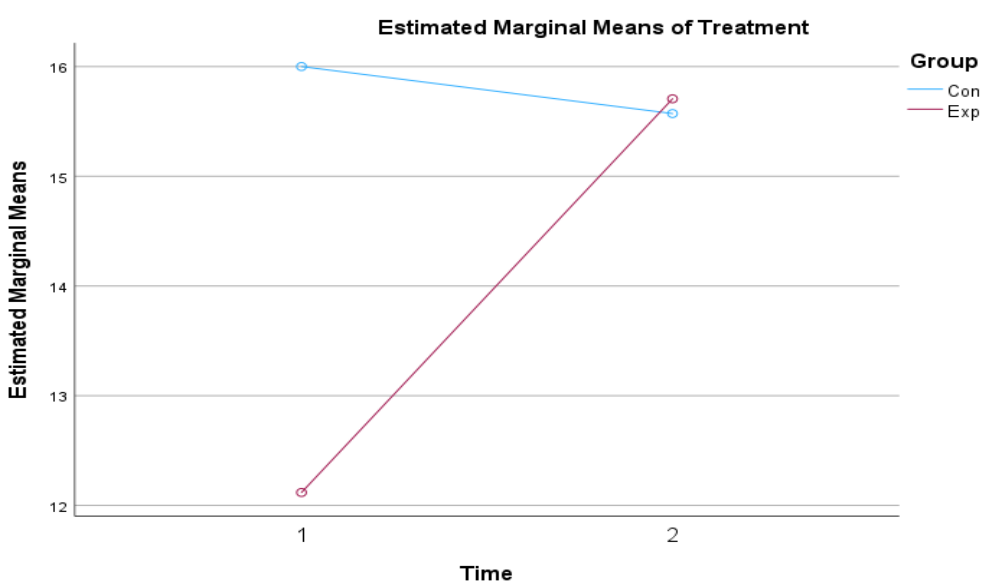


Figure 2

Pre-Test and Post-Test Total FMS Score Differences for the PG and CG Groups



The second hypothesis stated there would be significant group differences between experimental and control groups in functional movement patterns as tested by the seven FMS tests following a short-term Pilates exercise intervention administered through a series of videos. Descriptive statistics captured the seven individual FMS tests and differences in pre- and post-assessments in the PG and CG groups and displayed in Table 11. To examine the hypothesis, the Shapiro-Wilk and Kolmogorov-Smirnov tests were used to test for normality (see Table 12). A mixed model ANOVA was used to further analyze data. Mauchly's Test of Sphericity showed that due to the data violating assumptions of sphericity, ANOVA test statistics were estimated using the Greenhouse-Geisser method (1.000) (see Table 13).

Deep squat-

There was a significant main effect of time from pre to post within- subjects $F(22) = 5.70$, $p = .026$, $\eta_p^2 = .206$ (see Table 14). There was not a significant main effect of time from pre to post between- subjects $F(22) = .262$, $p = .614$, $\eta_p^2 = .012$ (see Table 15). Further analysis showed there wasn't a significant interaction effect of time within the PG and CG groups $F(22) = 5.70$, $p = .026$, $\boldsymbol{\eta}_p^2 = .206$ (see Table 14). Post-hoc tests with a Bonferroni adjustment revealed a significant main effect for time ($p = .026$) (see Table 16).

Hurdle step-

There was a significant main effect of time from pre to post within- subjects $F(22) = 11.72$, $p = .002$, $\eta_p^2 = .348$ (see Table 17). There was not a significant main effect of time from pre to post between- subjects $F(22) = .011$, $p = .918$, $\eta_p^2 = .000$ (see Table 18). Further analysis showed there was a significant interaction effect of time within the PG and CG groups $F(22) = 4.350$, $p = .049$, $\eta_p^2 = .165$ (see Table 17). Post-hoc tests with a Bonferroni adjustment revealed a significant main effect for time ($p = .002$) (see Table 19).

Inline lunge-

There was not a significant main effect of time from pre to post within- subjects $F(22) = 1.144$, $p = .296$, $\eta_p^2 = .049$ (see Table 20). There was not a significant main effect of time from pre to post between- subjects $F(22) = 2.161$, $p = .156$, $\eta_p^2 = .089$ (see Table 21).

Shoulder mobility-

There was not a significant main effect of time from pre to post within- subjects $F(22) = .737$, $p = .400$, $\eta_p^2 = .032$ (see Table 22). There was a significant main effect of time from pre to post between- subjects $F(22) = 6.209$, $p = .021$, $\eta_p^2 = .220$ (see Table 23). Further analysis showed there was a significant interaction effect of time within the PG and CG groups $F(22) = 6.151$, $p = .021$, $\eta_p^2 = .218$ (see Table 22). Post-hoc tests with a Bonferroni adjustment revealed a significant main effect for the group ($p = .021$) (see Table 24).

Active straight leg raise-

There was not a significant main effect of time from pre to post within- subjects $F(22) = 1.194$, $p = .286$, $\eta_p^2 = .051$ (see Table 25). There was not a significant main effect of time from pre to post between- subjects $F(22) = 3.115$, $p = .091$, $\eta_p^2 = .124$ (see Table 26)

Trunk stability push-up-

There was a significant main effect of time from pre to post within- subjects $F(22) = 6.170$, $p = .021$, $\eta_p^2 = .219$ (see Table 27). There was not a significant main effect of time from pre to post between- subjects $F(22) = .266$, $p = .611$, $\eta_p^2 = .012$ (see Table 28). Further analysis showed there was a significant interaction effect of time within the PG and CG groups $F(22) = 6.170$, $p = .021$, $\eta_p^2 = .219$ (see Table 27). Post-hoc tests with a Bonferroni adjustment revealed a significant main effect for time ($p = .021$) (see Table 29).

Rotary stability-

There was a significant main effect of time from pre to post within- subjects $F(22) = 4.650$, $p = .042$, $\eta_p^2 = .174$ (see Table 30). There was not a significant main effect of time from pre to post between- subjects $F(22) = 2.270$, $p = .146$, $\eta_p^2 = .094$ (see Table 31). Further analysis showed there was a significant interaction effect of time within the PG and CG groups $F(22) = 4.650$, $p = .042$, $\eta_p^2 = .174$ (see Table 30). Post-hoc tests with a Bonferroni adjustment revealed a significant main effect for time ($p = .042$) (see Table 32).

Table 33 displays the mean FMS score for each of the seven tests for PG and CG pre-test and post-test.

Table 33

Seven FMS Tests Pre- Test and Post- Test Mean FMS Scores for PG and CG Groups

	CG		PG		
	Pre-Test	Post-Test	Pre-Test	Post-Test	p- value
Deep squat*	2.00	2.00	1.65	2.12	0.026
Hurdle step*	1.71	1.86	1.47	2.06	0.002
Inline lunge	2.71	2.43	1.94	2.47	--
Shoulder mobility**	2.43	2.14	1.29	1.88	0.021
Active straight leg raise	3.00	3.00	2.59	2.82	--
Trunk stability push-up*	2.29	2.29	1.88	2.47	0.021
Rotary stability*	1.86	1.86	1.29	1.88	0.042

* Significant difference between pre-test and post-test scores

** Significant difference between CG and PG

The null hypothesis stated that a short-term Pilates exercise intervention administered through a series of videos will not improve functional movement patterns in healthy middle-aged adults. The Levene's Test of Equality of Error Variances showed that the variances for the PG and CG groups total FMS scores were statistically significantly different, so equal variances are not assumed $F(1, 22) = 4.40$, $p = .05$ (see Tables 34 and 35). Assumption of homogeneity of variance has been violated. The null hypothesis was rejected for the study.

Three hypotheses were established for the Pilates exercise intervention. The hypotheses evaluated total FMS scores, as well as the individual scores for the seven FMS tests, to further compare pre and post assessments. Two were supported and the null hypothesis was rejected after careful examination of statistical analysis. Careful evaluation of the first hypothesis demonstrated significant main and interaction effects within and between groups. The second hypothesis showed significant main effects of time from pre to post within- subjects in the hurdle step, trunk stability push-up, and rotary stability tests. Significant main effects of time from pre to post between- subjects were revealed in the shoulder mobility test. In addition, significant interaction effects of time within the PG and CG groups were reported in the hurdle step, inline lunge, shoulder mobility, trunk stability push-up, and rotary stability tests. Post-hoc tests noted significant main effects for time in the hurdle step, trunk stability push-up, and rotary stability tests. Also, post-hoc tests noted significant main effects for group in the shoulder mobility test. The study findings are supported by the statistical analysis of the research question and corresponding hypotheses.

Conclusion

The purpose of this chapter was to successfully examine and evaluate the studies hypotheses and answer the research question. The study population consisted of twenty-four participants who voluntarily completed the participant screening, informed consent, demographic survey, PAR-Q+, baseline measurements, and post-test measurements for the full 8-week intervention. The purpose of the study was to assess the impact of a short-term Pilates exercise intervention pre to post-test functional movement patterns as measured by the FMS in healthy middle-aged adults.

This research study provided an opportunity for middle aged adults to identify movement limitations, learn exercises to enhance fundamental movement patterns, and aid in future programming for this population. Based on the interpretation of the findings, a progressive action plan will be presented in chapter 5 to offer the study population further exploration in Pilates exercise. In addition, chapter 5 will reveal the contributions of this study to the body of knowledge and profession. Limitations of the study design will also be addressed, and future research recommendations will provide opportunities for growth in the field.

Chapter 5: Discussion

Interpretation of Findings

The purpose of this study was to assess the impact of a short-term Pilates exercise intervention pre to post-test on functional movement patterns as measured by the FMS in healthy middle-aged adults. One research question was addressed in this study, and three hypotheses were generated and analyzed following the data collection. Statistical tests were conducted to determine if a short-term Pilates intervention could have an impact on functional movement in healthy middle-aged adults.

The first hypothesis stated that a short-term Pilates exercise intervention administered through a series of videos will improve functional movement patterns as tested by the total FMS scores in healthy middle-aged adults. It is important to acknowledge that the CG group pre-test total FMS scores were greater than the PG group. Significant main effects of time from pre to post within and between- subjects were reported in the PG group. The PG group demonstrated significant improvements in total FMS scores following the intervention. The CG group did not show a significant difference in total FMS scores. The CG group showed a reduction in post-test total FMS scores.

Similar studies also found favorable total FMS scores in the middle-aged population following Pilates interventions. Akkoç and Kırandi (2019) and Lim and Park (2019) examined the impact of an 8-week Pilates intervention on functional movement. Both studies included pre- and post- measurements for all seven FMS tests and displayed statistically significant results. Akkoç and Kırandi (2019) reported FMS total score improvements from 13.08 to 17.58 ($p = 0.003$) following a progressive Pilates intervention completed two days per week. Lim and Park (2019) reported FMS total score test results improving from 10.36 ± 2.27 to 12.43 ± 2.13 following a Pilates intervention completed three days per week. The authors suggested the dynamic movement patterns of the Pilates exercises specifically designed to enhance balance, stability, and mobility attributed to the FMS test results.

Another study performed by Laws et al. (2017) reported a significant increase in total FMS scores following a 6-week progressive Pilates intervention performed one day a week (pre: 13.5 ± 2.5, post: 17.0 ± 1.7, $p < 0.01$). Also, Hatta et al. (2021) conducted a 5-week Pilates intervention and tested a similar hypothesis in college-aged students while examining pre and post-test total FMS scores. The authors reported total FMS scores increased from 15.9 ± 1.7 to 18.0 ± 1.6 ($p < 0.001$) following Pilates performed one day per week (Hatta et al., 2021). Furthermore, Kim et al. (2020) examined functional movement and balance following a 4-week Pilates-based intervention emphasizing core stability. Participants were asked to complete the video-based intervention twice a day, three days per week with a goal of twenty sessions over the course of 4-weeks. The researchers requested participants complete weekly check-ins and track exercise sessions in a training log. The authors found total FMS scores (pre- 14.6 ± 3.9, post- 17.4 ± 1.9, $p < 0.05$) significantly improved post-intervention.

The studies demonstrated Pilates exercise had a positive impact on FMS total scores and enhanced fundamental movement patterns. The current study focused on 6-weeks of Pilates exercise. The other studies developed interventions to be completed throughout the course of four to eight weeks. Also, the frequency of the Pilates sessions in these studies ranged from one to three days. The current study focused on four days per week based on Pilates and Miller (1945) recommendation of four practice sessions per week to develop greater muscular strength, flexibility, and normal muscle function.

Furthermore, the second hypothesis stated there would be significant group differences between experimental and control groups in functional movement patterns as tested by the seven

FMS tests following a short-term Pilates exercise intervention administered through a series of videos. The second hypothesis showed significant main effects of time from pre to post within-subjects in the hurdle step, trunk stability push-up, and rotary stability tests. Significant main effects of time from pre to post between- subjects were revealed in the shoulder mobility test. In addition, significant interaction effects of time within the PG and CG groups were reported in the hurdle step, inline lunge, shoulder mobility, trunk stability push-up, and rotary stability tests. Post-hoc tests noted significant main effects for time in the hurdle step, trunk stability push-up, and rotary stability tests. Also, post-hoc tests noted significant main effects for group in the shoulder mobility test.

A similar study performed by Akkoç and Kırandi (2019) evaluated pre and post- FMS scores for all seven independent tests following 8-weeks of Pilates exercises performed twice a week. Post- assessments showed improvements in all seven tests: Deep squat (pre: 1.75, post: 2.75, $p = 0.003$), hurdle step (pre: 2.16, post: 2.75, $p = 0.020$), in-line lunge (pre: 1.67, post: 2.08, $p = 0.025$), shoulder mobility (pre: 2.50, post: 2.58, $p = 0.564$), active straight-leg raise (pre: 2.50, post: 2.92, $p = 0.025$), trunk stability (pre: 1.33, post: 2.17, $p = 0.004$), and rotary stability (pre: 1.17, post: 2.33, $p = 0.002$) (Akkoç & Kırandi, 2019). The author’s findings are relatable to the current study demonstrating favorable improvement in all seven FMS tests.

Additional studies with similar hypotheses, but different population, also demonstrated favorable FMS scores following Pilates interventions. Hatta et al. (2018) examined Pilates exercise and its effects on hip joint flexion mobility in healthy collegiate athletes. Three weeks of Pilates exercise and static stretching produced significant changes in the FMS overhead squat assessment, specifically hip-to-floor distance ($F= 130.897$, $p < 0.001$, $\eta p^2 = 0.867$) (Hatta et al., 2018). This finding was further supported by Hatta et al. (2021) who tested a similar hypothesis in college-aged students. The authors found hurdle step (pre: 2.2 ± 0.4, post: 2.7 ± 0.5), in-line lunge (pre: 2.2 ± 0.4, post: 2.6 ± 0.5, $p < 0.05$), and rotary stability (pre: 2.2 ± 0.4, post: 2.5 ± 0.5, $p < 0.05$) FMS measurements increased following 5-weeks of Pilates (Hatta et al., 2021). Both studies demonstrated Pilates exercise diminished risk of musculoskeletal system dysfunction and enhanced fundamental movement patterns.

A video-based intervention by Kim et al. (2020) examined functional movement and balance in a younger population following a 4-week Pilates core stability program. The researchers requested participants complete weekly check-ins and track exercise sessions in a training log. The authors analyzed the seven FMS tests independently, as well as the total FMS score. Post- assessments showed improvements in all seven tests: Deep squat (pre: 2.4 ± 0.5, post: 2.9 ± 0.3), hurdle step (pre: 2.0 ± 0.5, post: 2.5 ± 0.5), in-line lunge (pre: 2.2 ± 0.9, post: 2.7 ± 0.5), shoulder mobility (pre: 2.0 ± 0.8, post: 2.1 ± 0.7), active straight-leg raise (pre: 1.9 ± 0.9, post: 2.5 ± 0.5), trunk stability push-up (pre: 2.4 ± 1.1, post: 2.6 ± 0.7), and rotary stability (pre: 1.7 ± 0.7, post: 2.1 ± 0.3) (Kim et al., 2020). A significant increase in hurdle step ($p = 0.024$, group × time effect) and shoulder mobility ($p = 0.037$, group × time effect) were determined following the intervention (Kim et al., 2020). Further analysis demonstrated there was a significant main effect of time on active straight leg raise ($p = 0.037$) and trunk stability ($p = 0.023$) tests (Kim et al., 2020). This study is closely related to the current findings, and it is important to note Kim et al. (2020) also encouraged observational learning and self-regulation throughout the intervention by way of videos and training logs.

Additionally, the null hypothesis stated that a short-term Pilates exercise intervention administered through a series of videos will not improve functional movement patterns in healthy middle-aged adults. The null hypothesis was rejected for the study. Rejecting the null hypothesis is a positive outcome for the short-term Pilates exercise intervention.

To conclude, the healthy middle-aged population demonstrated significant and favorable improvements in total FMS scores and the seven individual tests following the intervention. For professional practice, it is important to encourage the middle-aged population to focus on flexibility, stability, and mobility exercises to further enhance the efficiency of fundamental movement patterns. Fundamental movement patterns are vital for daily functioning throughout the lifespan.

Practical Applications

Pilates, offered by way of video, provided an opportunity for individuals to practice at a convenient time and place based on one's schedule. The intervention offered flexibility with the optimistic goal to increase adherence during a busy season in life. The intervention was based on the theoretical components of SCT including observational learning through YouTube videos and self-regulation by tracking weekly progress in a Pilates log.

This low-cost and short-term intervention impacts the field of kinesiology because it directly involves human movement and exercise. Kinesiology is the scientific study of human movement and explores the anatomical, biomechanical, and physiological mechanisms of movement for activities of daily living, physical activity, and exercise. Pilates exercises emphasize inter-segmental coordination of bodily movement and body realignment, and rhythmic breathing patterns actively engaging abdominal muscles to stabilize the core musculature and enhance movement efficiency (Kim et al., 2020). Pilates exercises were carefully selected and focused on fundamental movement patterns for daily living.

In addition, the intervention specifically impacts the local community because many campus faculty and staff members fall within the middle-aged range. This study provides a flexible opportunity for middle aged adults to participate in a video-based intervention at a convenient day and time based on individual personal and professional schedules. Middle-aged can often be a very busy season of life navigating multiple roles and responsibilities. Healthy functional movement will be important for all activities of daily living. It is imperative to identify movement limitations, evaluate movement efficiency, and learn exercises to enhance fundamental movement patterns.

The intervention specifically impacts the professionals working within the health, fitness, and wellness industry as well. Certified Pilates instructors and health and wellness professionals can review the intervention’s specific exercise list, accompanied by target muscles, and design a progressive program with the primary goal of improving functional movement in the middle-aged population. Working professionals can earn FMS certifications to test participants and administer pre and post-test assessments. Commercial, corporate, hospital-based, and/or laboratory settings may be suitable to serve as practice locations.

Contribution to Knowledge and Profession

The findings contribute to knowledge in the body of literature by expanding the current research on Pilates and functional movement. The benefits of Pilates are well documented, and Pilates interventions can positively impact health and quality of life. Despite previous research detailing the benefits of Pilates, limited research has investigated the impact of Pilates on functional movement patterns in healthy populations (Tolnai et al., 2016). Functional movement patterns in young and older adult populations have been examined, but limited research is available exploring age-related progressive loss in functionality in middle-aged adults. The current study demonstrated the positive effects of Pilates exercise on FMS scores and offered a unique perspective focusing on the middle-aged population. The favorable results help close the gap in literature for this specific population and acknowledge the value of Pilates exercise. Middle-aged adults can relate to the study's findings and implement Pilates exercise for movement health.

The potential impact on professional practice is understanding Pilates can improve core strength, balance, flexibility, muscle control, and improve postural awareness. The individual exercises induce muscle activity to mimic specific kinetic chain activation patterns in daily functional movements (Monger & Harrison, 2016). Functional movement deficiencies detected in middle-aged adults can minimize the risk of movement dysfunction and disability later in life. Fundamental movement patterns are vital for daily functioning throughout the lifespan.

The potential changes to practice can benefit practitioners by offering guidance on class design and exercise selection intentionally constructed to enhance fundamental movement patterns in healthy middle-aged adults. The study also provides instruction on appropriate length and duration of Pilates class sessions to seek favorable improvement in FMS testing.

In addition, the potential changes to practice can benefit colleagues by providing the opportunity to review evidence-based research in Pilates and understand the significance of the mind-body mat-based exercise conditioning system developed by Joseph Pilates. Pilates is systematically designed, and based on six key principles: Centering, concentration, control, precision, flow, and breath (Byrnes et al., 2017; Cruz-Ferreira et al., 2011; Eliks et al., 2019; Hatta et al., 2018; Hatta et al., 2021; Pilates & Miller, 1945; Yamato et al., 2015). Colleagues will have access to clear definitions for a healthy population and middle-aged adults to apply in future study design and interventions. Also, colleagues can gain a greater understanding of the population-specific needs regarding functional movement, examine the statistical data, and evaluate the limitations of the study. In addition, the FMS may be considered for future research testing as well. The FMS is a valid test with high levels of inter-rater and intra-rater reliability used to identify movement pattern limitations and/or dysfunctions (Beardsley & Contreras, 2014). Pilates produced favorable results in the FMS total score, as well as the seven individual tests.

Also, middle-aged clients will benefit from practitioners' greater knowledge base of Pilates class design, exercise selection, frequency, and duration of practice sessions. This low-cost and short-term Pilates intervention can provide an opportunity for middle aged adults to identify movement limitations, learn exercises to enhance fundamental movement patterns, and aid in future programming for this population.

Action Plan

Based on the findings of this study, an action plan was developed to generate possible strategies and interventions moving forward. The targeted focus was the promotion of Pilates exercise and its' positive impact on functional movement in healthy middle-aged adults. The overall goal was to educate the healthy middle-aged population on the benefits of Pilates exercise to improve functional movement. Specific goals included: (1) review the short-term 6-week Pilates intervention and evaluate the possibility of extending the time frame for another intervention, (2) identify number of potential middle-aged participants in local communities to expand recruitment efforts, (3) evaluate the Pilates exercises selected and weekly session content for the intervention, (4) assess social cognitive theory constructs of self-regulation and observational learning via Likert survey, and (5) prepare video-based intervention evaluation survey for comprehensive feedback on the intervention. Based on the goals, Pilates resources can guide the development of additional strategies and interventions, formative and summative assessments, and self-evaluation strategies. The action plan may include a proposed timeline that will allow adequate time to evaluate, collect, organize, and refine necessary information, as well as introduce future recommendations.

Limitations

There were several methodological limitations to the study. A major limiting factor was the age range, including only 40-59 years. By limiting the age range, younger and older adult populations were not examined. Several studies specifically examined younger and older adult populations, with a gap in existing research demonstrating the need for the middle-aged population. A second limitation was specific exercise selection and class design. Numerous Pilates exercises were considered, but a specific number was selected for each weekly session to be completed within a realistic time frame. The weekly class sessions were designed to focus on progressive full body exercises. A third limitation was Pilates exercise session duration and frequency. Exercise session duration and frequency were carefully considered to encourage participation within realistic time commitments, further potentially increasing adherence to the study. Accordingly, six weeks were selected to stay within research timelines and comparable to several studies which examined four-to-eight-week interventions. A fourth limitation was weekly video administration. Video administration did not allow the researcher to visually observe proper execution of all movements during weekly class sessions. A fifth limitation was the study took place in one central location, and the possibility of recruiting a small sample size existed and would not be representative of the population.

Recruitment and retention efforts were challenged by potentially interested participants' daily life activities and weekly schedules. Sixteen participants met exclusion criteria or left the study at different time points due to personal reasons. There are many competing demands for the middle-aged population that impact individual levels of commitment for study participation. Also, it is important to acknowledge the researcher cannot control unsupervised participant behavior and complete adherence to the intervention throughout the study period. To conclude, the study was intentionally designed to minimize the impact of limitations and ensure quality data collection from participants.

Recommendations for Further Research

Future research recommendations include a larger age range to examine various populations from younger to older adults. Expanding participant recruitment to several surrounding areas is another alternative for future research. Another recommendation is to modify the specific exercise selection and class design. Implementing different individual exercises and changing the class design of the structured Pilates session may impact the FMS test results. Additional possibilities include formal in-person weekly Pilates sessions offering guided instruction, modifying the frequency of the Pilates sessions, and/or ultimately changing the overall length of the intervention.

Conclusion

Functional movement plays an important role in activities of daily living and overall health. It allows an individual to move freely through a specific range of motion utilizing balance, core control, postural stability, muscular control, and strength. Efficient movement patterns can improve transitional movements and range of motion in daily activities to enhance quality of life. In addition to balance and muscular control, additional benefits include reducing the risk of injury and bodily pain. Daily activities such as walking, sitting, and standing can benefit from greater ease of movement.

Greater functional movement can reduce muscular imbalances, poor body alignment, and movement dysfunction. Fundamental movements of the upper and lower body target balance, stability, and mobility to enhance dynamic movement health, competency, and capacity (Cook et al., 2014a; Cook et al., 2014b; Lim & Park, 2019; Okada et al., 2011). Flexibility, mobility, and stability are integral components of efficient fundamental movement patterns (Okada et al., 2011).

First, flexibility is the ability of muscles and muscle joints to stretch temporarily, ultimately allowing the joint to move. Functional and neuromuscular efficiency, reduced muscular tension, and better muscle and tendon extensibility are benefits of whole-body flexibility (Ružić, 2020). Muscular imbalance corrections, increased joint range of motion, and reduced joint stiffness are additional benefits of greater flexibility (Ružić, 2020). Pilates structured exercise sequence of dynamic stretching and repetitive movements contributes to flexibility improvements.

Second, mobility is the ability of muscles and muscle joints to actively move through a full range of motion. Mobility impairments may lead to functional losses and impact fundamental movement patterns with increasing age (Grimmer et al., 2019). Pilates exercise has been shown to diminish risk of musculoskeletal system dysfunction and enhance fundamental movement patterns (Hatta et al., 2018; Hatta et al., 2021).

Third, stability is defined as muscle and surrounding tissue's ability to support and control movement patterns. Daily activities benefit from core stability exercises designed to target specific activation patterns, force, and power generation in three planes of movement to facilitate greater movement control in fundamental movement patterns (Kim et al., 2020; Monger & Harrison, 2016). Pilates exercises activate a broad range of core muscles and maximize core function, further strengthening abdominal and lumbar regions to support the spine and transfer during functional movements (Lee et al., 2016). In addition, Pilates exercises emphasize inter-segmental coordination of bodily movement and body realignment, and rhythmic breathing patterns actively engaging abdominal muscles to stabilize the core musculature and enhance movement efficiency (Kim et al., 2020). Dynamic stability and segmental movement patterns increased by way of core strengthening exercises, further develop fundamental movement patterns.

In addition, the video-based Pilates exercise intervention served as a convenient, accessible, and cost-effective option permitting individuals to schedule practice within realistic time commitments in a location of personal choice. The intervention was guided by the social cognitive theory (SCT) constructs of observational learning and self-regulation. The theory is recognized as one of the most common health behavior change models to successfully promote positive improvement in a variety of physical activity interventions (Bandura, 2004; Poddar et al., 2012). Health interventions that include weekly checkpoints can increase adherence and self-monitoring skills to encourage and adopt positive behavior change in the long term. Exercise self-regulation involved skills for planning, organizing, self-monitoring, and managing exercise activities throughout the intervention. SCT-based interventions have proven successful in young to middle-aged adults (Easton et al., 2017; Ehlers & Huberty, 2014; Rosenkrantz et al., 2018; White et al., 2012). Physical activity interventions specifically based on SCT are recommended for middle-aged adults to encourage positive behavior change, increase physical activity levels, and limit disability risk through self-regulation strategies (Easton et al., 2017; Ehlers & Huberty, 2014; Rosenkrantz et al., 2018; White et al., 2012).

To conclude, Pilates offered a series of dynamic movement patterns aimed to enhance movement efficiency, postural alignment, core stability, and functional mobility. The weekly sessions focused on the six key principles of centering, concentration, control, precision, flow, and breath, while offering exercises with fluid movements and smooth transitions (Cruz-Ferreira et al., 2011; Eliks et al., 2019; Hatta et al., 2018; Hatta et al., 2021; Tolnai et al., 2016). These principles embodied the Pilates practice and served as the foundation for training throughout the intervention. The series of exercises were purposefully designed to promote balanced muscle development and greater flexibility throughout the full range of motion to improve daily fundamental movement patterns (Akkoç & Kırandi, 2019; Hatta et al., 2018; Lim & Park, 2019; Sekendiz et al., 2007). Pilates-based classes embody a therapeutic role to reduce musculoskeletal discomfort and pain through a series of exercises designed to improve fundamental movement pattern efficiency (von Sperling de Souza & Brum Vieira, 2006). The mind-body connections, strength building exercises, and fluid transitions throughout a Pilates class generate increased awareness of bodily movements. Greater functional movement allows an individual to move freely and effectively through a full range of transitional movements in daily activities to enhance quality of life.

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Tables

Table 1

Participant Demographics

Demographic	Pilates Group	Control Group	Total Participants
	n	n	n
Gender			
Male	5	2	7
Female	12	5	17
Age (yrs)			
40- 44	9	5	14
45- 49	1	1	2
50- 54	4	0	4
55- 59	3	1	4

Table 2

Descriptives for Total FMS Scores in the PG and CG Groups

			Statistic	Std. Error
Pre-Total	Mean		13.25	.612
	95% Confidence Interval for Mean	Lower Bound	11.98	
		Upper Bound	14.52	
	5% Trimmed Mean		13.28	
	Median		13.00	
	Variance		8.978	
	Std. Deviation		2.996	
	Minimum		7	
	Maximum		19	
	Range		12	
	Interquartile Range		5	
	Skewness		-.009	.472
	Kurtosis		-.633	.918
Post-Total	Mean		15.67	.333
	95% Confidence Interval for Mean	Lower Bound	14.98	
		Upper Bound	16.36	
	5% Trimmed Mean		15.73	
	Median		16.00	
	Variance		2.667	
	Std. Deviation		1.633	
	Minimum		12	
	Maximum		18	
	Range		6	
	Interquartile Range		2	
	Skewness		-.520	.472
	Kurtosis		-.234	.918

Table 3

Descriptive Statistics for Total FMS Scores in the PG and CG Groups

	Group	Mean	Std. Deviation	N
Pre-Total	Con	16.00	2.160	7
	Exp	12.12	2.547	17
	Total	13.25	2.996	24
Post-Total	Con	15.57	1.512	7
	Exp	15.71	1.724	17
	Total	15.67	1.633	24

Table 4

Tests of Normality for Total FMS Scores in the PG and CG Groups

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Pre-Total	.149	24	.183	.963	24	.505
Post-Total	.164	24	.093	.940	24	.159

a. Lilliefors Significance Correction

Table 5

Mauchly's Test of Sphericity[a] for Total FMS Scores in the PG and CG Groups

Measure: Treatment

					Epsilon[b]		
Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Greenhouse-Geisser	Huynh-Feldt	Lower-bound
Time	1.000	.000	0	.	1.000	1.000	1.000

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. Design: Intercept + Group
 Within Subjects Design: Time

b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Table 6

Tests of Within-Subjects Effects for Total FMS Scores in the PG and CG Groups

Measure: Treatment

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Time	Sphericity Assumed	24.751	1	24.751	28.786	<.001	.567
	Greenhouse-Geisser	24.751	1.000	24.751	28.786	<.001	.567
	Huynh-Feldt	24.751	1.000	24.751	28.786	<.001	.567
	Lower-bound	24.751	1.000	24.751	28.786	<.001	.567
Time * Group	Sphericity Assumed	40.001	1	40.001	46.522	<.001	.679
	Greenhouse-Geisser	40.001	1.000	40.001	46.522	<.001	.679
	Huynh-Feldt	40.001	1.000	40.001	46.522	<.001	.679
	Lower-bound	40.001	1.000	40.001	46.522	<.001	.679
Error (Time)	Sphericity Assumed	18.916	22	.860			
	Greenhouse-Geisser	18.916	22.000	.860			
	Huynh-Feldt	18.916	22.000	.860			
	Lower-bound	18.916	22.000	.860			

Table 7

Tests of Between-Subjects Effects for Total FMS Scores in the PG and CG Groups

Measure: Treatment
Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	8745.908	1	8745.908	1105.217	<.001	.980
Group	34.824	1	34.824	4.401	.048	.167
Error	174.092	22	7.913			

Table 8

Paired Samples Test for Total FMS Scores in the PG and CG Groups

Group			Paired Differences					t	df	Significance	
						95% Confidence Interval of the Difference					
			Mean	Std. Deviation	Std. Error Mean	Lower	Upper			One-Sided p	Two-Sided p
Con	Pair 1	Pre-Total – Post-Total	.429	.787	.297	-.299	1.156	1.441	6	.100	.200
Exp	Pair 1	Pre-Total – Post-Total	-3.588	1.460	.354	-4.339	-2.837	-10.132	16	<.001	<.001

Table 9

Paired Samples Effect Sizes for Total FMS Scores in the PG and CG Groups

Group				Standardizer[a]	Point Estimate	95% Confidence Interval	
						Lower	Upper
Con	Pair 1	Pre-Total – Post-Total	Cohen's d	.787	.545	-.274	1.326
			Hedges' correction	.906	.473	-.238	1.151
Exp	Pair 1	Pre-Total – Post-Total	Cohen's d	1.460	-2.457	-3.416	-1.480
			Hedges' correction	1.533	-2.340	-3.253	-1.409

a. The denominator used in estimating the effect sizes.
Cohen's d uses the sample standard deviation of the mean difference.
Hedges' correction uses the sample standard deviation of the mean difference, plus a correction factor.

Table 10

Pairwise Comparisons for Total FMS Scores in the PG and CG Groups

Measure: Treatment

(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b] Lower Bound	Upper Bound
Con	Exp	1.874*	.893	.048	.021	3.727
Exp	Con	-1.874*	.893	.048	-3.727	-.021

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

b. Adjustment for multiple comparisons: Bonferroni.

Table 11

Descriptives for the Seven Individual FMS Tests Pre- and Post- Test Scores Separated by Group

	Group			Statistic	Std. Error
Pre-DS	Con	Mean		2.00	.218
		95% Confidence Interval for Mean	Lower Bound	1.47	
			Upper Bound	2.53	
		5% Trimmed Mean		2.00	
		Median		2.00	
		Variance		.333	
		Std. Deviation		.577	
		Minimum		1	
		Maximum		3	
		Range		2	
		Interquartile Range		0	
		Skewness		.000	.794
		Kurtosis		3.000	1.587
	Exp	Mean		1.65	.147
		95% Confidence Interval for Mean	Lower Bound	1.34	
			Upper Bound	1.96	
		5% Trimmed Mean		1.61	
		Median		2.00	
		Variance		.368	
		Std. Deviation		.606	
		Minimum		1	
		Maximum		3	
		Range		2	
		Interquartile Range		1	
		Skewness		.310	.550
		Kurtosis		-.479	1.063

Pre-HS	Con	Mean		1.71	.184
		95% Confidence Interval for Mean	Lower Bound	1.26	
			Upper Bound	2.17	
		5% Trimmed Mean		1.74	
		Median		2.00	
		Variance		.238	
		Std. Deviation		.488	
		Minimum		1	
		Maximum		2	
		Range		1	
		Interquartile Range		1	
		Skewness		-1.230	.794
		Kurtosis		-.840	1.587
	Exp	Mean		1.47	.125
		95% Confidence Interval for Mean	Lower Bound	1.21	
			Upper Bound	1.74	
		5% Trimmed Mean		1.47	
		Median		1.00	
		Variance		.265	
		Std. Deviation		.514	
		Minimum		1	
		Maximum		2	
		Range		1	
		Interquartile Range		1	
		Skewness		.130	.550
		Kurtosis		-2.267	1.063

Pre-IL	Con	Mean		2.71	.184
		95% Confidence Interval for Mean	Lower Bound	2.26	
			Upper Bound	3.17	
		5% Trimmed Mean		2.74	
		Median		3.00	
		Variance		.238	
		Std. Deviation		.488	
		Minimum		2	
		Maximum		3	
		Range		1	
		Interquartile Range		1	
		Skewness		-1.230	.794
		Kurtosis		-.840	1.587
	Exp	Mean		1.94	.160
		95% Confidence Interval for Mean	Lower Bound	1.60	
			Upper Bound	2.28	
		5% Trimmed Mean		1.93	
		Median		2.00	
		Variance		.434	
		Std. Deviation		.659	
		Minimum		1	
		Maximum		3	
		Range		2	
		Interquartile Range		1	
		Skewness		.057	.550
		Kurtosis		-.314	1.063

Pre-SM	Con	Mean		2.43	.297
		95% Confidence Interval for Mean	Lower Bound	1.70	
			Upper Bound	3.16	
		5% Trimmed Mean		2.48	
		Median		3.00	
		Variance		.619	
		Std. Deviation		.787	
		Minimum		1	
		Maximum		3	
		Range		2	
		Interquartile Range		1	
		Skewness		-1.115	.794
		Kurtosis		.273	1.587
	Exp	Mean		1.29	.166
		95% Confidence Interval for Mean	Lower Bound	.94	
			Upper Bound	1.65	
		5% Trimmed Mean		1.27	
		Median		1.00	
		Variance		.471	
		Std. Deviation		.686	
		Minimum		0	
		Maximum		3	
		Range		3	
		Interquartile Range		1	
		Skewness		.861	.550
		Kurtosis		1.421	1.063

Pre-ASLR	Con	Mean		3.00	.000
		95% Confidence Interval for Mean	Lower Bound	3.00	
			Upper Bound	3.00	
		5% Trimmed Mean		3.00	
		Median		3.00	
		Variance		.000	
		Std. Deviation		.000	
		Minimum		3	
		Maximum		3	
		Range		0	
		Interquartile Range		0	
		Skewness		.	.
		Kurtosis		.	.
	Exp	Mean		2.59	.150
		95% Confidence Interval for Mean	Lower Bound	2.27	
			Upper Bound	2.91	
		5% Trimmed Mean		2.65	
		Median		3.00	
		Variance		.382	
		Std. Deviation		.618	
		Minimum		1	
		Maximum		3	
		Range		2	
		Interquartile Range		1	
		Skewness		-1.275	.550
		Kurtosis		.877	1.063

Pre-TSP	Con	Mean		2.29	.184
		95% Confidence Interval for Mean	Lower Bound	1.83	
			Upper Bound	2.74	
		5% Trimmed Mean		2.26	
		Median		2.00	
		Variance		.238	
		Std. Deviation		.488	
		Minimum		2	
		Maximum		3	
		Range		1	
		Interquartile Range		1	
		Skewness		1.230	.794
		Kurtosis		-.840	1.587
	Exp	Mean		1.88	.146
		95% Confidence Interval for Mean	Lower Bound	1.57	
			Upper Bound	2.19	
		5% Trimmed Mean		1.92	
		Median		2.00	
		Variance		.360	
		Std. Deviation		.600	
		Minimum		0	
		Maximum		3	
		Range		3	
		Interquartile Range		0	
		Skewness		-1.945	.550
		Kurtosis		6.673	1.063

Pre-RS	Con	Mean		1.86	.261
		95% Confidence Interval for Mean	Lower Bound	1.22	
			Upper Bound	2.50	
		5% Trimmed Mean		1.84	
		Median		2.00	
		Variance		.476	
		Std. Deviation		.690	
		Minimum		1	
		Maximum		3	
		Range		2	
		Interquartile Range		1	
		Skewness		.174	.794
		Kurtosis		.336	1.587
	Exp	Mean		1.29	.143
		95% Confidence Interval for Mean	Lower Bound	.99	
			Upper Bound	1.60	
		5% Trimmed Mean		1.33	
		Median		1.00	
		Variance		.346	
		Std. Deviation		.588	
		Minimum		0	
		Maximum		2	
		Range		2	
		Interquartile Range		1	
		Skewness		-.109	.550
		Kurtosis		-.325	1.063

Post-DS	Con	Mean		2.00	.218
		95% Confidence Interval for Mean	Lower Bound	1.47	
			Upper Bound	2.53	
		5% Trimmed Mean		2.00	
		Median		2.00	
		Variance		.333	
		Std. Deviation		.577	
		Minimum		1	
		Maximum		3	
		Range		2	
		Interquartile Range		0	
		Skewness		.000	.794
		Kurtosis		3.000	1.587
	Exp	Mean		2.12	.118
		95% Confidence Interval for Mean	Lower Bound	1.87	
			Upper Bound	2.37	
		5% Trimmed Mean		2.13	
		Median		2.00	
		Variance		.235	
		Std. Deviation		.485	
		Minimum		1	
		Maximum		3	
		Range		2	
		Interquartile Range		0	
		Skewness		.399	.550
		Kurtosis		1.905	1.063

Post-HS	Con	Mean		1.86	.143
		95% Confidence Interval for Mean	Lower Bound	1.51	
			Upper Bound	2.21	
		5% Trimmed Mean		1.90	
		Median		2.00	
		Variance		.143	
		Std. Deviation		.378	
		Minimum		1	
		Maximum		2	
		Range		1	
		Interquartile Range		0	
		Skewness		-2.646	.794
		Kurtosis		7.000	1.587
	Exp	Mean		2.06	.135
		95% Confidence Interval for Mean	Lower Bound	1.77	
			Upper Bound	2.34	
		5% Trimmed Mean		2.07	
		Median		2.00	
		Variance		.309	
		Std. Deviation		.556	
		Minimum		1	
		Maximum		3	
		Range		2	
		Interquartile Range		0	
		Skewness		.051	.550
		Kurtosis		.991	1.063

Post-IL	Con	Mean		2.43	.202
		95% Confidence Interval for Mean	Lower Bound	1.93	
			Upper Bound	2.92	
		5% Trimmed Mean		2.42	
		Median		2.00	
		Variance		.286	
		Std. Deviation		.535	
		Minimum		2	
		Maximum		3	
		Range		1	
		Interquartile Range		1	
		Skewness		.374	.794
		Kurtosis		-2.800	1.587
	Exp	Mean		2.47	.151
		95% Confidence Interval for Mean	Lower Bound	2.15	
			Upper Bound	2.79	
		5% Trimmed Mean		2.52	
		Median		3.00	
		Variance		.390	
		Std. Deviation		.624	
		Minimum		1	
		Maximum		3	
		Range		2	
		Interquartile Range		1	
		Skewness		-.750	.550
		Kurtosis		-.223	1.063

Post-SM	Con	Mean		2.14	.340
		95% Confidence Interval for Mean	Lower Bound	1.31	
			Upper Bound	2.97	
		5% Trimmed Mean		2.16	
		Median		2.00	
		Variance		.810	
		Std. Deviation		.900	
		Minimum		1	
		Maximum		3	
		Range		2	
		Interquartile Range		2	
		Skewness		-.353	.794
		Kurtosis		-1.817	1.587
	Exp	Mean		1.88	.169
		95% Confidence Interval for Mean	Lower Bound	1.52	
			Upper Bound	2.24	
		5% Trimmed Mean		1.87	
		Median		2.00	
		Variance		.485	
		Std. Deviation		.697	
		Minimum		1	
		Maximum		3	
		Range		2	
		Interquartile Range		1	
		Skewness		.161	.550
		Kurtosis		-.674	1.063

Post-ASLR	Con	Mean		3.00	.000
		95% Confidence Interval for Mean	Lower Bound	3.00	
			Upper Bound	3.00	
		5% Trimmed Mean		3.00	
		Median		3.00	
		Variance		.000	
		Std. Deviation		.000	
		Minimum		3	
		Maximum		3	
		Range		0	
		Interquartile Range		0	
		Skewness		.	.
		Kurtosis		.	.
	Exp	Mean		2.82	.095
		95% Confidence Interval for Mean	Lower Bound	2.62	
			Upper Bound	3.03	
		5% Trimmed Mean		2.86	
		Median		3.00	
		Variance		.154	
		Std. Deviation		.393	
		Minimum		2	
		Maximum		3	
		Range		1	
		Interquartile Range		0	
		Skewness		-1.866	.550
		Kurtosis		1.665	1.063

Post-TSP	Con	Mean		2.29	.184
		95% Confidence Interval for Mean	Lower Bound	1.83	
			Upper Bound	2.74	
		5% Trimmed Mean		2.26	
		Median		2.00	
		Variance		.238	
		Std. Deviation		.488	
		Minimum		2	
		Maximum		3	
		Range		1	
		Interquartile Range		1	
		Skewness		1.230	.794
		Kurtosis		-.840	1.587
	Exp	Mean		2.47	.125
		95% Confidence Interval for Mean	Lower Bound	2.21	
			Upper Bound	2.74	
		5% Trimmed Mean		2.47	
		Median		2.00	
		Variance		.265	
		Std. Deviation		.514	
		Minimum		2	
		Maximum		3	
		Range		1	
		Interquartile Range		1	
		Skewness		.130	.550
		Kurtosis		-2.267	1.063

Post-RS	Con	Mean		1.86	.143
		95% Confidence Interval for Mean	Lower Bound	1.51	
			Upper Bound	2.21	
		5% Trimmed Mean		1.90	
		Median		2.00	
		Variance		.143	
		Std. Deviation		.378	
		Minimum		1	
		Maximum		2	
		Range		1	
		Interquartile Range		0	
		Skewness		-2.646	.794
		Kurtosis		7.000	1.587
	Exp	Mean		1.88	.081
		95% Confidence Interval for Mean	Lower Bound	1.71	
			Upper Bound	2.05	
		5% Trimmed Mean		1.92	
		Median		2.00	
		Variance		.110	
		Std. Deviation		.332	
		Minimum		1	
		Maximum		2	
		Range		1	
		Interquartile Range		0	
		Skewness		-2.610	.550
		Kurtosis		5.440	1.063

Note. DS-Deep Squat, HS- Hurdle Step, IL- Inline Lunge, SM- Shoulder Mobility, ASLR- Active Straight Leg Raise, TSP- Trunk Stability Push-up, RS- Rotary Stability

Table 12

Tests of Normality for the Seven Individual FMS Tests Pre- and Post- Test Scores Separated by Group

		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Group	Statistic	df	Sig.	Statistic	df	Sig.
Pre-DS	Con	.357	7	.007	.777	7	.024
	Exp	.308	17	<.001	.757	17	<.001
Pre-HS	Con	.435	7	<.001	.600	7	<.001
	Exp	.349	17	<.001	.642	17	<.001
Pre-IL	Con	.435	7	<.001	.600	7	<.001
	Exp	.300	17	<.001	.798	17	.002
Pre-SM	Con	.338	7	.015	.769	7	.020
	Exp	.372	17	<.001	.779	17	.001
Pre-ASLR	Con	.	7	.	.	7	.
	Exp	.394	17	<.001	.678	17	<.001
Pre-TSP	Con	.435	7	<.001	.600	7	<.001
	Exp	.460	17	<.001	.573	17	<.001
Pre-RS	Con	.296	7	.063	.840	7	.099
	Exp	.339	17	<.001	.750	17	<.001
Post-DS	Con	.357	7	.007	.777	7	.024
	Exp	.419	17	<.001	.659	17	<.001
Post-HS	Con	.504	7	<.001	.453	7	<.001
	Exp	.366	17	<.001	.732	17	<.001
Post-IL	Con	.360	7	.007	.664	7	.001
	Exp	.331	17	<.001	.738	17	<.001
Post-SM	Con	.258	7	.174	.818	7	.062
	Exp	.273	17	.002	.809	17	.003
Post-ASLR	Con	.	7	.	.	7	.
	Exp	.497	17	<.001	.470	17	<.001
Post-TSP	Con	.435	7	<.001	.600	7	<.001
	Exp	.349	17	<.001	.642	17	<.001
Post-RS	Con	.504	7	<.001	.453	7	<.001
	Exp	.521	17	<.001	.385	17	<.001

a. Lilliefors Significance Correction

Note. DS-Deep Squat, HS- Hurdle Step, IL- Inline Lunge, SM- Shoulder Mobility, ASLR- Active Straight Leg Raise, TSP- Trunk Stability Push-up, RS- Rotary Stability

Table 13

Mauchly's Test of Sphericity[a] for the Seven Individual FMS Tests Pre- and Post- Test Scores

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b] Greenhouse-Geisser	Huynh-Feldt	Lower-bound
time	1.000	.000	0	.	1.000	1.000	1.000

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. Design: Intercept + Group
 Within Subjects Design: time

b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Table 14

Tests of Within-Subjects Effects for the Deep Squat Test

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
time	Sphericity Assumed	.549	1	.549	5.704	.026	.206
	Greenhouse-Geisser	.549	1.000	.549	5.704	.026	.206
	Huynh-Feldt	.549	1.000	.549	5.704	.026	.206
	Lower-bound	.549	1.000	.549	5.704	.026	.206
time * Group	Sphericity Assumed	.549	1	.549	5.704	.026	.206
	Greenhouse-Geisser	.549	1.000	.549	5.704	.026	.206
	Huynh-Feldt	.549	1.000	.549	5.704	.026	.206
	Lower-bound	.549	1.000	.549	5.704	.026	.206
Error(time)	Sphericity Assumed	2.118	22	.096			
	Greenhouse-Geisser	2.118	22.000	.096			
	Huynh-Feldt	2.118	22.000	.096			
	Lower-bound	2.118	22.000	.096			

Table 15

Tests of Between-Subjects Effects for the Deep Squat Test Pre- and Post- Test Scores Separated by Group

Measure: MEASURE_1
Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	149.471	1	149.471	285.214	.000	.928
Group	.137	1	.137	.262	.614	.012
Error	11.529	22	.524			

Table 16

Pairwise Comparisons for the Deep Squat Test Pre- and Post- Test Scores

Measure: MEASURE_1

					95% Confidence Interval for Difference[b]	
(I) time	(J) time	Mean Difference (I-J)	Std. Error	Sig.[b]	Lower Bound	Upper Bound
1	2	-.235*	.099	.026	-.440	-.031
2	1	.235*	.099	.026	.031	.440

Based on estimated marginal means
*. The mean difference is significant at the .05 level.
b. Adjustment for multiple comparisons: Bonferroni.

Table 17

Tests of Within-Subjects Effects for the Hurdle Step Test

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
time	Sphericity Assumed	1.325	1	1.325	11.720	.002	.348
	Greenhouse-Geisser	1.325	1.000	1.325	11.720	.002	.348
	Huynh-Feldt	1.325	1.000	1.325	11.720	.002	.348
	Lower-bound	1.325	1.000	1.325	11.720	.002	.348
time * Group	Sphericity Assumed	.492	1	.492	4.350	.049	.165
	Greenhouse-Geisser	.492	1.000	.492	4.350	.049	.165
	Huynh-Feldt	.492	1.000	.492	4.350	.049	.165
	Lower-bound	.492	1.000	.492	4.350	.049	.165
Error(time)	Sphericity Assumed	2.487	22	.113			
	Greenhouse-Geisser	2.487	22.000	.113			
	Huynh-Feldt	2.487	22.000	.113			
	Lower-bound	2.487	22.000	.113			

Table 18

Tests of Between-Subjects Effects for the Hurdle Step Test Pre- and Post- Test Scores Separated by Group

Measure: MEASURE_1
Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	125.004	1	125.004	306.425	.000	.933
Group	.004	1	.004	.011	.918	.000
Error	8.975	22	.408			

Table 19

Pairwise Comparisons for the Hurdle Step Test Pre- and Post- Test Scores

Measure: MEASURE_1

(I) time	(J) time	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
1	2	-.366*	.107	.002	-.587	-.144
2	1	.366*	.107	.002	.144	.587

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

b. Adjustment for multiple comparisons: Bonferroni.

Table 20

Tests of Within-Subjects Effects for the Inline Lunge Test

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
time	Sphericity Assumed	.147	1	.147	1.144	.296	.049
	Greenhouse-Geisser	.147	1.000	.147	1.144	.296	.049
	Huynh-Feldt	.147	1.000	.147	1.144	.296	.049
	Lower-bound	.147	1.000	.147	1.144	.296	.049
time * Group	Sphericity Assumed	1.647	1	1.647	12.797	.002	.368
	Greenhouse-Geisser	1.647	1.000	1.647	12.797	.002	.368
	Huynh-Feldt	1.647	1.000	1.647	12.797	.002	.368
	Lower-bound	1.647	1.000	1.647	12.797	.002	.368
Error(time)	Sphericity Assumed	2.832	22	.129			
	Greenhouse-Geisser	2.832	22.000	.129			
	Huynh-Feldt	2.832	22.000	.129			
	Lower-bound	2.832	22.000	.129			

Table 21

Tests of Between-Subjects Effects for the Inline Lunge Pre- and Post- Test Scores Separated by Group

Measure: MEASURE_1
Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	226.325	1	226.325	369.171	.000	.944
Group	1.325	1	1.325	2.161	.156	.089
Error	13.487	22	.613			

Table 22

Tests of Within-Subjects Effects for the Shoulder Mobility Test

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
time	Sphericity Assumed	.227	1	.227	.737	.400	.032
	Greenhouse-Geisser	.227	1.000	.227	.737	.400	.032
	Huynh-Feldt	.227	1.000	.227	.737	.400	.032
	Lower-bound	.227	1.000	.227	.737	.400	.032
time * Group	Sphericity Assumed	1.894	1	1.894	6.151	.021	.218
	Greenhouse-Geisser	1.894	1.000	1.894	6.151	.021	.218
	Huynh-Feldt	1.894	1.000	1.894	6.151	.021	.218
	Lower-bound	1.894	1.000	1.894	6.151	.021	.218
Error(time)	Sphericity Assumed	6.773	22	.308			
	Greenhouse-Geisser	6.773	22.000	.308			
	Huynh-Feldt	6.773	22.000	.308			
	Lower-bound	6.773	22.000	.308			

Table 23

Tests of Between-Subjects Effects for the Shoulder Mobility Pre- and Post- Test Scores Separated by Group

Measure: MEASURE_1
Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	148.824	1	148.824	191.554	.000	.897
Group	4.824	1	4.824	6.209	.021	.220
Error	17.092	22	.777			

Table 24

Pairwise Comparisons for the Shoulder Mobility Pre- and Post- Test Scores Separated by Group

Measure: MEASURE_1

					95% Confidence Interval for Difference[b]	
(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig.[b]	Lower Bound	Upper Bound
CON	EXP	.697*	.280	.021	.117	1.278
EXP	CON	-.697*	.280	.021	-1.278	-.117

Based on estimated marginal means
*. The mean difference is significant at the .05 level.
b. Adjustment for multiple comparisons: Bonferroni.

Table 25

Tests of Within-Subjects Effects for the Active Straight Leg Raise

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
time	Sphericity Assumed	.137	1	.137	1.194	.286	.051
	Greenhouse-Geisser	.137	1.000	.137	1.194	.286	.051
	Huynh-Feldt	.137	1.000	.137	1.194	.286	.051
	Lower-bound	.137	1.000	.137	1.194	.286	.051
time * Group	Sphericity Assumed	.137	1	.137	1.194	.286	.051
	Greenhouse-Geisser	.137	1.000	.137	1.194	.286	.051
	Huynh-Feldt	.137	1.000	.137	1.194	.286	.051
	Lower-bound	.137	1.000	.137	1.194	.286	.051
Error(time)	Sphericity Assumed	2.529	22	.115			
	Greenhouse-Geisser	2.529	22.000	.115			
	Huynh-Feldt	2.529	22.000	.115			
	Lower-bound	2.529	22.000	.115			

Table 26

Tests of Between-Subjects Effects for the Active Straight Leg Raise Pre- and Post- Test Scores Separated by Group

Measure: MEASURE_1
Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	322.858	1	322.858	1172.319	.000	.982
Group	.858	1	.858	3.115	.091	.124
Error	6.059	22	.275			

Table 27

Tests of Within-Subjects Effects for the Trunk Stability Push-up Test

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
time	Sphericity Assumed	.858	1	.858	6.170	.021	.219
	Greenhouse-Geisser	.858	1.000	.858	6.170	.021	.219
	Huynh-Feldt	.858	1.000	.858	6.170	.021	.219
	Lower-bound	.858	1.000	.858	6.170	.021	.219
time * Group	Sphericity Assumed	.858	1	.858	6.170	.021	.219
	Greenhouse-Geisser	.858	1.000	.858	6.170	.021	.219
	Huynh-Feldt	.858	1.000	.858	6.170	.021	.219
	Lower-bound	.858	1.000	.858	6.170	.021	.219
Error(time)	Sphericity Assumed	3.059	22	.139			
	Greenhouse-Geisser	3.059	22.000	.139			
	Huynh-Feldt	3.059	22.000	.139			
	Lower-bound	3.059	22.000	.139			

Table 28

Tests of Between-Subjects Effects for the Trunk Stability Push-up Pre- and Post- Test Scores Separated by Group

Measure: MEASURE_1

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	197.452	1	197.452	443.335	.000	.953
Group	.118	1	.118	.266	.611	.012
Error	9.798	22	.445			

Table 29

Pairwise Comparisons for the Trunk Stability Push-up Pre- and Post- Test Scores

Measure: MEASURE_1

(I) time	(J) time	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b] Lower Bound	Upper Bound
1	2	-.294*	.118	.021	-.540	-.049
2	1	.294*	.118	.021	.049	.540

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

b. Adjustment for multiple comparisons: Bonferroni.

Table 30

Tests of Within-Subjects Effects for the Rotary Stability Test

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
time	Sphericity Assumed	.858	1	.858	4.650	.042	.174
	Greenhouse-Geisser	.858	1.000	.858	4.650	.042	.174
	Huynh-Feldt	.858	1.000	.858	4.650	.042	.174
	Lower-bound	.858	1.000	.858	4.650	.042	.174
time * Group	Sphericity Assumed	.858	1	.858	4.650	.042	.174
	Greenhouse-Geisser	.858	1.000	.858	4.650	.042	.174
	Huynh-Feldt	.858	1.000	.858	4.650	.042	.174
	Lower-bound	.858	1.000	.858	4.650	.042	.174
Error(time)	Sphericity Assumed	4.059	22	.184			
	Greenhouse-Geisser	4.059	22.000	.184			
	Huynh-Feldt	4.059	22.000	.184			
	Lower-bound	4.059	22.000	.184			

Table 31

Tests of Between-Subjects Effects for the Rotary Stability Pre- and Post- Test Scores Separated by Group

Measure: MEASURE_1

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	117.717	1	117.717	372.652	.000	.944
Group	.717	1	.717	2.270	.146	.094
Error	6.950	22	.316			

Table 32

Pairwise Comparisons for the Rotary Stability Pre- and Post- Test Scores

Measure: MEASURE_1

(I) time	(J) time	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
1	2	-.294*	.136	.042	-.577	-.011
2	1	.294*	.136	.042	.011	.577

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

b. Adjustment for multiple comparisons: Bonferroni.

Table 33

Seven FMS Tests Pre- Test and Post- Test Mean FMS Scores for PG and CG Groups

	CG		PG		
	Pre-Test	Post-Test	Pre-Test	Post-Test	p- value
Deep squat*	2.00	2.00	1.65	2.12	0.026
Hurdle step*	1.71	1.86	1.47	2.06	0.002
Inline lunge	2.71	2.43	1.94	2.47	--
Shoulder mobility**	2.43	2.14	1.29	1.88	0.021
Active straight leg raise	3.00	3.00	2.59	2.82	--
Trunk stability push-up*	2.29	2.29	1.88	2.47	0.021
Rotary stability*	1.86	1.86	1.29	1.88	0.042

* Significant difference between pre-test and post-test scores

** Significant difference between CG and PG

Table 34

Levene's Test of Equality of Error Variances[a] for Total FMS Scores

		Levene Statistic	df1	df2	Sig.
Pre-Total	Based on Mean	.796	1	22	.382
	Based on Median	.384	1	22	.542
	Based on Median and with adjusted df	.384	1	21.155	.542
	Based on trimmed mean	.786	1	22	.385
Post-Total	Based on Mean	.650	1	22	.429
	Based on Median	.525	1	22	.476
	Based on Median and with adjusted df	.525	1	21.854	.476
	Based on trimmed mean	.580	1	22	.454

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.

a. Design: Intercept + Group
Within Subjects Design: Time

Table 35

Tests of Between-Subjects Effects for Total FMS Scores

Measure: Treatment

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	8745.908	1	8745.908	1105.217	<.001	.980
Group	34.824	1	34.824	4.401	.048	.167
Error	174.092	22	7.913			

Figures

Figure 1

Pre-Test and Post-Test Total FMS Scores for the PG and CG Groups

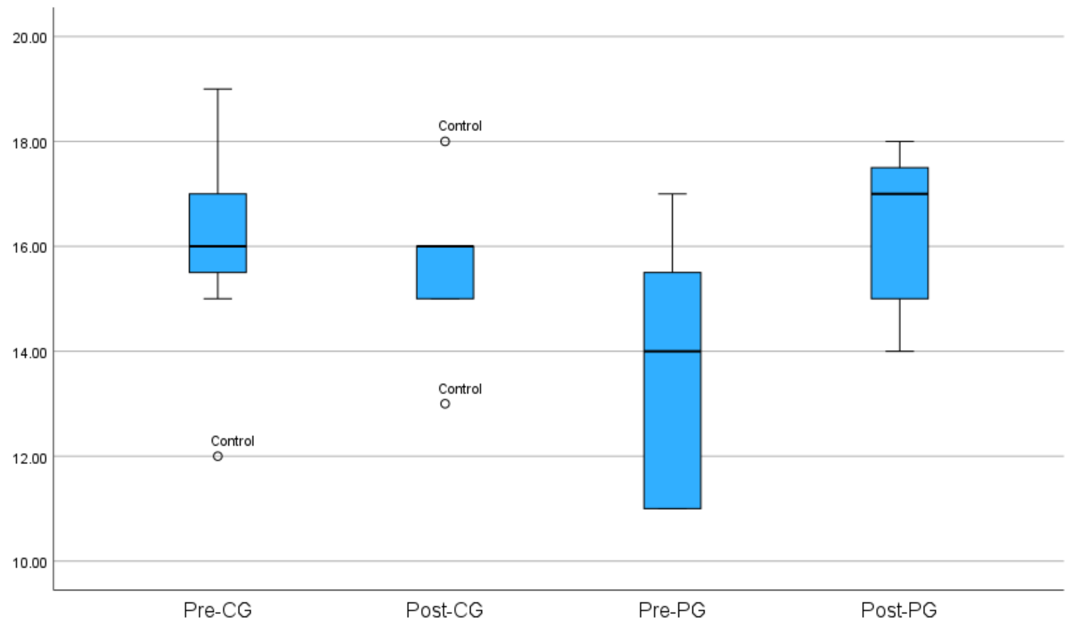
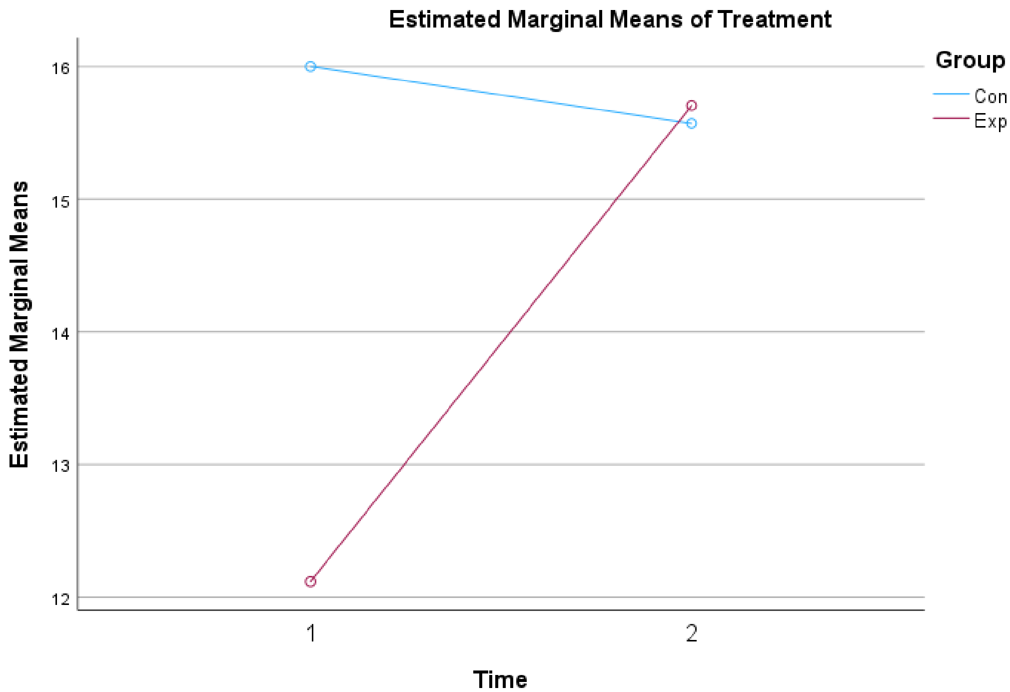


Figure 2

Pre-Test and Post-Test Total FMS Score Differences for the PG and CG Groups



Appendix

Appendix A: Social Cognitive Theory Application to Study Intervention

Appendix B: Informed Consent for Study Participants

Appendix C: Demographic Survey for Study Participants

Appendix D: PAR-Q+ for Study Participants

Appendix E: Functional Movement Screen Tests Descriptions and Visuals

Appendix F: Functional Movement Screen Scoring Sheet for Study Participants

Appendix G: Pilates Exercises Selected for the Intervention, Including Specific Target and Accompanying Muscles

Appendix H: Pilates Intervention Presented by Week, Focus, Specific Exercises and Repetitions for the Experimental Group

Appendix I: Pilates Log for the Experimental Group

Appendix J: Action Plan for Future Pilates Research

Appendix A

Social Cognitive Theory Application to Study Intervention

Construct	Intervention Component	Method of Delivery
Observational Learning	Pilates videos 1. Weekly YouTube videos prepared by the principal investigator. 2. Videos will be fully instructed by the principal investigator. Principal investigator will model all exercises to be implemented throughout the intervention. 3. Videos will demonstrate specific exercises with proper technique and cueing tips and contain weekly Pilates exercise sessions. 4. Participants are encouraged to complete the intervention while viewing the video 4x per week.	Emailed directly to experimental group participants only. YouTube videos delivered to personal email accounts every Sunday throughout 6-week intervention.
Self- Regulation	Pilates log 1. Contains a table with rows to complement 6-weeks, and four columns to represent completed weekly sessions. 2. Participants will track completed Pilates sessions on a weekly basis.	Hard copy will be distributed at meeting #1.

Appendix B

Informed Consent for Study Participants

Title of Study
Short- term Pilates exercise intervention and its impact on functional movement in healthy middle-aged adults

Investigator
Tara Bartolain

Introduction
The purpose of this study is to assess the impact of a short-term Pilates exercise intervention pre to post-test on functional movement patterns as measured by the Functional Movement Screen (FMS) in healthy middle-aged adults.

Description of Procedures
During the study you may expect the following study procedures to be followed:

<u>Familiarization Session</u>
Two weeks prior to the intervention, the researcher will share an introductory video (unlisted YouTUBE video) with all participants. The video will explain study protocols, participant screening process, pre- and post-testing requirements, and demonstration of the FMS. The video will also include an explanation of six key principles of Pilates, spinal alignment techniques, safety techniques, and brief familiarization session of exercises (fundamental movements- shoulder bridge, chest lift, one leg and double leg stretches, spine stretch).

<u>Meeting #1</u>
One week prior to the intervention, all study protocols will be reviewed with each participant, participant screening will occur, informed consent, demographic survey, and PAR-Q+ will be reviewed and signed prior to testing. Baseline FMS Measurements will be administered by the researcher.

<u>Pilates Intervention</u>
Participate in four video sessions per week for six weeks at location of choice. Track progress in a Pilates log provided by the researcher.

<u>Meeting #2</u>
One week following the intervention, Pilates exercise logs will be collected, and post-intervention FMS measurements will be administered by the researcher.

Risks

While participating in this study you may experience the risk of physical injury (i.e., fatigue, physical discomfort, bodily aches and pains, or injury).

Benefits

There may be no direct benefit to you for participating in this study. The goal of the study is to improve participants' functional movement. It is hoped that the information and experience gained in this study will benefit society by providing information about the positive benefits of Pilates exercise to improve fundamental movement patterns. Building off previously published research in this area, this work may provide a foundation for future research using Pilates exercise and FMS to evaluate the specific impact on fundamental movement patterns.

Costs and Compensation

You will not have any costs from participating in this study. You will not be compensated for participating in this study.

Participant Rights

Your participation in this study is completely voluntary, and you may refuse to participate or leave the study at any time. If you decide to not participate in the study or leave the study early, it will not result in any penalty or loss of benefits to which you are otherwise entitled.

Confidentiality

Records identifying participants will be kept confidential to the extent permitted by applicable laws and regulations and will not be made publicly available. However, federal government regulatory agencies, auditing departments of Concordia University, St. Paul, and the Institutional Review Board (a committee that reviews and approves human subject research studies) may inspect and/or copy your records for quality assurance and data analysis. These records may contain private information.

To ensure confidentiality to the extent permitted by law, the following measures will be taken: (1) Participants will be assigned a unique code number that will be used on forms instead of their name, (2) Only researcher will have access to participant records, which will be kept in a locked filing cabinet, and (3) Data will be retained for three years before destruction. If the results are published, your identity will remain confidential.

Questions or Problems

You are encouraged to ask questions at any time during the study. For further information about the study contact Principal Investigator, Tara Bartolain at bartolat@csp.edu. If you have any questions about the rights of research subjects or research-related injury, please contact Dr. Steve Ross (sross1@csp.edu), the IRB Administrator at Concordia University, St. Paul.

Participant Signature

Your signature indicates that you voluntarily agree to participate in the study, that the study has been explained to you, that you have been given the time to read the document, and that your questions have been satisfactorily answered. You will receive a copy of the written informed consent prior to your participation in the study.

____

Participant’s Name (printed)

____ ____________

(Participant’s Signature) (Date)

Investigator Statement

I certify that the participant has been given adequate time to read and learn about the study and all their questions have been answered. It is my opinion that the participant understands the purpose, risks, benefits, and the procedures that will be followed in the study and has voluntarily agreed to participate.

____ ____________

(Signature of Person Obtaining Informed Consent) (Date)

Appendix C

Demographic Survey for Study Participants

Name: ________________________________

Age: __________

Gender: ________

Physical Activity:

Do you currently exercise? ______

If so, what types of exercise are you currently doing?
____

Have you ever practiced Pilates? ______

Have you practiced Pilates in the last six months? ______

If so, how often did you practice? Daily ______ Weekly ______ Monthly ______

Approximate frequency- ____

Appendix D

PAR-Q+ for Study Participants

2020 PAR-Q+

The Physical Activity Readiness Questionnaire for Everyone

The health benefits of regular physical activity are clear; more people should engage in physical activity every day of the week. Participating in physical activity is very safe for MOST people. This questionnaire will tell you whether it is necessary for you to seek further advice from your doctor OR a qualified exercise professional before becoming more physically active.

GENERAL HEALTH QUESTIONS

Please read the 7 questions below carefully and answer each one honestly: check YES or NO.	YES	NO
1) Has your doctor ever said that you have a heart condition ☐ **OR** high blood pressure ☐?	☐	☐
2) Do you feel pain in your chest at rest, during your daily activities of living, **OR** when you do physical activity?	☐	☐
3) Do you lose balance because of dizziness **OR** have you lost consciousness in the last 12 months? Please answer **NO** if your dizziness was associated with over-breathing (including during vigorous exercise).	☐	☐
4) Have you ever been diagnosed with another chronic medical condition (other than heart disease or high blood pressure)? **PLEASE LIST CONDITION(S) HERE:** ______	☐	☐
5) Are you currently taking prescribed medications for a chronic medical condition? **PLEASE LIST CONDITION(S) AND MEDICATIONS HERE:** ______	☐	☐
6) Do you currently have (or have had within the past 12 months) a bone, joint, or soft tissue (muscle, ligament, or tendon) problem that could be made worse by becoming more physically active? Please answer **NO** if you had a problem in the past, but it **does not limit your current ability** to be physically active. **PLEASE LIST CONDITION(S) HERE:** ______	☐	☐
7) Has your doctor ever said that you should only do medically supervised physical activity?	☐	☐

If you answered NO to all of the questions above, you are cleared for physical activity.
Please sign the PARTICIPANT DECLARATION. You do not need to complete Pages 2 and 3.

- Start becoming much more physically active – start slowly and build up gradually.
- Follow Global Physical Activity Guidelines for your age (https://apps.who.int/iris/handle/10665/44399).
- You may take part in a health and fitness appraisal.
- If you are over the age of 45 yr and NOT accustomed to regular vigorous to maximal effort exercise, consult a qualified exercise professional before engaging in this intensity of exercise.
- If you have any further questions, contact a qualified exercise professional.

PARTICIPANT DECLARATION
If you are less than the legal age required for consent or require the assent of a care provider, your parent, guardian or care provider must also sign this form.

I, the undersigned, have read, understood to my full satisfaction and completed this questionnaire. I acknowledge that this physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if my condition changes. I also acknowledge that the community/fitness center may retain a copy of this form for its records. In these instances, it will maintain the confidentiality of the same, complying with applicable law.

NAME ______________________ DATE ______________

SIGNATURE ______________________ WITNESS ______________

SIGNATURE OF PARENT/GUARDIAN/CARE PROVIDER ______________________

If you answered YES to one or more of the questions above, COMPLETE PAGES 2 AND 3.

Delay becoming more active if:

- You have a temporary illness such as a cold or fever; it is best to wait until you feel better.
- You are pregnant - talk to your health care practitioner, your physician, a qualified exercise professional, and/or complete the ePARmed-X+ at www.eparmedx.com before becoming more physically active.
- Your health changes - answer the questions on Pages 2 and 3 of this document and/or talk to your doctor or a qualified exercise professional before continuing with any physical activity program.

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FOLLOW-UP QUESTIONS ABOUT YOUR MEDICAL CONDITION(S)

1. Do you have Arthritis, Osteoporosis, or Back Problems?

If the above condition(s) is/are present, answer questions 1a-1c — If **NO** ☐ go to question 2

1a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
1b.	Do you have joint problems causing pain, a recent fracture or fracture caused by osteoporosis or cancer, displaced vertebra (e.g., spondylolisthesis), and/or spondylolysis/pars defect (a crack in the bony ring on the back of the spinal column)?	YES ☐ NO ☐
1c.	Have you had steroid injections or taken steroid tablets regularly for more than 3 months?	YES ☐ NO ☐

2. Do you currently have Cancer of any kind?

If the above condition(s) is/are present, answer questions 2a-2b — If **NO** ☐ go to question 3

2a.	Does your cancer diagnosis include any of the following types: lung/bronchogenic, multiple myeloma (cancer of plasma cells), head, and/or neck?	YES ☐ NO ☐
2b.	Are you currently receiving cancer therapy (such as chemotherapy or radiotherapy)?	YES ☐ NO ☐

3. Do you have a Heart or Cardiovascular Condition? This includes Coronary Artery Disease, Heart Failure, Diagnosed Abnormality of Heart Rhythm

If the above condition(s) is/are present, answer questions 3a-3d — If **NO** ☐ go to question 4

3a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
3b.	Do you have an irregular heart beat that requires medical management? (e.g., atrial fibrillation, premature ventricular contraction)	YES ☐ NO ☐
3c.	Do you have chronic heart failure?	YES ☐ NO ☐
3d.	Do you have diagnosed coronary artery (cardiovascular) disease and have not participated in regular physical activity in the last 2 months?	YES ☐ NO ☐

4. Do you currently have High Blood Pressure?

If the above condition(s) is/are present, answer questions 4a-4b — If **NO** ☐ go to question 5

4a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
4b.	Do you have a resting blood pressure equal to or greater than 160/90 mmHg with or without medication? (Answer **YES** if you do not know your resting blood pressure)	YES ☐ NO ☐

5. Do you have any Metabolic Conditions? This includes Type 1 Diabetes, Type 2 Diabetes, Pre-Diabetes

If the above condition(s) is/are present, answer questions 5a-5e — If **NO** ☐ go to question 6

5a.	Do you often have difficulty controlling your blood sugar levels with foods, medications, or other physician-prescribed therapies?	YES ☐ NO ☐
5b.	Do you often suffer from signs and symptoms of low blood sugar (hypoglycemia) following exercise and/or during activities of daily living? Signs of hypoglycemia may include shakiness, nervousness, unusual irritability, abnormal sweating, dizziness or light-headedness, mental confusion, difficulty speaking, weakness, or sleepiness.	YES ☐ NO ☐
5c.	Do you have any signs or symptoms of diabetes complications such as heart or vascular disease and/or complications affecting your eyes, kidneys, **OR** the sensation in your toes and feet?	YES ☐ NO ☐
5d.	Do you have other metabolic conditions (such as current pregnancy-related diabetes, chronic kidney disease, or liver problems)?	YES ☐ NO ☐
5e.	Are you planning to engage in what for you is unusually high (or vigorous) intensity exercise in the near future?	YES ☐ NO ☐

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6. Do you have any Mental Health Problems or Learning Difficulties? This includes Alzheimer's, Dementia, Depression, Anxiety Disorder, Eating Disorder, Psychotic Disorder, Intellectual Disability, Down Syndrome

If the above condition(s) is/are present, answer questions 6a-6b — If **NO** ☐ go to question 7

6a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
6b.	Do you have Down Syndrome **AND** back problems affecting nerves or muscles?	YES ☐ NO ☐

7. Do you have a Respiratory Disease? This includes Chronic Obstructive Pulmonary Disease, Asthma, Pulmonary High Blood Pressure

If the above condition(s) is/are present, answer questions 7a-7d — If **NO** ☐ go to question 8

7a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
7b.	Has your doctor ever said your blood oxygen level is low at rest or during exercise and/or that you require supplemental oxygen therapy?	YES ☐ NO ☐
7c.	If asthmatic, do you currently have symptoms of chest tightness, wheezing, laboured breathing, consistent cough (more than 2 days/week), or have you used your rescue medication more than twice in the last week?	YES ☐ NO ☐
7d.	Has your doctor ever said you have high blood pressure in the blood vessels of your lungs?	YES ☐ NO ☐

8. Do you have a Spinal Cord Injury? This includes Tetraplegia and Paraplegia

If the above condition(s) is/are present, answer questions 8a-8c — If **NO** ☐ go to question 9

8a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
8b.	Do you commonly exhibit low resting blood pressure significant enough to cause dizziness, light-headedness, and/or fainting?	YES ☐ NO ☐
8c.	Has your physician indicated that you exhibit sudden bouts of high blood pressure (known as Autonomic Dysreflexia)?	YES ☐ NO ☐

9. Have you had a Stroke? This includes Transient Ischemic Attack (TIA) or Cerebrovascular Event

If the above condition(s) is/are present, answer questions 9a-9c — If **NO** ☐ go to question 10

9a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
9b.	Do you have any impairment in walking or mobility?	YES ☐ NO ☐
9c.	Have you experienced a stroke or impairment in nerves or muscles in the past 6 months?	YES ☐ NO ☐

10. Do you have any other medical condition not listed above or do you have two or more medical conditions?

If you have other medical conditions, answer questions 10a-10c — If **NO** ☐ read the Page 4 recommendations

10a.	Have you experienced a blackout, fainted, or lost consciousness as a result of a head injury within the last 12 months **OR** have you had a diagnosed concussion within the last 12 months?	YES ☐ NO ☐
10b.	Do you have a medical condition that is not listed (such as epilepsy, neurological conditions, kidney problems)?	YES ☐ NO ☐
10c.	Do you currently live with two or more medical conditions?	YES ☐ NO ☐

PLEASE LIST YOUR MEDICAL CONDITION(S) AND ANY RELATED MEDICATIONS HERE: ____________________

GO to Page 4 for recommendations about your current medical condition(s) and sign the PARTICIPANT DECLARATION.

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If you answered NO to all of the FOLLOW-UP questions (pgs. 2-3) about your medical condition, you are ready to become more physically active - sign the PARTICIPANT DECLARATION below:

- It is advised that you consult a qualified exercise professional to help you develop a safe and effective physical activity plan to meet your health needs.
- You are encouraged to start slowly and build up gradually - 20 to 60 minutes of low to moderate intensity exercise, 3-5 days per week including aerobic and muscle strengthening exercises.
- As you progress, you should aim to accumulate 150 minutes or more of moderate intensity physical activity per week.
- If you are over the age of 45 yr and **NOT** accustomed to regular vigorous to maximal effort exercise, consult a qualified exercise professional before engaging in this intensity of exercise.

If you answered **YES** to **one or more of the follow-up questions** about your medical condition:
You should seek further information before becoming more physically active or engaging in a fitness appraisal. You should complete the specially designed online screening and exercise recommendations program - the **ePARmed-X+ at www.eparmedx.com** and/or visit a qualified exercise professional to work through the ePARmed-X+ and for further information.

Delay becoming more active if:

- You have a temporary illness such as a cold or fever; it is best to wait until you feel better.
- You are pregnant - talk to your health care practitioner, your physician, a qualified exercise professional, and/or complete the ePARmed-X+ **at www.eparmedx.com** before becoming more physically active.
- Your health changes - talk to your doctor or qualified exercise professional before continuing with any physical activity program.

- You are encouraged to photocopy the PAR-Q+. You must use the entire questionnaire and NO changes are permitted.
- The authors, the PAR-Q+ Collaboration, partner organizations, and their agents assume no liability for persons who undertake physical activity and/or make use of the PAR-Q+ or ePARmed-X+. If in doubt after completing the questionnaire, consult your doctor prior to physical activity.

PARTICIPANT DECLARATION

- All persons who have completed the PAR-Q+ please read and sign the declaration below.
- If you are less than the legal age required for consent or require the assent of a care provider, your parent, guardian or care provider must also sign this form.

I, the undersigned, have read, understood to my full satisfaction and completed this questionnaire. I acknowledge that this physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if my condition changes. I also acknowledge that the community/fitness center may retain a copy of this form for records. In these instances, it will maintain the confidentiality of the same, complying with applicable law.

NAME ______________________ DATE ______________________

SIGNATURE ______________________ WITNESS ______________________

SIGNATURE OF PARENT/GUARDIAN/CARE PROVIDER ______________________

For more information, please contact
www.eparmedx.com
Email: eparmedx@gmail.com

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The PAR-Q+ was created using the evidence-based AGREE process (1) by the PAR-Q+ Collaboration chaired by Dr. Darren E. R. Warburton with Dr. Norman Gledhill, Dr. Veronica Jamnik, and Dr. Donald C. McKenzie (2). Production of this document has been made possible through financial contributions from the Public Health Agency of Canada and the BC Ministry of Health Services. The views expressed herein do not necessarily represent the views of the Public Health Agency of Canada or the BC Ministry of Health Services.

Key References

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3. Chisholm DM, Collis ML, Kulak LL, Davenport W, and Gruber N. Physical activity readiness. British Columbia Medical Journal. 1975;17:375-378.
4. Thomas S, Reading J, and Shephard RJ. Revision of the Physical Activity Readiness Questionnaire (PAR-Q). Canadian Journal of Sport Science 1992;17:4 338-345.

Appendix E

Functional Movement Screen Tests Descriptions and Visuals

1. DEEP SQUAT

The Deep Squat pattern challenges total body mechanics and neuromuscular control. We use it to test bilateral, symmetrical, functional mobility and stability of the hips, knees and ankles. The dowel overhead requires bilateral symmetrical mobility and stability of the shoulders, scapular region and the thoracic spine. The pelvis and core must establish stability and control throughout the entire movement to achieve the full pattern.

2. HURDLE STEP

The hurdle step pattern is an integral part of locomotion and acceleration. This movement challenges the body's step and stride mechanics, while testing stability and control in a single-leg stance. The hurdle step requires bilateral mobility and stability of the hips, knees and ankles. The test also challenges stability and control of the pelvis and core as it offers an opportunity to observe functional symmetry.

3. INLINE LUNGE

The Inline Lunge pattern places the body in a position to simulate stresses during rotation, deceleration and lateral movements. The inline lunge places the lower extremities in a split-stance while the upper extremities are in an opposite or reciprocal pattern. This replicates the natural counterbalance the upper and lower extremities use to complement each other, as it uniquely demands spine stabilization. This test also challenges hip, knee, ankle and foot mobility and stability.

4. SHOULDER MOBILITY

The Shoulder Mobility pattern demonstrates the natural complementary rhythm of the scapular-thoracic region, thoracic spine and rib cage during reciprocal upper-extremity shoulder movements. This pattern also observes bilateral shoulder range of motion, combining extension, internal rotation and adduction in one extremity, and flexion, external rotation and abduction of the other.

5. ACTIVE STRAIGHT-LEG RAISE

The Active Straight-Leg Raise pattern not only identifies the active mobility of the flexed hip, but looks at the core stability within the pattern, as well as the available hip extension of the alternate hip. This is not so much a test of hip flexion on one side, as it is an appraisal of the ability to separate the lower extremities in an unloaded position. This pattern also challenges the ability to dissociate the lower extremities while maintaining stability in the pelvis and core.

6. TRUNK STABILITY PUSH UP

The Trunk Stability Push-Up pattern is used as a basic observation of reflex core stabilization, and is not a test or measure of upper body strength. The goal is to initiate movement with the upper extremities in a push up pattern without allowing movement in the spine or hips. The movement tests the ability to stabilize the spine in the sagittal plane during the closed kinetic chain, upper body symmetrical movement.

7. ROTARY STABILITY

The Rotary Stability pattern is complex, requiring proper neuromuscular coordination and energy transfer through the torso. This pattern observes multi-plane pelvis, core and shoulder girdle stability during a combined upper and lower extremity movement. The movement demonstrates reflex stabilization and weight shifting in the transverse plane, and it represents the coordinated efforts of mobility and stability observed in fundamental climbing patterns.

Appendix F

Functional Movement Screen Scoring Sheet for Study Participants

FMS

FUNCTIONAL MOVEMENT SCREEN SCORE SHEET

NAME: ______ DATE: ______ DOB: ______

ADDRESS: ______

CITY, STATE, ZIP: ______ PHONE: ______

SCHOOL/AFFILIATION: ______

HEIGHT: ______ WEIGHT: ______ AGE: ______ GENDER: ______

PRIMARY SPORT: ______ PRIMARY POSITION: ______

HAND/LEG DOMINANCE: ______ PREVIOUS TEST SCORE: ______

TEST		RAW SCORE	FINAL SCORE	COMMENTS
DEEP SQUAT				
HURDLE STEP	L			
	R			
INLINE LUNGE	L			
	R			
SHOULDER MOBILITY	L			
	R			
SHOULDER CLEARING TEST	L +/-			
	R +/-			
ACTIVE STRAIGHT-LEG RAISE	L			
	R			
TRUNK STABILITY PUSHUP				
EXTENSION CLEARING TEST	+/-			
ROTARY STABILITY	L			
	R			
FLEXION CLEARING TEST	+/-			
TOTAL SCREEN SCORE				

Raw Score: This score is used to denote right and left side scoring. The right and left sides are scored in five of the seven tests and both are documented in this space.

Final Score: This score is used to denote the overall score for the test. The lowest score for the raw score (each side) is carried over to give a final score for the test. A person who scores a three on the right and a two on the left would receive a final score of two. The final score is then summarized and used as a total score.

Clearing Test: A positive indicates pain. A negative indicates no pain. If pain is present (+),the score for that test would result in a 0.

FMS

Scoring Criteria

The FMS uses a simplistic grading system. Each individual movement pattern has certain criteria that must be accomplished in order to obtain a high score. The scoring is broken down into four basic criteria:

3 Three is given if the individual can perform the movement without any compensations according to the established criteria

2 Two is given if the individual can perform the movement but must utilize poor mechanics and compensatory patterns to accomplish the movement

1 One is given if the individual cannot perform the movement pattern even with compensations

0 Zero is given if the individual has pain during any part of the movement

Appendix G

Pilates Exercises Selected for the Intervention, Including Specific Target and Accompanying Muscles

Pilates Exercise	Target Muscles	Accompanying Muscles
Shoulder bridge	spinal flexors, anterior spinal stabilizer, pelvic floor, hip extensors	spinal extensors, knee extensors, shoulder extensors
Chest lift	spinal flexors	anterior spinal stabilizers
One-leg stretch	spinal flexors, hip flexors, anterior spinal stabilizers	anterior spinal stabilizers, hip flexors and extensors, knee extensors, ankle-foot plantar flexors, shoulder flexors and extensors, elbow flexors and extensors
One-leg kick	spinal extensors, hip extensors	anterior spinal stabilizers, knee flexors and extensors, ankle-foot plantar flexors, shoulder extensors, scapular depressors, and abductors
Spine stretch	spinal extensors and flexors	anterior spinal stabilizers, hip extensors, ankle-foot dorsiflexors, shoulder flexors, elbow extensors
Spine twist	spinal rotators	anterior spinal stabilizers, ankle-foot dorsiflexors, shoulder abductors, elbow extensors, scapular adductors
Side kick	spinal lateral flexors and stabilizers, hip abductors	hip flexors and extensors, knee extensors, ankle-foot plantar flexors
Leg pull front	anterior spinal stabilizers, hip extensors, scapular abductors	posterior spinal stabilizers, knee extensors, ankle-foot plantar flexors and dorsiflexors, shoulder flexors, elbow extensors
Hundred	spinal flexors, hip flexors	anterior spinal stabilizers, hip adductors, knee extensors, ankle-foot plantar flexors, shoulder extensors and flexors, elbow extensors
Knee hug rocking	spinal flexors, anterior stabilizers	hip flexors, extensors, and adductors, knee extensors, shoulder extensors, elbow flexors
Shoulder bridge kick	posterior and anterior spinal stabilizers, hip extensors and flexors	knee extensors, ankle-foot plantar flexors, shoulder extensors, scapular adductors
Double leg stretch	spinal flexors, hip flexors	anterior spinal stabilizers, hip extensors, hip adductors, knee extensors, ankle-foot plantar flexors, knee flexors, shoulder flexors, elbow flexors, elbow extensors
Crisscross	spinal flexors and rotators	hip flexors and extensors, knee extensors, ankle-foot plantar flexors
Saw	spinal rotators and extensors	anterior spinal stabilizers, hip extensors, ankle-foot dorsiflexors, shoulder abductors, flexors and extensors, elbow extensors, scapular adductors
Side kick kneeling	spinal lateral flexors and stabilizers, hip abductors	hip flexors and extensors, knee extensors, ankle-foot plantar flexors, shoulder abductors, scapular depressors and abductors, elbow extensors
Cat	spinal extensors and flexors	anterior spinal stabilizers, hip extensors, shoulder flexors and extensors, elbow extensors, scapular abductors
Leg circles	targets anterior and posterior spinal rotators and stabilizers	hip flexors, extensors, abductors and adductors, knee extensors, ankle-foot plantar flexors, dorsiflexors
Swimming	spinal extensors and rotators, hip extensors	anterior spinal stabilizers, hip flexors, knee extensors, ankle-foot plantar flexors, shoulder flexors and extensors, scapular depressors, elbow extensors
Scissors	posterior and anterior spinal stabilizers, hip extensors and flexors	knee extensors, ankle-foot plantar flexors, shoulder extensors, scapular adductors

Seal	spinal flexors, anterior stabilizers	hip flexors, abductors, and adductors, knee extensors, shoulder flexors, elbow flexors
Bicycle	posterior and anterior spinal stabilizers, hip extensors and flexors	knee flexors and extensors, ankle-foot plantar flexors, shoulder extensors, scapular adductors
Rollup	spinal flexors	anterior spinal stabilizer, spinal extensors, hip flexors and extensors, ankle-foot dorsiflexors, shoulder flexors and extensors, scapular depressors, elbow extensors
Twist	spinal lateral flexors and rotators, shoulder abductors, shoulder horizontal abductors, scapular depressors and abductors	anterior spinal stabilizer, hip extensors and abductors, knee extensors and flexors, shoulder adductors, elbow extensors
Push-up	anterior spinal stabilizers, shoulder flexors, scapular abductors, elbow extensors	spinal extensors, posterior spinal stabilizers, hip extensors and flexors, knee extensors, shoulder extensors
Rocking	spinal extensors, hip extensors	anterior spinal stabilizers, knee extensors, ankle-foot plantar flexors, shoulder extensors, scapular depressors, elbow flexors
One-leg teaser	spinal flexors, hip flexors	anterior spinal stabilizer, hip adductors, knee extensors, ankle-foot plantar flexors, shoulder flexors, elbow extensors

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Appendix H

Pilates Intervention Presented by Week, Focus, Specific Exercises, and Repetitions for the Pilates group (PG)

Week	Focus	Pilates Exercises	Repetitions	Week	Focus	Pilates Exercises	Repetitions
1	Breathing	Breathwork	5	4	Breathing	Breathwork	10
	Upper body	Shoulder bridge	5		Upper body	Shoulder bridge kick	8
	Lower Body	Chest lift	5		Lower Body	Double leg stretch	8
		One-leg stretch	5		Abdominals	Crisscross	8
		One-leg kick	5			Saw	8
		Spine stretch	5			Side kick kneeling (Rt/Lt)	8
		Spine twist	5			Cat	8
		Side kick (Rt/Lt)	5			Leg circles	8
		Leg pull front	5			Swimming	10
		Hundred	5			Scissors	10
		Knee hug rocking	5			Seal (seated)	10
2	Breathing	Breathwork	10	5	Breathing	Breathwork	10
	Upper body	Shoulder bridge	5		Upper body	Hundred	10
	Lower Body	Chest lift	5		Lower Body	Bicycle	10
		One-leg stretch	5		Abdominals	Roll up	10
		One-leg kick	5			Twist	10
		Spine stretch	5			Cat	10
		Spine twist	5			Leg pull front	10
		Side kick (Rt/Lt)	5			Push-up	10
		Leg pull front	8			Swimming	10
		Hundred	8			Rocking	10
		Knee hug rocking	8			One-leg teaser	10
3	Breathing	Breathwork	10	6	Breathing	Breathwork	10
	Upper body	Shoulder bridge kick	8		Upper body	Hundred	10
	Lower Body	Double leg stretch	8		Lower Body	Bicycle	10
	Abdominals	Crisscross	8		Abdominals	Roll up	10
		Saw	8			Twist	10
		Side kick kneeling (Rt/Lt)	8			Cat	10
		Cat	8			Leg pull front	10
		Leg circles	8			Push-up	10
		Swimming	8			Swimming	10
		Scissors	8			Rocking	10
		Seal (supine)	8			One-leg teaser	10

Appendix I

Pilates Log for the Pilates group (PG)

Week	Intervention (Mark an 'X' for each completed session)			
1				
2				
3				
4				
5				
6				

Total number of completed sessions- ______