ORIGINAL RESEARCH

THE EFFECT OF PILATES EXERCISE ON TRUNK AND POSTURAL STABILITY AND THROWING VELOCITY IN COLLEGE BASEBALL PITCHERS: SINGLE SUBJECT DESIGN

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ABSTRACT

Background. Baseball pitchers need trunk strength to maximize performance. The Pilates method of exercise is gaining popularity throughout the country as a fitness and rehabilitation method of exercise. However, very few studies exist that examine the effects of the Pilates method of exercise on trunk strength or performance.

Objectives. Using a single subject, multiple baseline across subjects design, this study examines the effects of the Pilates method of exercise on performance of double leg lowering, star excursion balance test, and throwing velocity in college-aged baseball pitchers.

Methods. A convenience sample of three college baseball pitchers served as the subjects for this single subject design study. For each subject, double leg lowering, star excursion balance test, and throwing speed were measured prior to the introduction of the intervention. When baseline test values showed consistent performance, the intervention was introduced to one subject at a time. Intervention was introduced to the other subjects over a period of 4 weeks as they also demonstrated consistent performance on the baseline tests. Intervention was continued with periodic tests for the remainder of the 10 week trial.

Results. Each subject improved in performance on double leg lowering (increased 24.43-32.7%) and star excursion balance test (increased 4.63-17.84%) after introduction of the intervention. Throwing speed improved in two of the three subjects (up to 5.61%).

Discussion and Conclusions. The Pilates method of exercise may contribute to improved performance in double leg lowering, star excursion balance tests, and throwing speed in college baseball pitchers.

Key Words: trunk strength, throwing speed, core stability

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INTRODUCTION

Previous studies have demonstrated that proximal stability and strength of the abdominal and spinal muscles of the trunk are important in performance of many functions.[1-3] Rehabilitation and fitness specialists use a variety of combinations of exercises to address these muscles. A combination of mobility and stability is required by active people for optimal functional performance and for correction of poor posture, muscle imbalances, and poor biomechanics.[2]

This concept of trunk mobility and stability contributing to improved performance is being used in training and rehabilitating athletes today. In baseball, proximal strength through the scapular and pelvic girdles and the trunk coupled with appropriate mobility is important in reaching optimum performance levels in pitching and throwing.[4] Pitching a baseball is a total body activity that requires a coordinated sequence of movements involving upper and lower extremities and the trunk. This coordinated sequence involves dynamic balance as the pitcher alternately shifts weight from both feet to one foot, then sets the trunk, rotates and extends the arm, as he uses his strength, stability, and mobility to result in a highly skilled activity.[5] Tests of trunk strength and dynamic stability in this population may provide evidence for the contributions these characteristics may have on throwing velocity.

Several methods have been developed to address trunk stability and mobility issues in various populations. Among these methods is a static to dynamic muscular re-education approach founded in the Pilates tradition.[2,6] Joseph Pilates described his method of exercise as a "set of healthful lifestyle changes and corrective exercises." This method has become popular with a wide variety of athletes and people seeking fitness and rehabilitation[7] A key to successful use of the Pilates method of exercise lies in learning the proper way to activate abdominal and spinal muscles to maintain correct positioning while moving other segments of the body. Activation of trunk stabilizers in a variety of positions is believed to be a key in promoting more efficient performance of recreational and sport activities and activities of daily living. This trunk stabilization is the basis for many trunk stability programs because both upper and lower extremity muscles have proximal anchors at the shoulder and pelvic girdles, respectively.[2,3,6,8-10]

According to advocates, the Pilates method of exercise uses the concept of maintenance of the normal lumbar lordotic curve, called the neutral spine, coupled with movement of the lower and upper extremities to simultaneously enhance mobility through improved flexibility and proximal stability. However, only a few studies with dancers have been performed that demonstrate a positive impact of Pilates style exercises on function and posture.[6,11] Although the concepts and techniques utilized in this exercise approach appear to have application to other activities such as baseball, no studies exist to validate its use in this population. Based on the knowledge of the complex process used in pitching a baseball, it may be expected that a Pilates method exercise program will improve performance in baseball pitchers. For this reason, a need exist for controlled experimental trials to verify the effectiveness of this method in this population.

Studies have demonstrated that improved trunk stability may have a significant, positive impact on function and performance of activities.[12-14] Improved trunk muscle activity also has also been shown to have a positive effect on people with chronic back pain.[14,15] Since Pilates style exercises have been shown to result in increased activity and performance of the deep abdominal and spinal muscles,[2,6,7,14] a pilot study utilizing a single subject design with a population of baseball pitchers was developed to study the effects of a Pilates exercise intervention on three outcomes related to pitching a baseball: abdominal muscle strength, dynamic stability in single leg stance, and baseball throwing velocity.

As early as 1976, researchers have reported the procedures for single subject design studies and analysis of data in rehabilitation research.[16,17] Later, Zahn and Ottenbacher[18] and Fetko et al[19] further described how the single subject design can be effectively used in disability and rehabilitation research. The basic methodology sequence in single subject design allows each subject to be his own control. Baseline data is collected prior to introduction of the intervention to establish a stable performance level. This stable level helps account for a learning effect common with the introduction of a set of tests to a group of subjects. In a repeated measures design, the intervention is introduced to only one subject at a time. The other subjects continue testing to demonstrate maintenance of their baseline performance. The results of the study are strengthened by observing improvement in the subjects' performance only after introduction of the intervention.[2,18,19]

The purpose of this study was to examine the effects of the Pilates method of exercise targeting the deep abdominal and spinal muscles on a trunk strength test (double leg lowering), a single leg dynamic stability test (star excursion balance test), and throwing velocity in collegiate baseball pitchers.

METHODS

Subjects

Three subjects (ages 18-20 years) were recruited from a convenience sample of fit, healthy college baseball pitchers. Two subjects were second year players and one was a first year player. Two were right handed and one left handed. Subjects were excluded if there was a history of injury to the throwing arm, back, or lower extremities in the past year.

Each subject was given a written description of the study and signed an informed consent form in compliance with the Institutional Review Board (IRB) of the University of Kentucky. The rights of all human subjects were protected via the IRB oversight. Subjects were tested and the Pilates exercise program was completed in the Musculoskeletal Research Laboratory of the College of Health Sciences at the University of Kentucky.

Materials/Equipment

The Pilates method exercises were taught and performed on exercise mats and tables in the research area. No other equipment was required for this intervention.

A Chattanooga (Hixson, TN) High Low Therapy table was used for the double leg-lowering (DLL) test. A Stabilizer Unit (Chattanooga Group, Hixson, TN) was used to determine the ability of the subjects to hold the proper pelvic position. A large wall-mounted goniometer was used to measure the angle of hip flexion that corresponded to the loss of pelvic stability. A Bushnell Speedster Radar Gun (Bushnell Performance Optics, Overland Park, KS) was used to assess throwing speed and the throwing target was a large, strike zone sized piece of vinyl hanging within a portable throwing net. The radar gun measures the speed of a moving baseball at a distance up to 75 feet with an accuracy of +/- 1 mph.[20]

Procedures

To avoid threats to internal validity inherent in testing during baseball season, subjects were recruited during the off-season (fall semester) and were allowed to continue off-season conditioning. The off-season conditioning program consisted of running, weight lifting, and a long toss throwing program. These activities were performed by the subjects on an informal schedule and were not under the supervision of a coach or athletic trainer. Subjects, coaches, and athletic trainers were asked to avoid introducing new exercises during the study. Subjects reported compliance with this request throughout the course of the study.

The principal investigator collected baseline data prior to the introduction of the intervention. The double limb lowering (DLL), star excursion balance test (SEBT), and throwing speed data were collected three times per week until a subject reached a stable baseline in one of the dependent variable tests. The testing order was constant for each subject. Warm-up was done outside the building and throwing velocity was tested within 5 minutes of warm-up (subjects went directly from the warm-up to the throwing speed test to avoid cooling off). The DLL was tested followed by SEBT, as neither was expected to influence the other.

The DLL test was performed following the procedure outlined by Kendall et al[21] and the use of the Stabilizer was modeled after the procedure described by Hagins et al.[12] Subjects lay supine on the therapy table in a hooklying position with the greater trochanter aligned with the central axis of the wall-mounted goniometer *(Figure 1)*. Each subject was instructed to perform the abdominal hollowing maneuver used to stabilize the pelvis with the back in a neutral position. After each subject exhibited proficiency in the stabilization maneuver, the Stabilizer was placed between the subject's lumbar spine and the table while maintaining a neutral spine position. This neutral spine position was operationally defined as the position in which the subject felt a slight space between the table and the most lordotic point in the lumbar spine. The tester

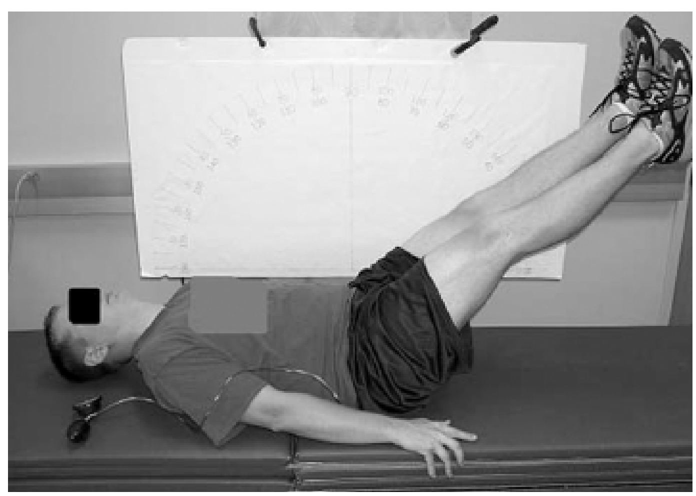


Figure 1. Performance of the double leg lowering test using the Stabilizer and wall goniometer. Subjects started with hips at 90° and knees fully extended and lowered the legs until pressure in the Stabilizer measured less than 40 mm Hg.

visually observed the subject's anterior superior iliac spines to be in the same plane as the pubic symphysis. The pressure gauge of the Stabilizer was increased to 40 mm Hg in this position. The examiner lifted the subject's legs to a position of 90 degrees of hip flexion with the knees fully extended. Each subject was able to maintain this test position of hips at 90 degrees with the knees extended so specific unilateral hamstring flexibility was not measured. The subject was asked to hold this position by performing the abdominal hollowing maneuver and to lower the legs toward the table. At the point when the stabilizer pressure dropped below 40 mm Hg, it was determined the subject was no longer able to maintain the neutral spine position and the examiner recorded the hip flexion angle in degrees. Subjects were given three trials with the average of the trials recorded.

The SEBT has been described and demonstrated to be of moderate to high reliability based on Intraclass Correlation Coefficient (ICC) ranging from .67-.87.[22] The test was performed as described by Kinzey and Armstrong.[22] A box, 2 feet square, was outlined with the center line marked by perpendicular lines that formed 45 degree angles from the horizontal in each of four directions (right-anterior, left-anterior, right-posterior, left-posterior). Each subject stood in the center on one leg and reached forward and back along the marked lines with the other leg as far as possible while maintaining balance. Subjects were allowed to lightly tap the floor to establish the point of the reach *(Figure 2)*. This distance was marked by the examiner and later measured with a tape measure in centimeters. Each subject was allowed six practice motions in each direction to control for a learning effect, and three trials in each direction were recorded and averaged.[22,23] This procedure was repeated with both legs.

Throwing velocity was measured after each subject had warmed-up in his usual manner. After warm-up, the subject was positioned 30 feet from a net and instructed to throw as hard as possible into the net at the strike zone target. Accuracy was not assessed in this study. The target was used as a focus point for the subjects. Three trials were recorded and averaged and speed was documented in miles per hour.[24]

The baseline data were collected by the principal author based on the subject availability. Data were graphed and a 2 standard deviation line was established after the first three testing periods by using the Microsoft Excel graphing function. The principal author also used visual inspection of the data points on the graphs of performance to determine baseline performance. If the data

Figure 2. Photo of performance of the star excursion balance test reaching in the right anterior direction. Subjects placed the stance foot in the center of the star and reached in the diagonal directions to the right and left.

points showed a level or decreasing performance and were within the 2 standard deviation line, baseline performance was determined to be stable. Subject 1 exhibited a decrease in performance during baseline within the 2 standard deviation line in throwing speed first and was introduced to the intervention on day seven at the start of week three. After the intervention was started on Subject 1, weekly testing began for all subjects. Subject 2 demonstrated maintenance of a stable baseline through three weeks of testing and was scheduled to start on the intervention in week four. A scheduling conflict pushed his intervention start back to day 13 at the beginning of week five. Beginning the following week, subject 3 had established a stable baseline and began the intervention period on day 20 during week seven. Once the intervention was started, weekly, random day testing of all subjects continued throughout the 10 week study. All three subjects had one week in which testing could not be performed due to school schedule conflicts or illness.

A Pilates method of exercise mat program was taught to the subjects and supervised by a physical therapist who was also a Pilates Certified Instructor (second author). Subjects were scheduled to attend sessions supervised by the physical therapist 2-3 times per week dependent on their availability. Each activity was performed for 5-10 repetitions each and each session lasted 30-40 minutes. Repetitions were based on the quality of performance as observed by the instructor. As quality of performance decreased, the activity was changed to facilitate the concept of high quality over quantity. The exercise instructor advanced each subject weekly according to the program outlined in Table 1. See Appendix A for the descriptions of each exercise.

Data Analysis

Data were analyzed in a variety of ways. Reliability of the measurements of throwing speed and double leg lowering was assessed by correlating the second and third baseline testing data. Test- retest reliability of the throwing speed data points was reliable with an Intraclass Correlation Coefficient (ICC) of 0.90 and a standard error of measure (SEM) of 1.48. Likewise, test-retest reliability of the double leg lowering procedure in the sample population was reliable with an ICC of .95 and a SEM of 2.52.

Table 1. Outline of Pilates exercise program intervention

Week One
1. warm-ups (choose 2-3 from among the following each week: ribcage breathing, pelvic rocking, knee folds, knee sways, upper body curl)
2. single leg stretch
3. double leg stretch
4. rolling
5. side kick: front/back
6. side kick: small circles
7. neck roll
8. pull straps 1
9. rolling down

Week Two
1. warm-ups
2. single leg stretch
3. double leg stretch
4. roll up
5. hundred
6. rolling
7. side kick: front/back
8. side kick: small circles
9. spine twist
10. spine stretch forward
11. pull straps 1
12. pull straps 2
13. rolling down

Week Three
1. warm-ups
2. single leg stretch
3. double leg stretch
4. criss cross
5. roll up
6. hundred
7. side kick: small circles
8. side kick: hot potato
9. spine twist
10. spine stretch forward
11. rowing 3
12. rowing 4
13. single leg kick
14. pull straps1
15. pull straps 2
16. rolling down

Week Four
1. warm-ups
2. single leg stretch
3. double leg stretch
4. single straight leg
5. criss cross
6. roll up
7. hundred
8. side kick: small circles
9. side kick: hot potato
10. spine twist
11. rowing 3
12. rowing 4
13. swimming
14. leg pull back
15. leg pull front
16. mermaid (modification)
17. teaser 1
18. rolling down

Week Five
1. warm-ups
2. single leg stretch
3. double leg stretch
4. criss cross
5. roll up
6. rolling
7. side kick: front/back
8. side kick: small circles
9. spine twist
10. saw
11. rowing 3
12. rowing 4
13. pull straps 1
14. pull straps 2
15. swan
16. teaser
17. twist
18. leg pull front
19. rolling down

Week Six
1. warm-ups
2. single leg stretch
3. double leg stretch
4. criss cross
5. single straight leg
6. roll up
7. rolling
8. side kick: front/back
9. side kick: small circles
10. spine twist
11. rowing 3
12. rowing 4
13. pull straps 1
14. pull straps 2
15. swimming
16. teaser 1
17. leg pull back
18. leg pull front
19. mermaid
20. rolling down

In addition to reporting the reliability of the dependent variable tests noted above, the two-member study team collected procedural reliability data on the delivery of the exercise program and the dependent variable data collection. The independent and dependent variable reliability was analyzed using the point to point method described by Fetko et al[19] and illustrated by the following formulas (≥90% agreement is considered acceptable reliability in single subject design studies).[25]

Independent Variable reliability = (# of procedures observed / # of procedures planned) X 100.
Dependent Variable reliability = (# of agreements / # of agreements + # of disagreements) X 100.

The principal author collected independent variable reliability data during 11 of the 32 training sessions to assure the physical therapist followed the procedure outlined. Of the 183 planned exercises, 94% were observed. The Pilates instructor observed and recorded measurements during seven of the 26 data collection periods to determine if the data were collected accurately. The two investigators agreed on the subjects' observed performance 100% of the time.

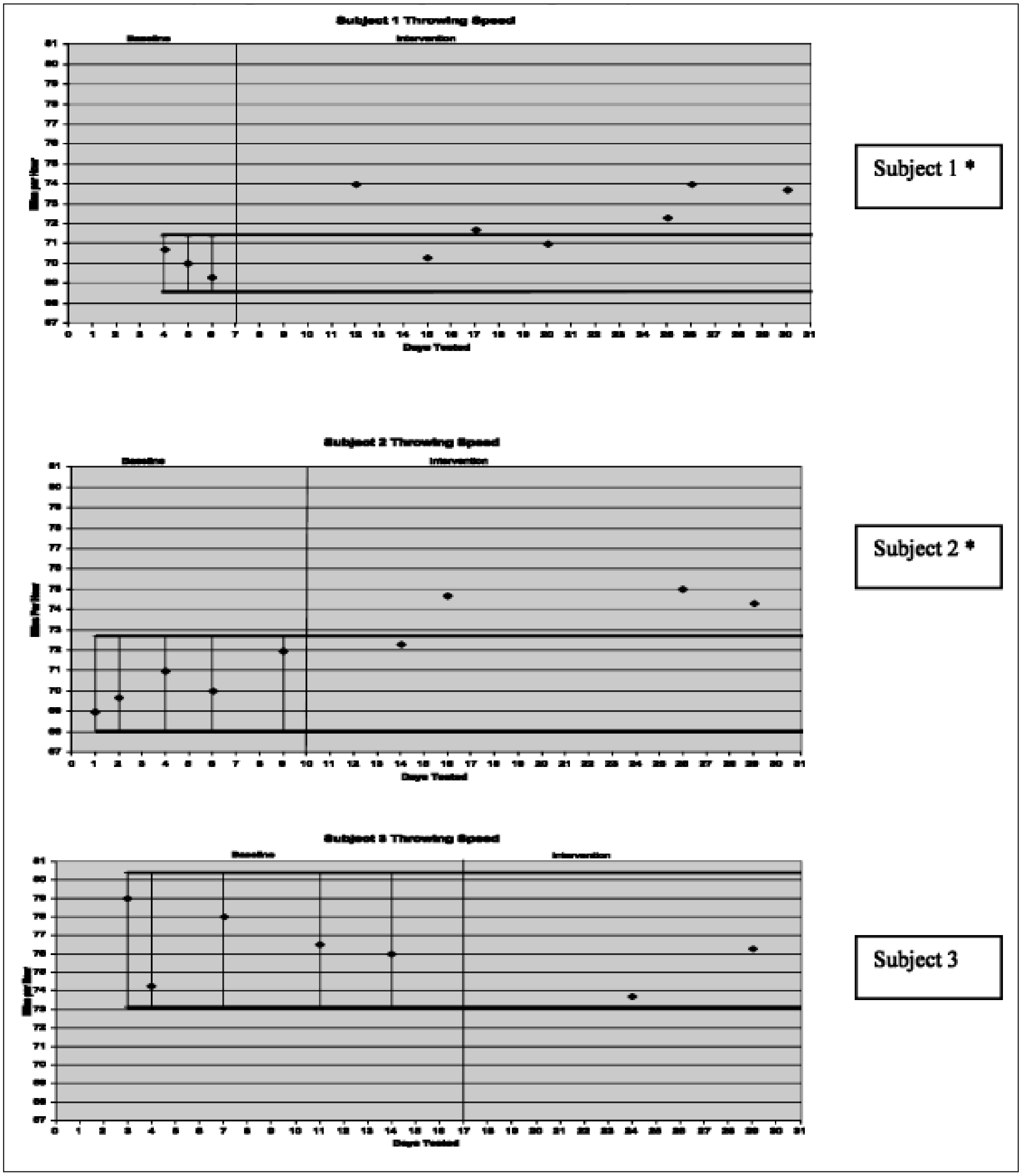
All data were ultimately analyzed by the principal author. Table 2 outlines the numerical changes in performance throughout the study. Baseline means and standard deviations were calculated for each dependent variable and post-intervention data is bold. Figures 3-5 graphically

Table 2. Data collected on each subject at each individual test session. Double leg lowering (DLL) is measured in degrees. Star Excursion Balance Test (SEBT) is measured in centimeters. Throwing (speed) is measured in miles per hour. Each reported test score is an average of three trials in a test session. Bold figures represent data collected after intervention had been introduced. In DLL, lower scores represent improved performance.

DLL(degrees)	**Test**								
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Subject									
1	65	68.3	63.3	**45**	**48.3**	**41.7**	**43.3**	**45**	**41.7**
2	71.67	73.3	81.7	71.7	75	**63.3**	**53.3**	**60**	**48.3**
3	55	53.3	56.7	65	56.7	**50**	**43.3**	**36.7**	
SEBT (cm)									
Subject 1									
RA	99.4	102.1	10.8	**99.5**	**100.1**	**103.5**	**109.1**	**111.7**	**111.5**
RP	112.3	112.9	108.3	**112**	**110**	**117.3**	**119**	**118.1**	**121.5**
LA	95.2	102.4	102.4	**104.9**	**104.3**	**107.3**	**107.5**	**111.3**	**109.9**
LP	110	115.2	106.9	**109.8**	**109.9**	**115.5**	**119.3**	**121.1**	**121.2**
Subject 2									
RA	81	86.7	91.57	89.1	87.8	**96.5**	**105.1**	**106.8**	**102.8**
RP	88	89.2	102.5	102.2	101.6	**104.6**	**113.3**	**115.7**	**113.6**
LA	85.4	95.9	95	93.4	93.1	**100.8**	**109.8**	**109.9**	**106.4**
LP	90	99.9	101	102.8	105.8	**107.3**	**116.9**	**115**	**121.1**
Subject 3									
RA	101.2	107.6	104.8	104.3	110.7	**118.7**	**119**	**117.5**	
RP	102.3	109.8	116.6	121.6	120	**121.7**	**125.5**	**123.2**	
LA	114	106.7	109.7	115.3	113.7	**118.5**	**121.2**	**117**	
LP	110.8	118.9	111.6	118.7	118.4	**123.8**	**122.5**	**129.4**	
Speed (mph)									
Subject									
1	70.7	70	69.3	**74**	**70.3**	**71**	**72.3**	**74**	**73.7**
2	69	69.7	71	70	72	**72.3**	**74.7**	**75**	**74.3**
3	79	74.3	78	76.5	76		**73.7**	**76.3**	

RA= Right Anterior
RP= Right Posterior
LA=Left Anterior
LP= Left Posteror

Figure 3. Graph of three subjects' performance on the throwing velocity test. Measured in mph. Black horizontal lines mark 2-standard deviatons from baseline mean. (* Improvement is significant at $p < 0.05$)



illustrate the subjects' performance on each dependent variable. Baseline data is separated from the data collected during the intervention in the graphs by a vertical line. Visual inspection of the graphs was used in conjunction with the two standard deviation band method of analysis described by Ottenbacher.[25] A two standard deviation line above and below the calculated means were marked on each graph. According to this method, if over half of the data points in the intervention period fall above or below these lines, the difference during the intervention phase is significant at the $p < 0.05$ level.

Upon initially graphing the SEBT data, it was noted that the graphs in each of four directions made the graphs unusually complex. Pearson product moment correlation analysis of the SEBT data between the right and left legs demonstrated high correlations for the majority of the trials (r = 0.77- 0.88). Since the correlations were high, the data for left and right reach in the SEBT for each subject were collapsed into one graph for clarity of graphic display.

RESULTS

The three subjects recruited completed each phase of the study from baseline through the complete 10-week period, but were unable to attend every exercise session planned. Subject 1 was originally scheduled to attend 16-24 sessions and attended 12. Subject 2 was scheduled to attend 14-21 sessions and attended 14. Subject 3 was scheduled to attend 9-12 sessions and attended 6. All data were analyzed by the principal author. Table 2 outlines the numerical changes in performance throughout the study and Figures 3-5 graphically illustrate the subjects' performance on each dependent variable.

Improvement in performance during intervention is noted for each subject in each outcome variable. Subject 1 demonstrated improvement in the SEBT posterior reach in four of seven data points during the intervention. However, only three of these points fell above the 2 standard deviation band so the improvement was not considered significant at the level of $p < 0.05$. Subject 3's performances in the SEBT posterior reach showed improvement in all data points collected, but the changes were also below the 2 standard deviation band. Throwing speed data for subject 3 during the intervention phase fell between the 2 standard deviation band lines and were considered insignificant. All other changes observed were significant at the $p < 0.05$ level.

Figure 4. Graph of three subjects' performance on the double leg-lowering test, measured in degrees. Black horizontal lines mark 2-standard deviatons from baseline mean. (* Improvement is significant at $p < 0.05$) Improvement is notred by lower number of degrees.

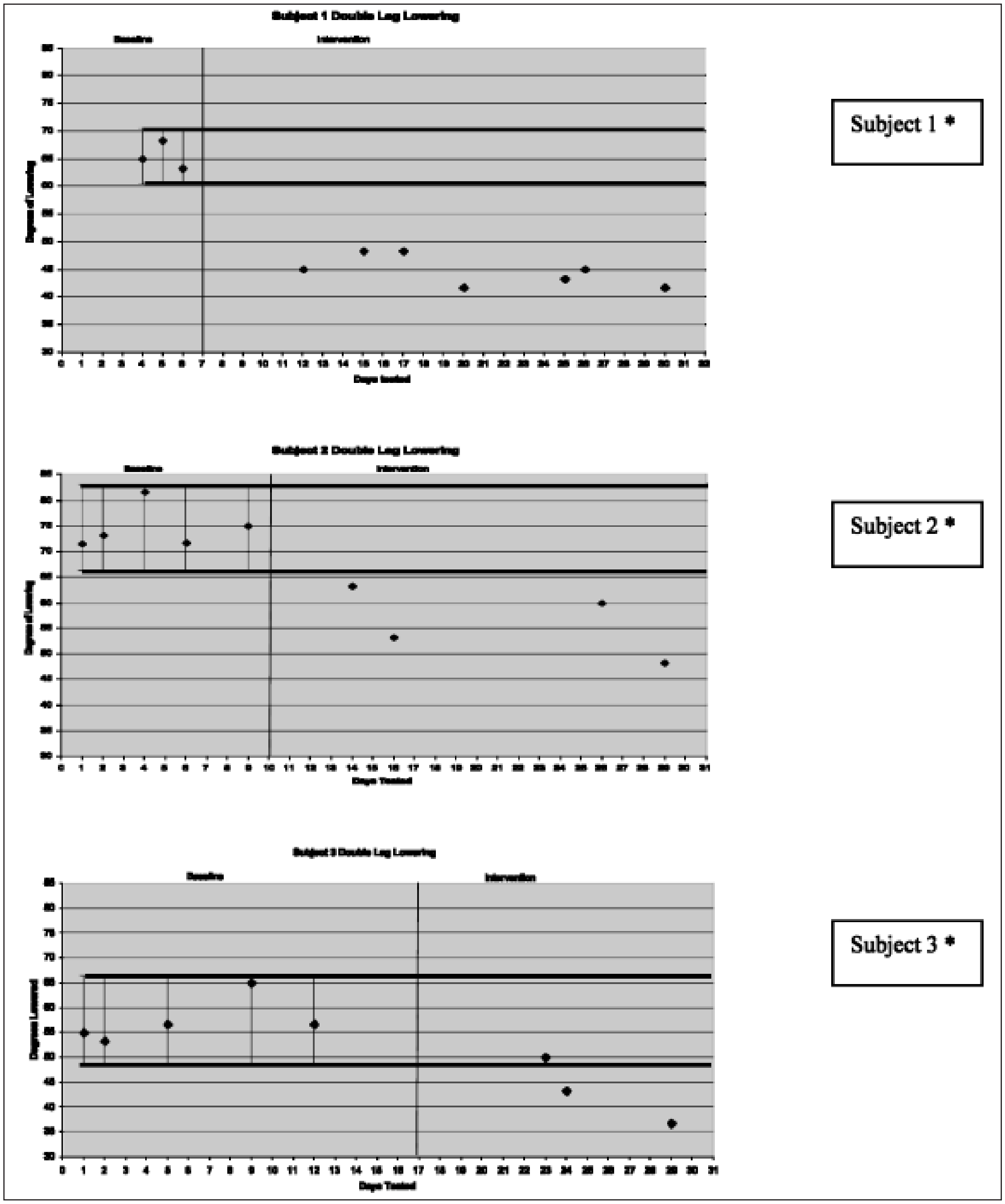


Table 2 displays the numerical values of the data collected during each test session. Table 3 displays pre-intervention and post-intervention change data. The average of all data collected during baseline testing was compared to the average of the data collected after introduction of the intervention. The percent change is noted. The largest percent change is noted in the DLL test with a range from 24.43-32.6%. Improvement in the SEBT ranged from 4.63-17.84%. Throwing speed improvements ranged from -2.29-5.3%.

DISCUSSION

The dependent variables in this study were chosen to address outcomes related to the specific foundation strength of the targeted muscles (DLL), a single leg dynamic stability activity related to function in this population (SEBT), and the specific outcome of throwing speed that is important to performance in baseball. Each dependent variable shows significant improvement in the subjects' performances after the intervention was introduced with the exception of subject 3's throwing

Table 3. Table of percent change from baseline averages to average of performance after intervention was introduced.

	Subject 1	Subject 2	Subject 3
Double Leg Lowering avg pretest	65.53	74.67	57.304
Double Leg Lowering avg posttest	44.17	56.23	43.33
DLL % change	**32.60**	**24.71**	**24.43**
SEBT reach Left Anterior avg pretest	100.77	87.23	105.72
SEBT reach Left Anterior avg posttest	105.90	102.80	118.40
SEBT LA % change	**5.09**	**17.84**	**11.99**
SEBT reach Left Posterior avg pretest	111.17	96.70	114.06
SEBT reach Left Posterior avg posttest	116.32	111.80	123.48
SEBT LP % change	**4.63**	**15.65**	**8.25**
SEBT reach Right Anterior avg pretest	100.00	92.56	111.88
SEBT reach Right Anterior avg posttest	107.53	106.73	118.90
SEBT RA % change	**7.53**	**15.30**	**6.27**
SEBT reach Right Posterior avg pretest	110.70	99.90	115.68
SEBT reach Right Posterior avg posttest	116.13	115.08	125.23
SEBT RP % change	**4.91**	**16.39**	**8.26**
Throwing Speed avg pretest	70.00	70.34	76.76
Throwing Speed avg posttest	72.55	74.08	75.00
Throwing Speed % Change	**3.64**	**5.31**	**-2.29**

speed and SEBT posterior reach and subject 1's SEBT posterior reach. Positive changes occurred in the DLL test very early in the intervention in each subject. For all subjects this trend toward improvement stabilized or continued throughout the course of the study. The immediate improvement noted in this dependent variable may correspond to motor learning and improved motor control, as previously reported. [13]

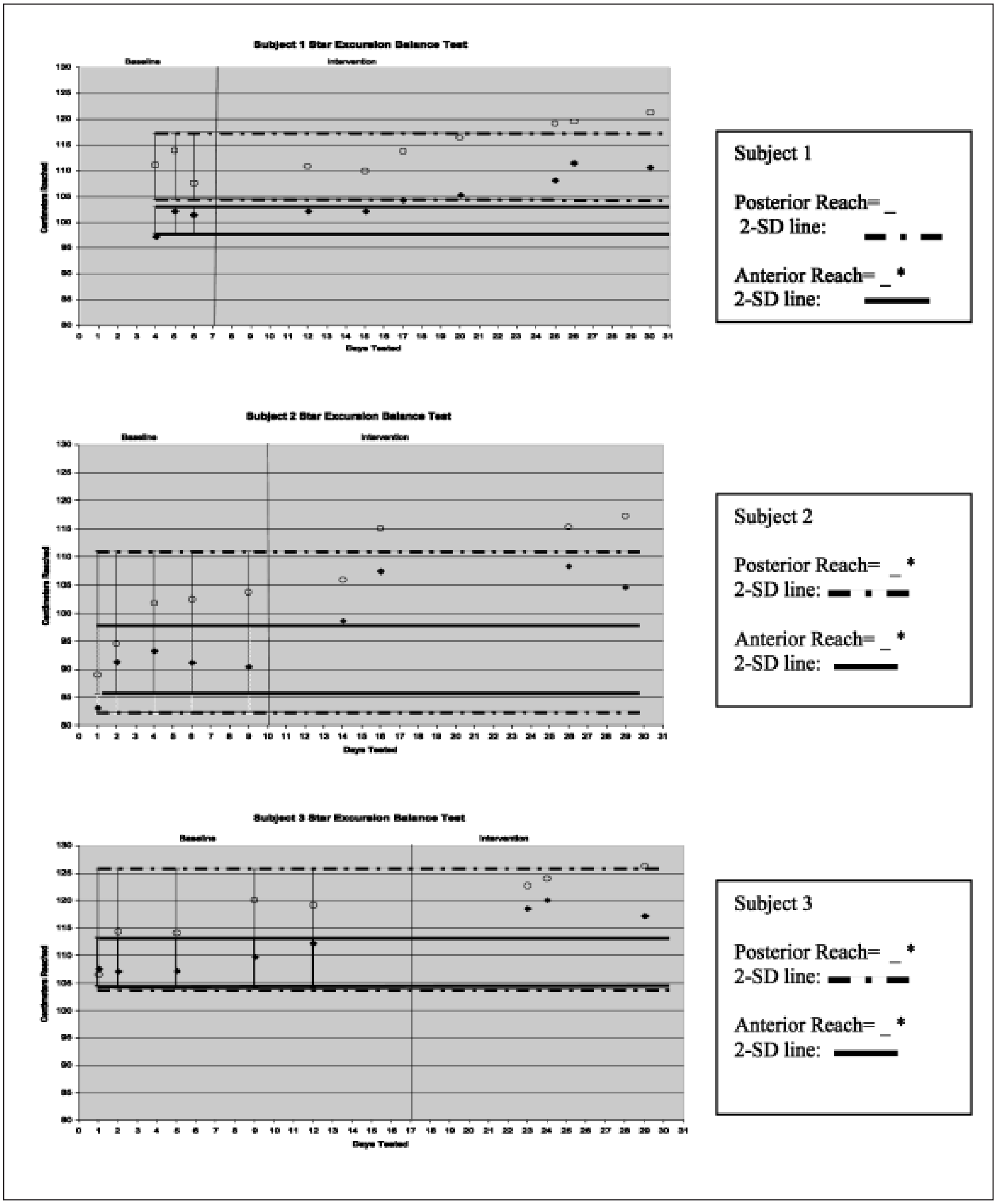
All subjects improved in the distance reached with the SEBT with the exception of posterior reach. It is interesting to note that subject 2 showed much greater improvement in all four directions than subject 1 or subject 3, but that all subjects demonstrated a gradual improvement in each direction over the course of the intervention. This finding may support the importance of proximal stability in functional lower extremity activities involving balancing on a single leg. In pitching, dynamic balancing on a single leg is a key component of the total body motion used.

Figure 3 depicts the differences measured in throwing velocity before and after the intervention. Possible reasons for these small differences include the many factors that contribute to increased throwing velocity and the fact that near maximal values such as throwing velocity in mature pitchers will demonstrate very small changes with interventions. However, a small change can be very significant at this level of competition.

Subjects 1 and 2 showed small, but statistically significant increases in their average throwing speed. Subject 3 showed a slight decrease in performance that was statistically insignificant. In all cases, the fall practice season had ended just prior to the start of the study. The first test of throwing speed was performed when the subjects had been throwing regularly in practice for 5-6 weeks and they considered themselves to be in good condition and form. When formal practice stopped, the subjects reduced their throwing practice to 1-2 times per week.

Even though their workouts did not consistently include throwing, when the Pilates intervention began, all subjects exhibited a gradual improvement in throwing speed. Subject 1 showed an initial spiked improvement and then returned to the baseline level. After this return to baseline, he gradually increased his throwing speed on

Figure 5. Graph of three subjects' performance on the star excursion balance test, measured in centimeters. Black horizontal lines mark 2-standard deviatons from baseline mean. (* Improvement is significant at $p < 0.05$) Right and left leg performance was combined for graph.



each subsequent test day. Subject 2 showed more marked improvement in the first 1-2 weeks after intervention, and was able to maintain this throughout the study. After an initial drop in performance that was a continuation of baseline testing, subject 3 began improvement after week 2 of his intervention period and gradually increased performance back near the average baseline level noted prior to the intervention. With the improvements noted after introducing the intervention, evidence appears to exist of a positive result regarding the outcomes measured.

Limitations do exist to this study. A small sample size, although adequate for a single subject design, limits the external validity of the study. Findings related to the study sample may confidently be applied only to this group. It is also unclear whether the positive results observed in the outcomes may have been even better had the subjects been able to attend all planned sessions.

Tester bias is a possibility, but unavoidable issue as well in this study. In future studies, this bias can be limited by having the tester be blinded to when or if subjects are receiving the intervention. A primary purpose of this single subject design study was to gather data that may illuminate the value of a Pilates method exercise program on outcomes relevant to baseball players and coaches. The principal author identified when subjects demonstrated stable baselines so they could begin the intervention. As each subject was his own control and the principal author knew when the intervention was started, blinding was not possible. Future studies should include control groups and more personnel to allow for blinding of the testers to the status of the subjects regarding the group to which they are assigned.

Some inconsistencies were also noted with the measurement of throwing speed. With a distance of only 30 feet, difficulty existed in focusing completely on ball speed without including arm movement. To control for this difficulty, additional repetitions of throwing were allowed until the investigator was able to obtain accurate ball speed readings.

Finally, although the exercise program was complete and addressed trunk mobility and stability as planned, a Pilates trained practitioner was required to implement the program. The need for a Pilates trainer practitioner could limit implementation of this type of exercise program in a typical baseball team setting. In addition, subjects may not comply with the program since it is a nontraditional exercise method for this population. However, each of the players reported compliance with the program and asked for a follow-up program to continue after the study was completed.

CONCLUSION

Visual and statistical analysis of the graphs and data demonstrates that the introduction of the Pilates method of exercise into an off-season baseball conditioning program had a positive and desired effect on performance in a trunk strength and stability test and a single leg balance test in all three subjects studied. Throwing velocity was also positively affected in two of the three subjects. The trunk stability and balance tests were chosen for their ease of performance in any clinical setting and because of their potential importance to throwing performance.

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Appendix A. Exercises used with position and description.

Exercise	Position	Description
ribcage breathing	Hooklying	Inhale letting ribs rise and expand, exhale encouraging ribs to descend and come together.
pelvic rocking	Hooklying	Inhale tilting pelvis into an anterior position, exhale tilting pelvis posteriorly.
knee folds	Hooklying	Inhale and exhale engaging the deep abdominals by connecting your navel to your spine. Raise one knee up toward the chest and back down to the floor while the deep abdominals are engaged.
knee sways	Hooklying	Feet off the floor, legs/knees hugging together. Inhale and let knees drop to one side, exhale return knees to center position.
upper body curl	Hooklying	Inhale and exhale lifting head, neck, and shoulders off floor, reaching toward feet with hands.
hundred	Lie on back, arms along sides, hips and knees flexed to 90º	Inhale for 5 counts, and exhale for 5 counts contracting the deep abdominals and encouraging the abdominals to hollow out during the exhales.
roll-up	Lie supine on mat, arms overhead, lower extremities extended	Inhale to prepare, exhale as you slowly roll up through spine to long sitting. Inhale and exhale as you roll down slowly articulating through the spine.
rolling	Seated, hip/knees flexed, hands "holding on" posterior knees, feet on mat	Back gently flexed to promote "c-shape" of spine. Inhale to prepare and exhale contacting the deep abdominals and rolling backward and returning to starting position.
single-leg stretch	One knee flexed with hands holding knee toward chest, other leg extended with 45º hip flexion	Inhale as you exchange legs and exhale as you arrive other side with opposite knee to chest and opposite leg extended. Optional head, neck, and shoulders off mat ("upper body curl").
double-leg stretch	Lower extremities flexed (knees to chest), hugging. One hand on each knee.	Inhale extending to 45º hip flexion; arms overhead. Exhale circling arms down close to mat, finishing with hands on flexed knees (original position).
single straight leg	Both legs extended; one leg close to floor, other leg extended hip flexion 90º or greater while holding on to leg with hands, arms extended.	Upper body curl. Inhale as you exchange legs and exhale as you arrive with opposite leg in hands emphasizing a navel to spine connection by drawing the lower abdominals inward.
side kick hot potato	Performed on mat on side	Legs in front of torso at approximately 45º angle. Top/working leg raised 6 inches. Inhale: Foot dorsiflexed as leg is kicked forward. Exhale: Foot plantarflexed as leg is kicked back beyond base leg on mat. Kick forward and back equals "one set."
side kick front/back	Performed on mat; patient lying on side	Working leg extended, foot dorsiflexed entire exercise. Keeping leg extended pulse leg and touch heel softly to mat five times behind base leg and five times in front of base leg. Inhale as you switch from back to front and exhale as you gently tap heel on floor.
side kick small circles	Performed on mat; patient lying on side	Working leg extended, foot dorsiflexed. Make small circles (size of soccer ball) counterclockwise and then clockwise. Alternate inhaling for two circles and exhaling for two circles.
spine stretch forward	Seated in "v-position" (legs extended, feet dorsiflexed, legs in approximately 30º abduction.) Arms extended, abducted 90º	Inhale to prepare, exhale as arms reach forward, spine flexes above waist and deep abdominals hollow out. Return to original position.

Exercise	Position	Description
spine twist	Seated in v-position. Arms extended, abducted 90º	Inhale as arms and torso are rotated to one side. Exhale return to center.
saw	Seated in v-position. Arms extended, abducted 90º.	Inhale as you rotate arms and torso to one side. Exhale as you reach toward lateral side of foot with opposite hand. Inhale as you recover from position and rotate to other side.
swan	Lying prone, legs extended, arms flexed	Inhale for preparation, exhale extending arms and back keeping pelvis on floor.
neck roll	Lying prone, legs extended, arms flexed, hands adjacent to shoulders, back extended	Rotate head to the right. Flex cervical spine as you rotate to the left. Remain back extension for entire exercise keeping lower abdominals engaged toward spine.
pull straps 1	Prone	Arms extended, shoulders flexed forward off mat. Inhale and extend shoulders as hands reaching toward toes.
pull straps 2	Prone	Arms extended, shoulders abducted out to sides off mat. Inhale extending shoulders, reaching toward toes.
single-leg kick	Prone, propped in extension on forearms, hands clasped.	Legs extended. Inhale and kick one foot twice toward buttocks. Exhale, kick other leg towards buttocks. Opposite leg extended while working leg kicks.
swimming	Prone	Lift opposite arm and leg off floor. Head and chest come off floor too. Alternate "kicking" legs and arms continuously as if swimming. Inhale for 5 counts and exhale for 5 counts.
teaser	Supine	Legs extended, arms along sides. Inhale for preparation, exhale as you lift legs off mat to 45° of hip flexion while torso lifts off floor and arms reach forward toward legs. Body is in a v-position; balancing
rowing 3	Seated. Legs extended in front, hugging. Arms along sides, elbows flexed, palms facing downward	Inhale as you extend arms forward at 45° angle, exhale lower arms in front of body until tips of fingers touch mat, inhale raising arms overhead, exhale arms open up and out to sides - 90° abduction.
rowing 4	Seated. Legs extended in front, hugging. Arms by sides	Inhale and exhale as you engage lower abdominals; roll through spine as you flex torso and reach arms toward toes. Inhale rolling back up through spine and reach arms high to ceiling, finishing with arms opening out to sides and 90° abduction.
criss-cross	Supine	One knee flexed to chest, other leg extended with 45° hip flexion. Upper body curled to lift shoulders off floor. Hands behind head. Inhale as you rotate to one side and exhale as opposite elbow and knee touch.
leg pull back	Push-up position, hand and wrists under shoulders	Inhale lifting and extending right leg, allowing weight to shift backward and stretching the supporting heel cord.
leg pull front	Sitting position, legs extended in front, hands by hips. Lift pelvis in a front "plank" position	Keep chin tucked to chest gently. Inhale and kick one leg up to ceiling, foot plantar flexed. Exhale, dorsiflex foot and return to mat with foot.
mermaid	Seated position, legs flexed and tucked into right side. Right hand holds onto ankles. Extend left arm to ceiling	Inhale stretching up high and laterally flex to the right as you exhale engaging the deep abdominals. Inhale as you recover and bring left forearm down to mat. Right arms extends and reaches overhead as you laterally flex to the left.
rolling down	Standing, feet shoulder-width apart	Inhale and exhale as you sequentially roll down through the spine. Let upper body and arms hang down as you keep the lower abdominals engaged. Inhale and exhale again as you sequentially roll up through the vertebrae back to the original standing position.