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**THE EFFECTS OF HOME-BASED PILATES
IN HEALTHY COLLEGE-AGE FEMALES**

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ABSTRACT

Objectives: To quantify and determine the effects of Pilates on core endurance, hamstring flexibility, balance, body composition/mass and perceived stress level in healthy college age females. **Study Design:** Randomized controlled trial design. **Background:** Emerging research on the Pilates technique is inconclusive regarding benefits to core endurance, flexibility, balance, body mass, and perceived stress. **Methods and Measures:** Female college students (n=57; 18-35 years old) were randomly assigned to a Pilates group, who exercised at home with a DVD, or a control group who did not engage in Pilates practice. Core endurance, hamstring flexibility, balance, body composition and stress measurements were taken at baseline and at 10 weeks. **Results:** There was a statistically significant difference between groups for multidirectional standing reach test results, specifically reaching to the right and right hamstring flexibility. **Conclusion:** Pilates practice resulted in gains in balance and hamstring flexibility among college-aged females. Limitations in this study including the unknown level of activity of the control group warrant further investigation. Additional research is needed to determine if Pilates has a significant effect on core endurance, body composition and perceived stress level.

Key Words: women, exercise, stress, fitness

INTRODUCTION

Pilates, a popular fitness trend especially among women, which focuses on stretching and strengthening muscles, including core and lower extremity musculature, was developed by Joseph Pilates during WWI to maintain the fitness of fellow internees. His techniques emphasized the mind-body connection while stretching and strengthening musculature.¹ Pilates is intended to improve general body flexibility and health by emphasizing “core” (back extensors and abdominal musculature) strength, posture, and coordination of breathing with movement.² Current proponents of Pilates assert the exercises help decrease low back pain, increase proprioception, and improve posture and motor control through the use of closed kinetic-chain exercises.^{3,4} Research on the Pilates technique is inconclusive regarding benefits to core endurance, flexibility, balance, body mass, and perceived stress.

Improving strength and endurance of the core musculature is a reason participants practice Pilates. Multiple studies examining the effects of Pilates on abdominal strength reported gains following Pilates exercise.^{5,6,7,8} Sekendiz et al⁶ also reported gains in lower back strength following Pilates. Other studies measuring trunk muscle endurance reported significant gains in both abdominal and trunk extensor muscle endurance.^{6,8,9}

Research is emerging on the effects of Pilates practice on flexibility. A study by Segal et al¹⁰ investigated the effects of Stott Pilates (a contemporary approach to the original Pilates method which emphasizes pelvic and scapular stabilization and restoring the natural curves of the spine)¹¹ and found a significant increase in flexibility as fingertip-to-floor measurement improved at 2, 4 and 6 months. Sekendiz et al⁶ found a significant improvement in sit and reach scores. Kloubec⁹ also found an improvement in sit and reach distance and supine hamstring flexibility. A study by Keays et al¹² found that Pilates exercises showed improvements in

shoulder abduction and external rotation in women who had been treated for breast cancer. Research on flexibility gains with Pilates is beginning to show effectiveness in improving flexibility in multiple joints.

The current research demonstrates that Pilates exercise can have an impact on improving balance in the adult population; however, findings are inconsistent. Joseph Pilates used the powerhouse exercise to stress the importance of proprioceptive input for motor learning improvement, and believed better motor performance was attained by repetition of correct movements.¹³ Improving balance by improving motor learning has been shown to increase coordination and decrease fall risks as people age.¹⁴ Johnson et al¹⁵ reported positive effects of Pilates on dynamic balance in healthy adults. De Siqueira Rodrigues and colleagues¹⁶ showed participation in a Pilates program improved static balance. Conversely, Kloubec⁹ found no improvement in balance among healthy adults who performed Pilates mat exercises, and Caldwell et al¹⁷ showed no change in balance between groups when comparing a Pilates mat class, a taiji quan class, and a general recreation group.

There are discrepancies within the current literature regarding the effects of Pilates on body mass and body composition. Many factors contribute to gaining the “freshman fifteen” during collegiate years, and female students were shown to have a higher risk of gaining weight while attending college.¹⁸ Pilates programs researched reveal inconsistent frequency of practice, and only two studies showed a decrease in body fat. Also, these studies do not include intensity measures, such as heart rate during exercise. Segel et al¹⁰ studied health club members who were enrolled in a 60 minute Pilates class, 1x/week for 6 months, for a total 1440 minutes. The authors believed that 1x/week was not enough for weight loss. Sekendiz et al’s⁶ program was 60 minutes, 3x/week for 5 weeks (total 900 minutes), and involved more sedentary individuals.

Neither study showed changes in BMI. Jago et al¹⁹ studied 11 year old females who performed 60 minutes of Pilates 5x/week for 4 weeks, for a total of 1200 minutes. This study found that the subjects had lower BMI values after 4 weeks.¹⁹ Rogers and Gibson's²⁰ subjects, who were adults enrolled in a Pilates class, performed Pilates for 60 minutes, 3x/week for 8 weeks (1440 minutes), and showed a decrease in body fat. It appears that over 900 minutes of total exposure and a frequency of at least 3x/week is needed to have an effect on body fat.

An increasing trend of high levels of perceived stress in college aged students has been reported in recent literature,²¹ and these stress levels may affect student's overall health.^{21,22} Since Pilates focuses on the mind-body connection, researchers have investigated the effect of Pilates on emotional aspects of participants, such as mood. Caldwell et al¹⁷ reported significant improvement in self-efficacy and mood and a trend toward improved sleep quality in those who participated in Pilates. It is reasonable to assume, then, that Pilates may have a positive effect on reducing stress levels among female college students, as the Caldwell et al¹⁷ study showed increases in mood and sleep quality. However, no studies have been conducted where stress was directly monitored during or following a group of Pilates exercise sessions.

Overall, evidence for positive impact on fitness parameters through the practice of Pilates remains inconclusive. Shedden and Kravitz²³ reviewed several studies on variable subject populations, and found peer-reviewed research lacks statistical power, incorporates low reliability instrumentation for measuring flexibility and strength, and lacks adequate controls of the intervention. Bernardo²⁴ recently found only 3 studies that focused on healthy adults, and those studies lacked sound research methodology.

Pilates is available in most fitness centers, or can be performed at home without instructor supervision. Little research is available on the effects of Pilates in healthy individuals,

especially college aged females, and only one study⁸ has investigated the effects of a home-based program. College aged females, although overall typically healthy, may have increased stress levels, weight gain and balance and flexibility deficits as stated above. Therefore, the purpose of this study was to quantify and determine the effects of home-based Pilates on core endurance, flexibility, balance, body composition/mass and perceived stress level in healthy college age females compared to age-matched controls who did not engage in a Pilates program and avoided core strengthening exercises.

METHODS and MEASURES

Subjects: The Institutional Review Board at the University of Dayton approved the current study and written informed consent was obtained from all participants. Subjects were recruited using flyers and word of mouth. Students who responded and volunteered to participate were randomly assigned into a home-based Pilates (n=27) or a control (n=30) group. Mean ages of participants in the home based and control groups were 22.46 (sd ± 4.57), and 22.08 (sd ± 4.25) years, respectively.

Inclusion criteria consisted of: female, ages 18 to 35, medically stable, and no participation in Pilates more than 5 sessions in the previous year. Medical status was determined through a health questionnaire completed by all subjects and reviewed by the primary investigator prior to enrollment in the study. Exclusion criteria included women who were pregnant or had a history of back surgery or self-reported chronic back pain.

Procedures: All measurements were taken at baseline and after the 10 weeks of intervention by the same investigator.

Intervention:

The Pilates group was given an introductory 8 minute DVD, which instructed the participants in six exercises to familiarize them with Pilates and included the concepts of diaphragmatic breathing, abdominal engagement and head float. For the first 3 weeks of the study, this DVD was to be performed twice each session, with a total of 3 sessions per week. They were then given a 50 minute DVD of a Pilates exercise class (including 30 activities) and were instructed to perform this DVD twice per week, for the remaining 7 weeks. See Appendix for the list of exercises included in the DVD. The participants in the control group were to continue with their current exercise program but agreed not to perform Pilates, yoga, abdominal crunches, or sit-ups throughout the study period and to attempt to maintain their body weight during the study.

Outcomes:

Core Endurance: Trunk extensor endurance was measured using the modified Biering-Sorenson Test.²⁵ Subjects laid prone with their lower body strapped to a plinth at the ankles, knees, and hips. The upper body extended over the edge of the plinth with the subject's upper limbs held across her chest with her upper body supported by a level surface and positioned 25 centimeters (cm) below the plinth. When given the start signal, the subject raised her upper body until it was parallel to the floor and maintained that position as long as possible. Endurance timing started when the subject's body reached horizontal, and ended at either 240 seconds or when the subject's body came in contact with the lower surface. The reliability for this technique is $r > 0.97$.²⁵

Trunk flexor endurance was measured with subjects seated on a firm plinth with their knees and hips flexed at 90 degrees, while the upper body was positioned at a 60 degree angle against a wooden support. The subject's ankles were strapped to the test plinth and her arms

were held across her chest. The subject was instructed to maintain this upright 60 degrees of extension position for as long as possible up to 240 seconds. Endurance timing began when the back support was moved 10 centimeters posterior to the subject; the investigator stopped the timer when the subject came in contact with the back support, rounded her shoulders, or obtained the 240 second maximum time criterion. The reliability for this technique is reported to be $r = 0.98$.²⁵

Flexibility: Flexibility was measured using the single leg seated hamstring flexibility test, which was validated on college aged females by Baltaci et al.²⁶ The participant was seated on the floor with shoes off and with one leg fully extended, so that the sole of that foot was flat against the Acuflex I Sit and Reach tester (Novel Products, Inc, Rockton, Illinois). Subjects placed one hand on top of the other and slowly reached forward as far as possible, keeping palms down and without flexing the knee. The score was recorded as the final position of the third digit on the ruler in centimeters. Three trials were performed on each side and the average of the three was entered as the final measurement. The procedure was repeated on the opposite leg.

Balance: Balance was measured using the Multi-Directional Reach Test (MDRT) as described by Newton,²⁷ using a simple clinical apparatus consisting of a leveled yardstick secured to the wall at the right acromion height. Subjects were asked to stand in a normal, relaxed stance so their right acromion was perpendicular to the measurement tool. Subjects were asked to extend their right arm with the shoulder flexed at ninety degrees and make a fist. Newton's technique was modified to use the third metacarpal as is used in the functional reach assessment. Placement of the third metacarpal was recorded. Subjects were then asked to reach as far forward (encourage trunk flexion) without losing their balance or taking a step, and the placement of their third metacarpal was recorded again. The upper extremity was not allowed to contact the wall at any time. Functional reach was defined

as the difference between positions 1 and 2 and recorded in centimeters. Subjects repeated the same procedure reaching to the right, to the left, and backward. The subjects were randomized into two groups for the order in which they would perform the reach. The MDRT provided a valid assessment of stability as derived by reach in four directions, and the reliability coefficient for the MDRT was reported as 0.92.²⁷

Height and Weight Measurements: Body weight was taken in light clothing without shoes to the nearest tenth of a pound on an analog scale, and was then converted to kilograms. Height was measured without shoes with a tape measure mounted on the wall to the nearest 1/8 inch then converted to meters. Body Mass Index (BMI) was calculated from these values by the formula $\text{weight (kg)} \div \text{height (m}^2\text{)}$.

Body Composition Measurements: Body composition was measured using the OMRON Fat Analyzer Model HBF-3ed (Model HB-300, Omron Healthcare, Vernon Hills, Illinois). Height, weight, age, and gender were entered, and the subjects lightly grasped the bioelectrical impedance tool on each handle with arms extended for approximately 30 seconds. The measurement was then recorded by the researcher. Validity measurements for bioelectrical impedance analysis (BIA) have shown comparable results to x-ray absorptiometry, air displacement, skin-fold, and hydrostatic weighing.^{28,29,30,31} Validity measurements were shown to be reduced when the BIA measurements were taken with subjects in the supine position, so subjects in this study stood while measurements from the hand-held bioelectrical impedance assessor were recorded.³⁰ Reliability for BIA is 0.70-0.80 compared to 0.88-0.93 with air displacement densitometry.^{29,31}

Perceived Stress: Stress was measured using the Cohen Perceived Stress Scale (PSS).³² The PSS is a 14-item scale designed to measure the degree to which life situations are appraised as

stressful. PSS scores are obtained by reversing the scores on the seven positive items and then summing across all 14 items, utilizing a rating scale of 0-4. High scores indicate elevated stress. The PSS has been validated for use with college students, and internal consistency coefficients for the PSS range from 0.84 to 0.86, with a test-retest reliability of 0.85.³²

Statistical Design: Data was analyzed using Statistical Software for the Social Sciences (SPSS, v 16.0, Chicago, IL). Descriptive statistics were calculated for all pre- and post-test values for each dependent variable. Change scores were calculated as the difference between the pre- and post-test values for each dependent variable. Independent samples T-tests were run to determine if there were statistically significant differences between the two study groups at baseline for any of the dependent variables, except for the Perceived Stress Score, which was analyzed using Mann-Whitney U for pre- and post-test values as the data is not normally distributed. Repeated measures (RM) analysis of variance (ANOVA) tests were run with pre- and post-test scores for all measured variables as the within-group/repeated measure comparison, and with the 2 study groups as the between-group comparison. Differences were considered statistically significant if $p \leq 0.05$.

RESULTS

Fifty seven subjects completed all pre- and post-tests (27 Pilates and 30 controls). For the flexibility data (sit and reach right and left), data was lost on 3 subjects, with results reported for 26 and 28 for the Pilates and control groups, respectively.

Pre-test: Independent samples T-tests revealed there were no statistically significant differences between the two study groups at pre-test for any of the measured variables. The Perceived Stress Score was not different at pre-test between groups as analyzed by Mann-Whitney U.

Pre-test to Post-test Changes: Means and standard deviations for the pre- and post-test values for all dependent variables are presented in Tables 1-4. Repeated measures ANOVA tests

revealed statistically significant differences across groups for changes in left hamstring flexibility, trunk flexor endurance, and multidirectional standing reach test results, specifically reaching to the right and left. The change scores on the PSS were also statistically significant across groups with an increase in scores, indicating an increase in perception of stress. The change in balance reach right was statistically significant within groups and between groups, with the Pilates group demonstrating greater change. Additionally, there was a statistically significant difference in right hamstring flexibility between groups.

COMMENT

This study showed statistically significant changes in multidirectional standing reach test results, specifically reaching to the right and hamstring flexibility (right) between groups. The findings in this study substantiate the general belief that Pilates can have a positive effect on certain fitness parameters, including balance and flexibility. These results are similar to other research findings investigating the effects of Pilates on hamstring flexibility and balance.

Pilates Frequency and Duration: In studies that have shown positive changes in the variables that were also measured in the current study, total exposure time ranged from 900-1440 minutes with intervention duration of 5-12 weeks (with only 1/5 studies being for 5 weeks).^{5,6,9,16,20} The original research design for this study included 17 weeks (1472 exposure minutes) for Pilates practice, but was limited to 10 weeks to complete recruitment and testing of subjects within a college semester. Therefore exposure in the current study was 772 minutes over 10 weeks. Based on review of other study findings^{6,9,16,20}, the exposure time to Pilates in our study may not have been adequate to promote full fitness effects.

Core Endurance: On average, participants in Pilates group showed statistically significant gains in trunk flexor endurance, which is consistent with other research.^{5,6,9} However, the control

group also made statistically significant gains in trunk flexor strength. The core endurance measurement method may not have been responsive enough, which could be one explanation for the null difference between the control and Pilates groups on this outcome. Furthermore, the normative value for mean flexion endurance time among female college students is 147 seconds.²⁵ Both study groups demonstrated mean endurance times exceeding 147 seconds (205 and 196 seconds for Pilates and control groups, respectively), indicating the test measure may not be sensitive among healthy individuals. The control group, although instructed not to participate in exercise related to abdominal strengthening, may have participated in some exercise which indirectly effected core flexion endurance.

It was hypothesized that Pilates training would positively affect trunk endurance in both the flexion and extension planes. Although average extension endurance times improved in the Pilates group, they was not statistically significant. This finding may be due to the fact that the exercises given to the subjects may not have emphasized the extensors enough as only one exercise in the Intro DVD and five in the Pilates class DVD focused on the extensor muscles. The gains made in the Pilates group are consistent with findings in the only other study examining trunk extensor endurance and Pilates. Rogers and Gibson²⁰ measured trunk extensor endurance in novice Pilates practitioners by the number of trunk extension repetitions from 45 degrees flexion to neutral, positioned against gravity. Using this outcome measures, their results showed endurance gains following 8 weeks of exercise. Furthermore, the mean post exercise (Pilates group) endurance time of 176 seconds in this group is similar to the normative value of 189 seconds reported by McGill et al.²⁵ Because the gains made in the experimental group did not meet statistical significance, a need for further research is indicated in the parameters of Pilates dosage required to make a significant gain.

Flexibility: The results of this study, showing improvements in flexibility of the hamstrings following Pilates training, are in support of the emerging evidence that Pilates can have a positive effect on flexibility. Sekendiz et al⁶ and Kloubec⁹ measured hamstring flexibility using sit and reach, as was done in this study, and both reported gains following Pilates training. Sit and reach values at pre-test for both groups were greater than 24 inches which is the 99 percentile rank for women ages 20-29 years.³³ The study population, therefore, may already have adequate flexibility with limited room for change with Pilates practice. That some gains were evident does support the emerging evidence that Pilates may be effective in improving flexibility.

Balance: The effect of Pilates on balance has not been clearly substantiated in the literature due to the use of varying outcome measures. Caldwell et al¹⁷ and Kloubec⁹ studied the effects of Pilates on balance and found no change pre- to post-intervention. In Caldwell,¹⁷ balance was measured using single leg stance eyes closed while in the Kloubec,⁹ study the balance outcome was time that participants stood on a modified balance board. Both the Pilates and the control groups mean reach values in all directions were greater at baseline than the reported norms for this age group (forward 28.3 cm, backward 18.8 cm, left 17.9 cm and right 18.9cm)³⁴ which may be due to the self-selection for this study. The gains seen among the Pilates groups are in agreement with a study by De Siqueria Rodrigues et al,¹⁶ in which static balance was measured among healthy elderly females using the Tinetti, and found statistically significant gains in the Pilates group compared to controls. Our study shows these gains as well, however, it seems dynamic assessment is more appropriately matched to the dynamic activity engaged in with Pilates, and may be a better measure of balance skills. The MDRT is more of a dynamic balance test than the measurements taken by Caldwell et al¹⁷ and Kloubec,⁹ and may, in part, account for

the gains seen among the exercise group. The exercises and activities that the control group performed during the study may have helped to improve their balance as well but these were not monitored.

Perceived Stress: Stress experienced by individuals often varies with differing life events, and college students are no different. The participants in this study may have experienced differing levels of stress from the baseline data collection at the beginning of a semester to the final measurements taken at the end of the semester simply based on the timing of the measurements. The finding that stress scores increased in both groups may reflect the increasing demand placed on students from the beginning to the end of the semester. It should be noted, however, that the Pilates group had lower levels of stress than the control at the completion of the study. It is reasonable to suppose that Pilates had some effect on mitigating the level of stress experienced by the participants; however, as these results were not statistically significant, this conclusion must be further researched. To further examine whether Pilates has an effect on stress levels among college students, repeated measures throughout the exercise time period may provide more information about stress and any effect Pilates exercise may have on it. No other studies examined the effects of Pilates on stress levels; however, Caldwell and colleagues¹⁷ examined the effect of Pilates on sleep quality and mood among college aged females, and found a statistically significant improvement in mood, and a trend toward improved sleep quality among those who participated in Pilates. As stress can affect mood and sleep, it is reasonable to conclude that improvements in these areas would coincide with improvements in stress levels.

Body Composition: The results in this study found no within or between group statistically significant differences in body mass index or body fat percentage. These findings are in partial agreement with the current literature. Segal et al,¹⁰ in studying the effects of a 6 month Pilates

program among adults, showed no change in body mass. Another study, however, did show significant gains in decreased body fat and body circumference measures among adults participating in an 8 week Pilates program.²⁰ The lack of a statistically significant change among the participants in the present study may be attributable to the baseline level of fitness among participants. Before participating in Pilates, the mean BMI was 23.71, which is already within the normal BMI range of 18.5-24.9.³³⁵ It is possible that with continued participation in Pilates, and controlling for the level of activity of the control group, statistically significant changes may be found.

Limitations of the Current Study: Several limitations of the current study were identified. The length of the study and frequency of Pilates practice could have been longer to increase total exposure time, in order to be more consistent with other research. Another limitation was that, although the control group was advised to avoid particular exercise activities, they were not given very clear and comprehensive restrictions and were permitted to engage in other exercise. No log was kept to determine what exercise or change in activity level occurred over the intervention time period, especially in the control group. It is conceivable that because many of the participants were freshman at a residential university which requires walking or bicycling to class, it is possible that their activity level increased from baseline. Additionally, instruments such as those used to measure balance and core strength may not have been as responsive to changes in subject performances. Lastly, no follow-up questionnaire was given to participants regarding any changes in health status at the final measurements. Researchers in this study were not able to determine if any adverse occurrences during the intervention period might have explained the decline seen in trunk extensor endurance from baseline to final measurement.

Further research in this area is needed and there are a few recommendations. Future researchers are advised to include between 900 and 1440 minutes of Pilates practice to be more in line with previous studies. To minimize the history threat to internal validity, strict and comprehensive physical activity restrictions on control group activities during the intervention period are recommended. Logs of activity or a pre-, post-intervention assessment of activity such as the International Physical Activity Questionnaire could be used to quantify physical activity among the participants, especially in the control group. Researchers should consider selecting instruments, especially those used to measure balance and core strength, that are more responsive to changes in subject performance. For example, trunk flexor endurance may be best measured by the number of sit-ups in a minute, as advocated by the American College of Sports Medicine, rather than the flexion endurance test used in this study, which may not be responsive enough to differentiate among groups. Lastly, since many of the published studies employ class-based Pilates, it would be interesting to compare the same Pilates program performed in the typical class setting to one performed at home. This would allow researchers to see if performing exercises in a class setting may motivate subjects to be more engaged in the exercises.

CONCLUSION

The current study showed gains in balance and hamstring flexibility among college-aged females who completed Pilates training. However, further research is needed to determine if Pilates has a significant effect on the indices of core endurance, hamstring flexibility, overall balance, body composition and perceived stress level. Future researchers are advised to include between 900 and 1440 minutes of Pilates practice, impose strict restrictions on control group

activities during the intervention period, and select instruments that are responsive to changes in healthy active subjects.

Table 1: Mean (SD) of Body Fat Percentage, Body Mass Index, and Perceived Stress

	Pilates Group n = 27		Control Group n = 30	
	Pre-Test	Post-Test	Pre-Test	Post-test
BF%	24.08 (5.70)	24.42 (5.25)	23.02 (4.68)	23.33 (4.90)
BMI (kg/m ²)	23.69 (2.85)	23.53 (2.67)	23.12 (3.06)	23.18 (3.09)
Stress	21.78 (6.02)	24.78 (6.90)*	23.30 (6.68)	26.97 (6.48)*

BF% = Body Fat Percentage; BMI = Body Mass Index.

**Significant change pre- to post-test ($p \leq 0.05$).*

Table 2: Mean (SD) Balance Measures

	Pilates Group n= 27		Control Group n = 30	
	Pre-Test	Post-Test	Pre-Test	Post-test
Reach Forward (cm)	38.38 (6.22)	38.95 (6.47)	38.71 (6.34)	38.38 (4.47)
Reach Backward (cm)	28.11 (7.49)	31.76 (8.35)	28.81 (8.08)	32.15 (5.95)
Reach Right (cm)	26.17 (7.07)	28.72 (7.54)*§	25.85 (5.36)	27.30 (6.69)*§
Reach Left (cm)	25.85 (7.73)	30.53 (6.31)*	25.15 (5.84)	26.29 (5.83)*

**Significant change pre- to post-test ($p \leq 0.05$). §Pre- to Post-test change value significantly different between Pilates and Control groups ($p = 0.006$).*

Table 3: Core Endurance

	Pilates Group n = 27		Control Group n = 30	
	Pre-Test	Post-Test	Pre-Test	Post-test
Trunk Flexor (sec)	183.46 (68.63)	205.00 (58.15)*	170.08 (74.60)	195.93 (66.39)*
Trunk Extensor (sec)	160.89 (65.84)	176.00 (61.32)	166.90 (58.09)	166.27 (59.43)

**Significant change pre- to post-test ($p \leq 0.05$).*

Table 4: Mean (SD) Hamstring Flexibility

	Pilates Group n= 26		Control Group n = 28	
	Pre-Test	Post-Test	Pre-Test	Post-test
SR Right (cm)	24.91 (6.97)	26.47 (8.89)§	28.47 (6.55)	27.86 (6.39)§
SR Left (cm)	24.26 (7.28)	26.17 (8.62)*	27.74 (6.35)	28.19 (6.15)*

SR = Sit and Reach Test.

**Significant change pre- to post-test ($p \leq 0.05$). §Pre- to Post-test change value significantly different between Pilates and Control groups ($p = 0.003$).*

REFERENCES

1. Pilates JH, Miller W. *Return to Life Through Contrology*. New York: Presentation Dynamics; 1945.
2. Mayo Clinic. Pilates: Strength for Your Core and More. *Mayo Clinic Women's Healthsource*. June 2009;13(6):7.
3. Siler B. *The Pilates Body: The Ultimate At-Home Guide to Strengthening, Lengthening and Toning Your Body- Without Machines*. New York: Broadway Books; 2000.
4. Herman E. *Pilates for Dummies*. John Wiley & Sons; 2011.
5. Emery K, DeSerres SJ, McMillian A, Cote JN. The effects of a Pilates training program on arm-trunk posture and movement. *Clin Biomech*. 2009;25:124-130.
6. Sekendiz B, Altun O, Korkusuz F, Akin S. Effects of Pilates exercise on trunk strength, endurance and flexibility in sedentary adult females. *J Bodyw Mov Ther*. 2007;11:318-326.
7. Herrington L, Davies R. The influence of Pilates training on the ability contract the Transversus Abdominis muscle in asymptomatic individuals. *J Bodyw Mov Ther*. 2005;9:52-57.
8. Donahoe-Fillmore B, Hanahan N, Mescher M, Addison N, Clapp ED, Weston C. The effects of a home Pilates program on muscle performance and posture in healthy females: A pilot study. *J Womens Health Phys Therap*. 2007;31(2): 6-11.
9. Kloubec JA. Pilates for improvement of muscle endurance, flexibility, balance and posture. *J Strength Cond Res*. 2010;24:661-667.
10. Segal NA, Hein J, Basford JR. The effects of Pilates training on flexibility and body composition: an observational study. *Arch Phys Med Rehabil*. 2004;85:1977-1981.

11. Merrithew M, Dubeau L, Della Pia, S. *Stott Pilates Comprehensive Matwork Manual*. Merrithew International Inc; 2010.
12. Keays KS, Harris SR, Lucyshyn JM, MacIntyre DL. Effects of Pilates exercises on shoulder range of motion, pain, mood, and upper-extremity function in women living with breast cancer: a pilot study. *Phys Ther*. 2008;88(4):494-510.
13. Anderson B, Spector A. Introduction of Pilates-based rehabilitation. *Balanced Body*. Orthopedic Physical Therapy Clinics of North America; 2000;9(3):395-410.
14. DiStefano LJ, Clark MA, Padua DA. Evidence supporting balance training in healthy individuals: A systematic review. *J Strength Cond Res*. 2009;23(9):2718-2731.
15. Johnson EG, Larsen A, Ozawa H, Wilson CA, Kennedy KL. The effects of Pilates-based exercise on dynamic balance in healthy adults. *J Bodyw Mov Ther*. 2007;11(3):238-242.
16. De Siqueira Rodrigues BG, Ali Cader S, Bento Torres NV, Olivera EM, Martin Dantas EH. Pilates method in personal autonomy, static balance and quality of life of elderly females. *J Bodyw Mov Ther*. 2010;14:195-202.
17. Caldwell K, Harrison M, Adams M, Triplett NT. Effects of Pilates and taiji quan training on self –efficacy, sleep quality, mood and physical performance on college students. *J Bodyw Mov Ther*. 2009;13(2):155-63.
18. Adams T, Rini A. Predicting 1-year change in body mass index among college students. *J Am Coll Health*. 2007;55:361-365.
19. Jago R, Jonker ML, Missaghian M, Baranowski T. Effect of 4 weeks of Pilates on the body composition of young girls. *Am J Prev Med*. 2006;42:177-180.
20. Rogers K, Gibson AL. Eight-week traditional mat Pilates training-program effects on adult fitness characteristics. *Res Q Exerc Sport*. 2009;80(3):569-574.

21. Misra R, McKean M. College students' academic stress and its relation to their anxiety, time management, and leisure satisfaction. *Am J Health Stud.* 2000;16(1):41-43.
22. Sheu S, Lin H, Hwang S. Perceived stress and physio-psycho-social status of nursing students during their initial period of clinical practice: the effect of coping behaviors. *Int J Nurs Stud.* 2002;39:165-175.
23. Shedden M, Kravitz L. Pilates Exercise: A Research-Based Review. *J Dance Med Sci.* 2006;3-4:111-115.
24. Bernardo L. The effectiveness of Pilates training in healthy adults: An appraisal of the research literature. *J Bodyw Mov Ther.* 2007;11:106-110.
25. McGill S, Childs A, Liebenson D. Endurance Times for Low Back Stabilization Exercises: Clinical targets for testing and training from a normal database. *Arch Phys Med Rehabil.* 1999;80: 941-943.
26. Baltaci G, Un N, Tunay V, Besle A, Gerçeker S. Comparison of three different sit and reach tests for measurement of hamstring flexibility in female university students. *Br J Sports Med.* 2003;37:59–61.
27. Newton RA. Validity of the multi-directional reach test: A practical measure for limits of stability in older adults. *J Geriatr Oncol.* 2001;56A(4):M248-M252.
28. Demura S, Sato S. Prediction of visceral fat area at the umbilicus level using fat mass of the trunk: the validity of bioelectrical impedance analysis. *J Sports Sci.* 2007;25:823-833.
29. Dixon C, Deitrick R, Pierce J, Cutrufello P, Drapeau L. Evaluation of the bod pod and leg-to-leg bioelectrical impedance analysis for estimating percent body fat in national collegiate athletic association division III collegiate wrestlers. *J Strength Cond Res.* 2005;19:85-91.

30. Rush E, Crowley J, Freitas I, Luke A. Validity of hand to foot measurement of bioimpedance: standing compared with lying position. *Obesity (Silver Spring)*. 2006;14:252-257.
31. Lukaski HC. Methods for the measurement of human body composition: traditional and new. *Am J Clin Nutr*. 1986;46:637-566.
32. Cohen S, Kamarck T, Mermelstein R. A global measure of perceived stress. *J Health Soc Behav*. 1983;24(4):385-396.
33. American College of Sports Medicine. *Principles of Exercise Prescription*. William & Wilkins; 1995.
34. Tantisuwat A, Chamonchant D, Boonyong S. Multi-directional Reach Test: An Investigation of the Limits of Stability of People Aged between 20–79 Years. *J Phys Ther Sci*. 2014; 26(6): 877–880.
35. Centers for Disease Control and Prevention. Defining Overweight and Obesity. Available at: <http://www.cdc.gov/obesity/adult/defining.html>. Accessed on April 20, 2010.

Appendix: Pilates Exercises

Introductory DVD

Exercise 1 – Ab crunch

- Starting Position
 - Supine on mat/table
 - Knees bent
 - Flat on the floor in line w/ the pelvis
 - Arms extended by sides
- Second Position – inhale while rising
 - Chin tuck
 - Elevate scapulae off of floor
 - Reach hands towards feet
 - Hold position (about 2-3 sec)
- Return to starting position – exhale while lowering

Exercise 2 – Single Leg Stretch

- Starting position
 - Supine
 - Hips 90 degrees (deg)
 - Knees bent (loose)
 - Hands on lateral knee
 - Chin tucked
- Second position – breath in then exhale while performing
 - Flex lumbar spine (press into mat)
 - Raise scapulae off of mat
 - Straighten one leg (extend knee/hip, but keep foot elevated off of mat)
 - Flex opposite hip and overstretch w/ hands
 - Hold position 2-3 sec while inhaling
 - Exhale and alternate leg positions

Appendix: Pilates Exercises, page 2

Exercise 3 – Bicycle

- Starting position
 - Same as above, except hands are behind head
- Second position
 - Exhale
 - Straighten one leg
 - Bring elbow to opposite, bent knee
 - Do not let opposite leg touch the ground
 - Alternate position in a slow and controlled manner

Exercise 4 – “The Hundred” 100 counts

- Starting position
 - Same as exercise 2
- Second position
 - Chin tuck
 - Scapulae off of mat
 - Extend knees while keeping hips flexed
 - Pump arms up and down
 - Exhale 5 counts, inhale 5 counts

Exercise 5 – Breaststroke

- Starting position
 - Prone w/ forehead resting on dorsum of hands
- Second position
 - Raise chest and thighs off of mat
 - Keep thighs together
 - “Squeeze gluts”
 - Hold 5 sec while taking a deep breath
 - Return to starting position

Exercise 6 – Cat Stretch

- Starting position
 - Quadruped
- Second position
 - Inhale and arch back towards ceiling
 - Exhale and return to starting position

Appendix: Pilates Exercises, page 3

Exercise Class DVD

Exercise 1 – The Hundred 100 counts

- Performed as described above

Exercise 2 – Roll-up, Roll-down

- Starting position
 - Supine
 - Shoulders flexed to 120 deg
- Second position
 - Inhale and roll up (sit up) such that arms are parallel to legs
 - Exhale and roll down to starting position
- Modification
 - Sitting erect on mat
 - Knees bent
 - Feet flat on mat
 - Roll back 45 deg
 - Return to starting position

Exercise 3 – Roll over Prep

- Starting position
 - Supine
 - Arms by side
 - Hips flexed to 90 deg
 - Knees extended
- Second position
 - Slowly extend hips to 60 deg
 - Return to starting position
- Progression
 - From starting position, raise feet towards the ceiling and pelvis off of the mat
- Final Progression (roll over)
 - From starting position: contract abdominals such that the legs move over the head and are parallel to the mat
 - Return to starting position

Appendix: Pilates Exercises, page 4

Exercise 4 - Single Leg Circle

- Starting position
 - Supine
 - Arms by side
 - Knees bent
 - Feet flat on mat
- Second position
 - Flex one hip to 90 deg
 - Extend ipsilateral knee
 - Plantar flex ipsilateral ankle
 - Perform counterclockwise circles with pointed toe
 - Perform clockwise circles with pointed toe
 - Return leg to starting position
- Third position
 - Flex same hip towards body as far as possible while keeping the knee extended
 - Perform a crunch by “climbing” the leg w/ the hands

Exercise 5 – Eccentric ab rolls

- Starting position
 - On end 1/3 of mat
 - Flex hips and trunk such that you are supported only by the pelvis
 - Knees flexed
 - Hands under knees
- Second position
 - While holding starting position, roll onto your back.
 - Roll back to starting position

Exercise 6 – Single Leg Stretch

- Performed as “bicycle” from “Intro” video, except that hands are used to passively overstretch the hip when placed in flexion.

Exercise 7 – Double leg stretch

- Starting position
 - Supine
 - Trunk flexed such that scapulae are off the mat
 - Knees tucked to chest
- Second position
 - Hips extended to 45 deg
 - Knees fully extended
 - Shoulders flexed to counterbalance

Appendix: Pilates Exercises, page 5

Exercise 8 – Single Leg Stretch

- As performed in “intro” video under “single leg stretch”

Exercise 9 – Double straight leg stretch

- Starting position
 - Supine
 - Hips at 90 deg
 - Knees fully extended
 - Ankles plantar flexed
 - Arms by side, but off of the mat
- Second position
 - Hips lowered towards 45 deg
 - Ankles dorsiflexed
 - Return to starting position

Exercise 10 – Criss Crosses

- Starting position
 - Bicycle position from “Intro” video
- Second position
 - Same as bicycle position from “intro,” except that one scapulae is on the mat at all times
 - Alternate

Exercise 11 – Forward spine stretch

- Starting position
 - Long sit position
 - Back erect as if against wall
 - Arms outstretched parallel to legs
- Second position
 - Extend arms forward by flexing cervical and thoracic spine
 - Keep lumbar spine erect

Exercise 12 – Open Leg Rocker

- Starting position
 - Same as Exercise 5 of this video, except knees extended to 90 deg or higher
- Second position
 - Tuck chin
 - Roll back
 - Roll up

Appendix: Pilates Exercises, page 6

Exercise 13 – Half roll back w/ an opening twist

- Starting position
 - Long sit position on outer 3rd of mat
 - Flex knees such that feet are flat on the mat
 - Arms outstretched in front
- Second position
 - Extend trunk to 45 deg
 - Horizontally abduct arm past neutral with ipsilateral trunk rotation
 - Return to forward position
 - Return to starting position
 - Alternate sides

Exercise 14 – Corkscrew

- Starting position
 - Supine
 - Hips at 90 deg
 - Knees extended
 - Hands by or under hips
- Second position
 - Rotate legs at hips counterclockwise and then clockwise
 - Keep legs together

Exercise 15 – “The Saw”

- Starting position
 - Long sit
 - Legs mat width apart
 - Arms abducted to 90 deg
- Second position
 - Inhale
 - Rotate trunk such that one arm is parallel of the contralateral leg
 - Chin tuck and flex forward slightly
 - Return to starting position
 - Alternate

Appendix: Pilates Exercises, page 7

Exercise 16 – Swan Dive

- Starting position
 - Prone
 - Palms on mat under shoulder
- Second position
 - Extend spine while bearing weight through the hands
 - Return to starting position
- Progression – “release and catch”
 - Prone
 - Extend back by pushing up with arms
 - Keeping back extended, remove hands from mat so to roll forward
 - When roll back (by momentum), stop and return to extended position.
 - Repeat

Exercise 17 – Single leg kicks

- Starting position
 - Prone
 - Bearing weight through forearms
- Second position
 - Flex knee w/ ankle dorsiflexed
 - Extend knee
 - Flex knee again w/ ankle plantar flexed
 - Extend knee
 - Alternate

Exercise 18 – Double leg kicks

- Starting position
 - Prone
 - Dorsum of hands resting on low back
- Second position
 - Flex knees
 - Relax
 - Extend back
 - Rotate neck
 - Relax
 - Repeat

Appendix: Pilates Exercises, page 8

Exercise 19 – Spinal bridges

- Starting position
 - Supine
 - Hips flexed
 - Knees bent
 - Feet flat on mat
 - Arms by sides
- Second position
 - Extend hips such that pelvis rises off the mat
- Third position
 - Hold end position
 - Extend one knee
 - Flex ipsilateral hip to 90 deg
 - Return to down position
 - Alternate

Exercise 20 – Spine twist

- Starting position
 - Long sit
 - Arms abducted to 90 deg
- Second position
 - Rotate spine one direction
 - Return to neutral
 - Rotate opposite direction

Exercise 21 – Jackknife

- Starting position
 - Supine
 - Hips flexed to 90 deg
 - Knees extended
- Second position
 - Roll hips such that legs are parallel over upper body
 - Extend hips such that feet elevate towards ceiling above head
 - Return to starting position

Appendix: Pilates Exercises, page 9

Exercise 22 – Side leg series

- Starting position
 - Lie on side
 - Bearing weight through elbow, place hand on head for support
 - Legs extended
- Second position
 - Abduct top leg to 30-45 deg
 - Relax
- Third position
 - Abduct leg
 - Flex hip and knee
 - Return to starting position
- Fourth position
 - Slight abduction
 - Make small circles w/ abducted leg
- Fifth position
 - Extend leg behind bottom leg
 - Tap heel on mat 5 times
 - Flex hip in front of bottom leg
 - Tap heel on mat 5 times
- Sixth position
 - Flex top hip (to move leg out of the way)
 - Adduct bottom hip
 - Relax/repeat
- Seventh position
 - Adduct bottom hip (same as above)
 - Perform small circles (5)
 - Relax

Exercise 23 –Heel taps

- Starting position
 - Prone
 - Dorsum of hands supporting forehead
- Second position
 - Extend hips
 - Tap heels together
- Third position
 - Flex knees
 - Extend hips
 - Taps heels

Appendix: Pilates Exercises, page 10

Exercise 24 – Tweezers

- Starting position
 - Supine
 - Hips flexed to 45 deg
 - Knees extended
 - Shoulders flexed to 120 deg
- Second position
 - Flex trunk to perform a sit up
 - Return to starting position

Exercise 25 – Hip circles

- Starting position
 - Trunk flexed supported on forearms
 - Knees flexed feet flat on floor
- Second position
 - Extend knees
 - Make circles w/ legs
 - Return to starting position
- Third position
 - From starting position
 - Raise feet off of mat
 - Rotate hips sideways
 - Extend knees
 - Return to neutral
 - Alternate

Exercise 26 – Swimming

- Starting position
 - Prone position
- Second position
 - Extend hips and back
 - Arms straight in front
 - Kick one leg up while raising contralateral arm
 - Alternate quickly

Appendix: Pilates Exercises, page 11

Exercise 27 – Mermaid

- Starting position
 - Sit w/ legs half circle to right side
- Second position
 - Left arm flexed to 180 deg
 - Right sidebend
 - Return to neutral
 - Arms abducted to 90 deg
 - Left sidebend and touch mat w/ left hand
- Third position
 - Left sidebend
 - Left leg abduction

Exercise 28 – Boomerang

- Starting position
 - Long sit
 - Legs crossed in front
 - Arms by side
- Second position
 - Roll back
 - Keep hips at 90 deg
 - Horizontally abduct hips
 - Return to neutral
 - Return to starting position

Exercise 29 - Seals

- Starting Position
 - Diamond (prop) sit
 - Trunk slightly extended
 - Elevate feet off the mat keeping heels together
- Second position
 - Roll onto back
 - Tap heels
 - Return to starting position

Appendix: Pilates Exercises, page 12

Exercise 30 – Pushup series

- Starting position
 - Stand erect
- Second position
 - Bend forward
 - Walk with hands into pushup position
 - Perform plank or pushup
 - Return to starting position
- Third position
 - Same as previous progression, but on one leg
 - Perform plank or pushup
 - Return to starting position