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CORE STRENGTH AND ITS RELATION TO STATIC AND DYNAMIC BALANCE

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ABSTRACT

Core Strength and its Relation to Static and Dynamic Balance

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Objective: Recent evidence has suggested that core stability is a determinant of lower-extremity musculoskeletal injury. However, studies have yet to examine if core stability influences postural control and functional performance in a healthy population. Therefore, the purpose of this study was to investigate the effects of core stability as measured by core endurance strength on measures of postural control via dynamic and static balance in a healthy college-age cohort. It was hypothesized that patients with greater core endurance strength would demonstrate heightened postural control.

Design and Setting: Controlled laboratory environment. **Subjects:** 32 (twenty-two women and 10 men) participants (age = 20.9 ± 0.8 years, height = 1.7 ± 0.09 m, mass = 65.1 ± 13.0 kg, BMI = 22.6 ± 2.6 and RPI = 42.2 ± 1.4) volunteered for this study. No participants presented with a history of previous low back injury, lower extremity injury or cerebral concussion within the preceding six months. **Main Outcome Measures:** Participants performed four timed isometric core muscle endurance tests (seated flexion, left and right lateral planks and the Biering-Sorensen back extension) for as long as possible. Participants were classified into strong and weak groups according to whether the flexion-to-extension ratio was greater than or less than unity ($P < 0.001$). A force plate recorded center of pressure data during a static single-leg balance task under eyes open and eyes closed conditions. Averaged maximum distances during a single-legged balance reach task were normalized to the non-stance leg-length (%LL). Averaged maximum distances during a single-legged hop were normalized to leg-length (%LL). Two-sample t-tests were calculated to analyze statistically significant differences between the strong and weak groups for each dependent variable of interest. A probability level of $P \leq 0.05$ was set a priori to denote statistical significance. **Results:** There was a statistically significant difference between groups for the flexion core endurance strength time (strong = 215.8 ± 79.5 s, weak = 104.14 ± 59.1 s, $P < 0.001$). Greater anterior reach distances were achieved by the strong group completing the single-legged balance reach task with the dominant (72.2 ± 3.5 %LL, $P = 0.040$) and non-dominant (69.8 ± 4.2 %LL, $P = 0.050$) legs compared to the weak group (dominant = 74.4 ± 4.8 %LL, non-dominant = 71.9 ± 3.7 %LL). Ironically, the weak group demonstrated a lesser path length compared to the strong group with eyes

closed ($81.7 \pm 16.6\text{cm}$, $P = 0.002$) on the non-dominant leg, eyes open ($36.6 \pm 7.6\text{cm}$, $P = 0.020$) and closed ($80.6 \pm 21.5\text{cm}$, $P = 0.020$) on the dominate leg. Average velocity was significantly slower in the weak group ($8.1 \pm 2.2\text{cm/s}$, $P = 0.020$) for eyes closed on the dominate leg. All other comparisons were not found to be statistically different ($P > 0.05$). **Conclusions:** Our study suggests that participants with increased flexion core endurance strength demonstrate a greater degree of dynamic balance during single-legged anterior reaches. It is also suggested that weak participants may adopt compensatory postural control mechanisms different than strong participants to maintain static balance. **Word Count:** 502

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CHAPTER 1: INTRODUCTION

Trunk, or core, stability is accomplished through a coordinated interaction between the passive (non-contractile) structures of the thoracolumbar spine and pelvis (disc, joints, ligaments, etc.) and the active (contractile) elements (musculotendinous structures) under the control of the nervous system in response to internal and external perturbations¹⁻². Moreover, core stability is essential for the “production, transfer, and control of force and motion to distal segments of the kinetic chain”³⁻⁴. While balance is a complex interaction of vestibular, visual, somatosensory, musculoskeletal and cognitive systems, it can be characterized as either static or dynamic⁵⁻⁶. Static postural control involves maintaining one’s center of mass over a fixed base of support. Dynamic postural control can be described as performance of purposeful movements in completion of a prescribed task without compromising a stable base of support⁷. These tasks usually involve displacing one’s center of mass toward the limits of stability outside the base of support^{5, 7}.

Automatic or pre-programmed reactions are functionally organized responses to perturbation that activate muscle to bring the center of mass back into a state of equilibrium. These reactions incorporate stereotypical but adaptable coordinated activation of leg and trunk muscles producing

movement around the ankle and hip to control posture. The postural control system of the body uses either an ankle strategy (movement around the ankle joint resembling an inverted pendulum) or a hip strategy (pike-type flexion and extension movements around the hip) to maintain postural equilibrium over a stable base⁸. Weakness in any of the muscles associated with these strategies could compromise postural stability. Postural control is seen as an essential factor in overall neuromuscular performance and injury prevention⁵. Most functional activities require coordinated movement through the entire kinetic chain. Oliver and colleagues⁹ suggest that improved core stability could lead to more efficient movement through the kinetic chain and ultimately decrease the kinetic chain deficits that result in injury or dysfunction. Core musculature activation is often anticipatory in nature, leading to the production of trunk stability prior to extremity movements in many athletic activities. Weakness or delayed activation of core muscles may lead to an unstable core platform upon which extremity movement can occur, resulting in trunk or extremity injury. Cholewicki et al¹⁰, has shown that delayed trunk muscle reflexes predicted low-back injuries in college athletes. In addition, Zazulak et. al², suggest that increased error in core proprioception is associated with risk of knee injury due to

altered valgus positioning, ligament strain and increased knee abduction and torque.

Trunk muscle isometric endurance tests are viewed as a functional measure of core strength¹¹⁻¹⁵. Furthermore, isometric endurance measurements have proven to be a reliable and valid method to assess trunk muscle strength¹⁴⁻¹⁸. Although evidence exists to demonstrate the relationship between core strength, lower-extremity function and injuries, little is known about the relationship between core strength and the performance of specific functional tasks. Therefore, it is the purpose of this paper to examine the relationship between core strength functional activities such as static and dynamic postural control as well as a hop task requiring muscular power. It was hypothesized that subjects with greater core muscle endurance would exhibit better performance in the balance and hopping tasks included in this study.

CHAPTER 2: METHODS

This research study was conducted in a controlled university laboratory setting and all data collection took place over an 8-week period.

Participants

Thirty-two (22 women and 10 men) participants (age = 20.9 ± 0.8 years, height = 1.7 ± 0.09 m, mass = 65.1 ± 13.0 kg, Body Mass Index (BMI) = 22.6 ± 2.6 and Rostral Pondral Index (RPI) = 42.2 ± 1.4) volunteered for this study. No participants had a history of previous cerebral concussion, or low back or lower extremity injury within the preceding six months. Patients who met all inclusion criteria and exclusion criteria (Table 1) were enrolled in this study.

Table 1. Inclusion and Exclusion Criteria

Inclusion: Must be able to answer “Yes” to these questions

- 1) Are you between the ages of 18-35?
- 3) Are you generally healthy (not overweight, non-smoker or non-consumer of nicotine products)?
- 4) Do you speak English?

As a general health screen, you must be able to answer “No” to the following questions

- 5) Have you had a history of musculoskeletal or neurological injury to the low-back or lower body within the last six months?
- 6) Do you have a history of low-back or lower body surgery?
- 7) Have you sustained a cerebral concussion within the last six months?
- 8) Do you have a history of physical rehabilitation within the last six months?
- 9) Do you have minimal to no significant low-back or lower body pain (0-1 pain on a 10-point scale)?
- 10) Have you had a history of diabetes or peripheral neuropathy?
- 11) Currently, do you have acute lower body joint swelling?

Participants were recruited from The Pennsylvania State University student population and each potential participant completed an informed consent demographic questionnaire, and a general health screen (Appendix A & C).

Outcome Measures

Biering-Sorensen Back Extension Test

The Biering-Sorensen Back Extension test required the participants to keep the unsupported upper part of the body (from the anterior superior iliac spine) parallel to the floor while placed prone with the ankles fixed to the table by a strap and the arms folded across the chest (Figure 1). The test was evaluated by measuring the seconds the participant could maintain the position and/or an individual reached a limit of tolerance of symptoms of fatigue¹⁹. Reliability studies conducted by Paalanne et al.¹⁵ and Latimer et al.²⁰ demonstrated Intraclass Correlation Coefficient (ICC) values for the test to be 0.93 and 0.83 respectively.

Figure 1: Biering-Sorensen Back Extension Test



Isometric Endurance Flexion Test

The Isometric Endurance Flexion Test is a reliable means to test trunk flexion strength (ICC = .87 & .92¹⁴⁻¹⁵). The participant was initially posed in a sit-up position with their back resting on a wedge angled at 60° from the floor²¹. While both knees and hips are flexed at 90° and arms are crossed against the chest, the wedge is pulled back 10cm and the individual begins the timed isometric test²¹ (Figure 2). The test concluded once a participant fatigued beyond comfort or their body fell below the 60° plane.

Figure 2: Isometric Core Endurance Flexion Test at 60°



Lateral Plank Endurance Test

The lateral plank test required the participants to lay on their sides with legs extended and their top foot placed in front of the lower foot. Hips are then lifted upward, off the mat to attain a straight line over their full body length, while supported with one elbow and both feet¹⁴ (Figures 3 & 4). The

unsupporting arm was held across the chest and the hand placed on opposite shoulder.

Figure 3: Left Lateral Plank



Figure 4: Right Lateral Plank

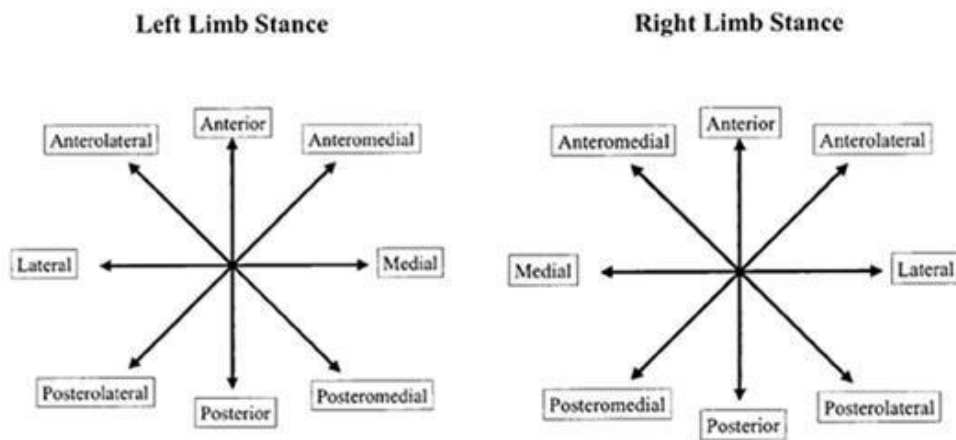


The test concluded when a participant fatigued beyond comfort or when the hips dropped below the straight line initially formed by the body. The test has been demonstrated to be a reliable measure of lateral trunk strength (right side bridge: ICC = .84 left side bridge: ICC = .99)¹⁴⁻¹⁵.

Star Excursion Balance Test

The test required participants to stand barefoot at the center of an 8-spoked grid taped on the floor with lines spaced 45° apart (Figure 5).

Figure 5: SEBT Directions



The participants were instructed to reach with their non-stance leg as far as possible in one of three directions (anterior, posteromedial and posterolateral) while keeping their hands on their hips (Figure 6, 7 & 8).

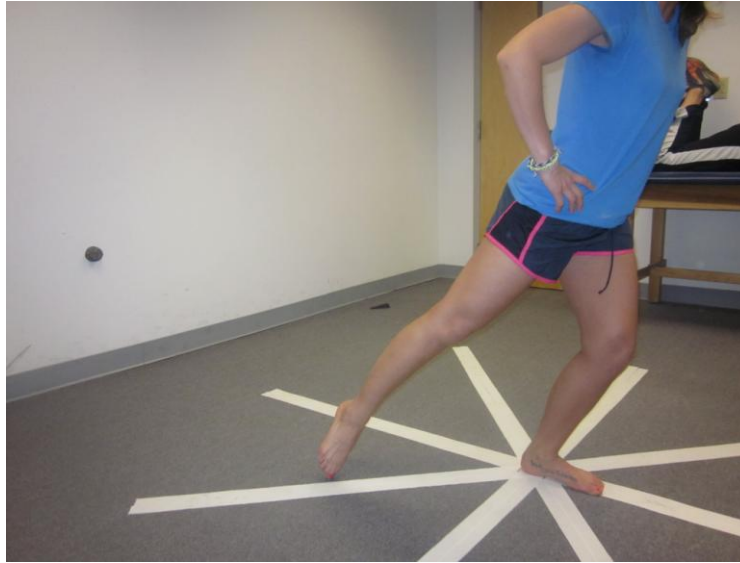
Figure 6: Anterior Single-Leg Balance Reach Task



Figure 7: Posteromedial Single-Leg Balance Reach Task



Figure 8: Posterolateral Single-Leg Balance Reach Task



Hertel et al, found significant correlations between these 3 reach directions and the remaining 5 directions²². Reducing the number of directions administered from 8 to 3 lines could be achieved without compromising validity of the test due to functional redundancy across all directions. The participants' toes were aligned with the horizontal line of the grid for the anterior reach and their heel was aligned with the horizontal line of the grid for the posterior reaches. At the maximal reach point the subject lightly touched the floor with a minimal transfer of body weight to the reach foot and then returned to the starting position^{5, 7, 23-24}. Trials where a loss of balance, removal of hands from the hips, or excessive transfer of weight to the reach foot occurred were not recorded. The maximal reach distance was

marked by the same examiner each time to produce accurate results.

Reliability of the Star Excursion Balance Test (SEBT) has been established ($ICC = 0.81 - 0.86$)²². This test proves to be a reliable measure to assess reach deficits in subjects ($ICC = 0.81 - 0.86$)²².

Single-Legged Balance

Participants were asked to stand bare foot on one leg in the center of a force plate with their hands placed on their hips and the non-stance leg bent at 90° adjacent to the stance leg without contacting any object or the other leg (Figure 9).

Figure 9: Center of Pressure Single Leg Balance Stance



Participants were instructed to stand as still as possible during the test^{17, 25}. The participants were asked to look straight ahead at an “X” on the wall in front of them and maintain this position for 10 seconds²⁶⁻²⁷. Trials were performed with the eyes opened and eyes closed. Center of pressure measures were recorded with the force plate (AMTI, Watertown, NY). The sensitivity and testing duration have been demonstrated in previous studies as reliable and repeatable²⁸⁻²⁹.

Single-Legged Hop

A strip of tape was placed along the floor in front of the subject. The subject was asked to hop as far as they could along the line, taking off and landing with the same foot (Figure 10 & 11)³⁰⁻³².

Figure 10: Single-Legged Hop Start Stance

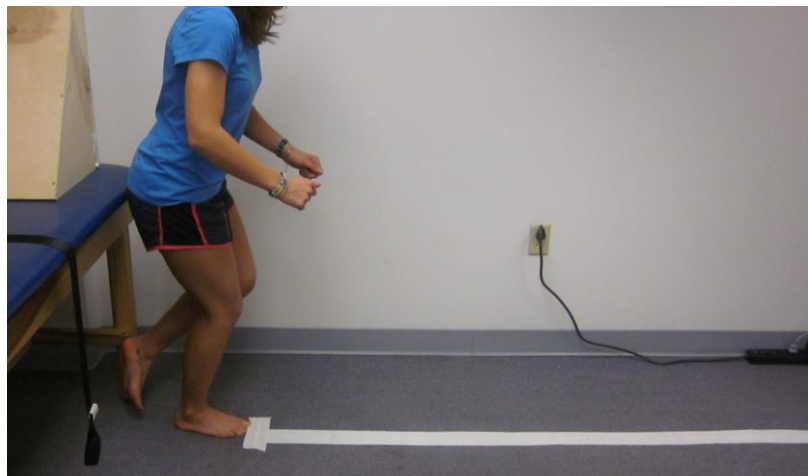


Figure 11: Single-Legged Hop Landing Stance



The distance of the hop was measured from the position of the toes of the hop leg at the beginning and end positions of the hop. The participants had to maintain a controlled stance position for 2 s at the end of the hop for it to be recorded. Distances were measured from the point of origin for the jump to the end of their toes once the participant completed a successful hop³². This test has been shown to be valid and reliable (ICC = 0.97)³⁰.

Procedures

After all appropriate consent forms were signed by both the participant and test administrator, anthropometric measures were taken including height, weight, and leg length. Leg length measures were recorded

by having the participant lay supine to allow for clearing of the hips, then measuring from the anterior superior iliac spine to the distal tip of the medial malleolus. Leg length measures were necessary to normalize reach distances of the SEBT test and jump distances of the single-legged hop test in order to compare distances among participants. BMI and RPI were calculated from the anthropometric data. Participants' leg dominance was verified by their leg used to kick a soccer ball. Randomizations for the sequence of reach directions, core endurance tests, as well as dominant and non-dominant legs were conducted to prevent order effects. Randomizations were completed using permutations generated by a statistical software program (Minitab, Inc., State College, PA). No verbal cues or encouragement were given to the participants during measurement of any test.

Each participant performed isometric core endurance tests first. For each test, participants were required to maintain each isometric position for as long as possible with proper form^{11, 14-15, 18, 33}. Proper form was demonstrated by the same examiner each time and these tests were performed on a cushioned table placed against one wall. Judgment of test form was evaluated by the same examiner for each participant and this examiner would determine the validity of each position in accordance with

literature. One trial of each test was performed with a five-minute break given between each test to prevent fatigue¹⁴.

Each participant was then asked to perform the single-leg quiet stance on the force plate. Six trials of the task were performed for each leg: 3 trials completed with eyes open and 3 trials completed with eyes closed for each participant. Each trial lasted 10 s with a 30 s break between trials. If a participant touched any object, or made contact with the weight-bearing limb with the opposite leg, or was unable to maintain posture, the test was terminated and repeated²⁵.

Participants were then asked to perform the SEBT test in the anterior, posteromedial and posterolateral directions. Participants were allotted 4 warm-up trials prior to testing^{5, 7}. Three trials were performed in each direction. A verbal and visual demonstration of the test was given to each participant prior to testing. Each trial was marked with a colored pen on the tape and trials were measured to the nearest millimeter using a standard tape measure, by the same examiner to avoid intertester variability. Reach distances were expressed as a percent of leg length (%LL) and calculated by dividing the reach distance (cm) by leg length (cm)⁵ then multiplying by 100. The three trials in each direction were averaged for data analysis. Breaks of 30 s were given between each reach with a 2 min break between each

direction²². Trials were discarded if the participant placed substantive support on the reaching leg as it touched the white tape, the hands moved from the hip, or if the supportive, stance leg moved from its original mark^{5, 24}. It was also instructed that the reaching leg return to its original start position, but the participant was able to lift the stance heel off the ground during the test.

Finally, participants were asked to perform the single-legged hop test. Unlike the SEBT and single-leg balance tests, participants did not have to keep their arms on their hips. Each participant was given one practice trial and then one test trial. Hop distance was measured to the nearest millimeter and marked with a colored pen by the same examiner each time. If the participant could not maintain a stable posture for 2 s at the end of the hop, they were reminded of the stipulations of the test and the trial was repeated. Participants were given 30 s between each hop^{30, 32}. Hop distances were expressed as a percent of leg length (%LL) and calculated by dividing the hop distance (cm) by leg length (cm) then multiplying by 100⁵.

Data Analysis

Participants were classified into strong (flexion-to-extension ratio > 1.00) and weak (flexion-to-extension ratio < 1.00) groups based upon their

flexion-to-extension ratio ($P < 0.001$). Two-sample t-tests were calculated to analyze statistically significant differences among groups for each dependent variable of interest. A probability level of $P \leq 0.05$ was set a priori to denote statistical significance.

CHAPTER 3: RESULTS

This research study was conducted in a controlled university laboratory setting and all data collection took place over an eight-week period.

Participant Demographics

There were no statistically significant differences between strong and weak group demographics (Table 2).

Table 2. Participant Demographics

	Strong Group	Weak Group	P-Value
Participants	18	14	
Sex (Men/Women)	6/12	4/10	
Age (years)	21.1 ± 0.8	20.6 ± 0.7	0.096
Height (m)	1.7 ± 0.1	1.7 ± 1.1	0.893
Mass (kg)	64.1 ± 14.5	66.3 ± 11.5	0.649
BMI (kg/m ²)	22.2 ± 2.8	23.2 ± 2.2	0.265
RPI (cm/kg ³)	42.5 ± 1.4	41.8 ± 1.3	0.144

An independent t-test was performed to insure no significant differences existed between the Strong and Weak Groups.

Values are Mean ± SD

Timed Isometric Core Endurance Measures

Core endurance ratios comparing the timed endurance tests were used as a means to filter participants into strong and weak groups.

Participants with a flexion-to-extension ratio greater than 1 were classified

as strong and ratios of less than 1 were classified as weak. There was a statistically significant difference in average flexion-to-extension ratios ($P < .001$) between the strong and weak groups (Table 3). No other ratio differences were observed between the strong and weak groups.

Table 3. Isometric Core Endurance Ratios

Direction	Strong Group	Weak Group	P-Value
Flexion to Extension	1.61 ± 0.36	0.69 ± 0.25	$<0.001^*$
Right to Left Plank	1.11 ± 0.27	0.95 ± 0.27	0.125
Left Plank to Extension	0.61 ± 0.23	0.60 ± 0.42	0.928
Right Plank to Extension	0.66 ± 0.26	0.57 ± 0.48	0.531

* Denotes statistical significance ($P \leq 0.05$).

Values are Mean \pm SD

Flexion endurance times were significantly greater in the strong group than the weak group (Table 4). Extension and plank endurance times were not significantly different between the strong and weak groups.

Table 4. Isometric Core Endurance Times

Direction	Strong Group	Weak Group	P-Value
Extension (s)	136.5 ± 49.8	139.3 ± 59.1	0.884
Flexion (s)	215.8 ± 79.5	104.0 ± 62.6	$<0.001^*$
Left Plank (s)	80.0 ± 36.4	66.0 ± 29.2	0.247
Right Plank (s)	84.2 ± 33.9	62.6 ± 31.5	0.075

* Denotes statistical significance ($P \leq 0.05$).

Values are mean \pm SD

Normalized SEBT Reach Distances (%LL)

The strong group achieved significantly greater normalized reach distances than the weak group for the anterior direction for both the dominant leg ($P = 0.040$) (Appendix D, Figure 1) and the non-dominant leg ($P = 0.050$) (Appendix D, Figure 2) (Table 5).

Table 5. Balance Reach Task Distance Measures

Direction	Strong Group	Weak Group	P-Value
<i>Dominant Leg</i>			
Anterior (% LL)	72.2 ± 3.5	69.8 ± 4.2	0.040*
Posteromedial (% LL)	75.2 ± 13.8	71.8 ± 8.2	0.208
Posterolateral (% LL)	83.3 ± 8.6	79.6 ± 6.7	0.098
<i>Non-Dominant Leg</i>			
Anterior (% LL)	74.4 ± 4.8	71.9 ± 3.7	0.050*
Posteromedial (% LL)	76.3 ± 11.5	72.9 ± 7.7	0.171
Posterolateral (% LL)	83.2 ± 8.3	80.5 ± 7.5	0.173

*Denotes statistical significance ($P \leq 0.05$).

Values are Mean ± SD

Center of Pressure Path Length and Average Velocity

The static single-legged balance task revealed several significant differences between the strong and weak groups. The weak group had a shorter COP path length than the strong group with the eyes open ($P = 0.020$) and the eyes closed conditions ($P = 0.020$) for the dominant leg. The weak group also had a shorter COP path length than the strong group with the eyes

closed ($P = 0.002$) for the non-dominant leg. These differences can be seen in Figures 3, 4, and 5 in Appendix D.

Table 6. Center of Pressure Path Lengths

Direction	Strong Group	Weak Group	P-Value
<i>Dominant Leg</i>			
Eyes Open (cm)	36.6 ± 7.6	31.5 ± 5.1	0.020*
Eyes Closed (cm)	80.6 ± 21.5	66.6 ± 12.8	0.020*
<i>Non-Dominant Leg</i>			
Eyes Open (cm)	37.1 ± 7.5	36.2 ± 10.7	0.395
Eyes Closed (cm)	81.7 ± 16.6	64.1 ± 15.3	0.002*

*Denotes statistical significance ($P \leq 0.05$).

Values are Mean \pm SD

A slower COP average path velocity was found in the weak group compared to the strong group in the eyes closed condition for the dominant ($P = 0.02$) leg (Appendix D, Figure 6).

Table 7. Center of Pressure Average Path Velocities

Direction	Strong Group	Weak Group	P-Value
<i>Dominant Leg</i>			
Eyes Open (cm)	4.2 ± 2.3	3.4 ± 0.7	0.113
Eyes Closed (cm)	8.1 ± 2.2	6.7 ± 1.3	0.020*
<i>Non-Dominant Leg</i>			
Eyes Open (cm)	3.7 ± 0.7	3.6 ± 1.1	0.460
Eyes Closed (cm)	8.2 ± 1.7	7.5 ± 4.0	0.260

*Denotes statistical significance ($P \leq 0.05$).

Values are Mean \pm SD

Normalized Single-Legged Hop Distances

No significant differences were found between the weak and strong groups with regard to normalized single-legged hop distances (Table 8).

Table 8. Single-Legged Hop Distance Measures

Direction	Strong Group	Weak Group	P-Value
Dominant Leg (% LL)	104.8 ± 28.5	105.4 ± 22.7	0.477
Non-Dominant Leg (% LL)	108.8 ± 26.1	104.7 ± 23.8	0.322

Values are mean ± SD

CHAPTER 4: DISCUSSION

In this study, strong and weak groups were created in accordance with a pre-determined ratio of flexion-to-extension hold times as found by McGill et al^{14, 18}. Participants with a flexion-to-extension ratio greater than one were placed in the strong group while those with a ratio less than one were placed in the weak group. Participants in both groups had equivalent extension endurance times while the weak group had significantly lower levels of core flexion endurance time compared to the strong group. Differences in the performance of the balance and power tasks in this study are therefore attributable to differential in trunk flexion endurance between the participants in the strong and weak groups.

Center of Pressure

Shorter COP path lengths and slower COP average velocities typically indicate greater stability in single-legged quiet stance postural control tasks²⁸⁻²⁹. Our data showed shorter COP path lengths in the weak group compared to the strong group in the eyes closed condition for the dominant and non-dominant legs and the eyes open condition for the dominant leg. COP average velocity was slower in the weak group as compared to the strong group for the eyes closed condition for the dominant leg. These findings suggest that participants with relative trunk flexor weakness had

greater stability in the single-legged balance task in our study. A possible explanation for our findings is the use of overconstrained or altered postural control mechanisms to compensate for the trunk flexor weakness.

Hypothetically, participants with weak trunk flexor muscles would have greater difficulty controlling posterior postural sway movements that require trunk, hip and ankle flexor synergistic muscle activity. These individuals may have overconstrained their postural sway movements to favor anterior movements that create a flexion moment around the ankle and facilitates trunk, hip and ankle extensor muscle activity while limiting excursion in the posterior direction that require flexor activity. Altered positioning of the hip or ankle may have acted as an additional constraint to the postural control mechanism utilized in the task. In spite of the uniform guidelines for participant positioning during the single-legged balance task, participants with weak trunk flexor muscles may have positioned their hip in slightly more flexion stance during the task to shift their center of mass anterior to their hips and shield their weak trunk flexor muscles and facilitate use of their strong back and hip extensors. Shifts in hip position shift center of mass and compensate for postural alignment has been previously demonstrated⁸. Once positioned, the knee, hip and lower back could work as a rigid inverted pendulum and COP would be highly

correlated to movement at the ankle³⁴. These postural control system compensations may have placed weak group participants nearer in time to episodes of postural stability therefore resulting in shorter COP path lengths and slower COP average velocities¹⁷. Participants in the strong group may have wider limits of stability than the weak group, especially in the posterior direction, allowing less-constrained postural control mechanisms resulting in greater COP path lengths and COP average velocities. We hypothesize that our participants in the strong group probably showed normal measures of single-legged stance stability while the participants in the weak group showed measures of over-constrained postural control mechanisms.

The relationship between trunk muscle strength/endurance and postural control is evident in the literature. Low back pain patients often demonstrate altered patterns of postural control during voluntary tasks³⁵. Trunk muscle weakness is common in low back patients and performance in core muscle endurance tests such as those implemented in this study is usually poor^{10-12, 14, 18, 20, 33}. The differences in postural control seen between the weak and strong groups in the current study may be similar to the changes seen in the low back pain population with weak trunk muscles and supports our hypothesis. Further biomechanical analysis in healthy participants and low back pain patients is required to validate our hypothesis

regarding overconstrained postural control mechanisms due to trunk muscle weakness.

Star Excursion Balance Test

Participants in our weak group produced lower anterior reach distances than subjects in the strong group. The greater anterior reach distances achieved by the strong group are attributable to the greater endurance capabilities of the flexor musculature of the subjects in this group.

The anterior reach task requires the subject to maintain a controlled posterior lean of the trunk while reaching forward with the non-stance leg. This posterior lean posture requires preferential activity of the trunk flexor muscles to counter the forces of gravity on the trunk. Participants with weaker trunk flexor muscles would be less stable in this posterior lean position, therefore compromising dynamic balance during the task. It is important to note that no significant differences were found in either of the posterior reach tasks between the weak and strong groups. Posterior reach tasks require controlled hip flexion and an anterior lean of the trunk producing an anti-gravity challenge to the trunk and hip extensor muscles. The lack of significant differences between the weak and strong groups with

regard to extension endurance hold times correlates well with the lack of significant differences in posterior reach distance.

The relationship between core strength and dynamic balance is supported by Tsukagoshi et al., who found better dynamic balance lower-body functionality in participants with greater forward plank and left lateral plank strengths³⁶. It is further supported by Khale who found that improvement in dynamic balance seen in the SEBT can be attributed to the postural control muscles of the trunk⁷. Like Tsukagoshi et al. and Khale, our findings demonstrate a relationship between core strength and dynamic balance task performance. Future studies incorporating inverse dynamics and electromyography should be undertaken to reveal the specific contributions of the different trunk muscle groups to performance of dynamic balance tasks.

Single-legged Hop

Our results showed no significant difference between the weak and strong groups with regard to single-legged hop distance. It is our conclusion that the dynamics of the single-legged hop task did not expose the trunk flexor weakness of the weak group and therefore no impairment of performance was observed. The flexed hip posture assumed during the

propulsion and landing phases of the single-legged hop create a flexion moment at the hip that the hip and back extensors are best able to counter. Since there was no significant difference in back extensor strength between participants in our weak group and our strong group, no detriment in performance of this dynamic task was found. If our hypothesis is correct, single-legged hop performance may be impaired in a group with back extensor muscle weakness.

To our knowledge, no previous study has compared single-legged hop measures to core strength. One study conducted by Myer et al. did utilize the single-legged hop test as a training measure to reduce lower-limb injury. With neuromuscular training, they saw increased distances over time; however, it did not say whether increased hop distances were due to participant familiarity to the task, increased leg strength or increased core strength³⁷. Further kinematic, kinetic and electromyographic studies are required to validate our conclusions.

Limitations

Our study enrolled a relatively small number of subjects which may not have provided enough power to fully support the conclusions from our analysis. Large numbers of subjects may further elucidate trends seen in this

study. It would also allow us to attain balanced numbers in each experimental group. Another limitation of our study is that all of our subjects were between the ages of 19 and 22 thereby limiting the ability to generalize the results of our study to other populations.

Also, we did not gather kinematic or electromyographic data during the experiment thereby limiting the validity of the explanations we provided to explain our data. Repeating the study while collecting this data would further clarify the results of our study.

CHAPTER 5: CONCLUSIONS

The findings of our study suggest that deficits in trunk muscle endurance can adversely affect performance in dynamic balance tasks and alter postural control mechanisms used in static balance tasks. The altered performance appears to be specific to tasks that utilize the weak muscle group. Subjects with weak trunk flexor muscles demonstrated shorter anterior reach distances during the SEBT and more constrained postural control mechanisms during a static single-legged balance task. Tests such as the single-legged hop and SEBT posterior reaches that did not challenge the weak trunk flexor muscles did not demonstrate a detriment in performance. Static and dynamic balance in the lower extremities is affected by trunk muscle endurance. Further research is required to identify the influence of trunk muscle endurance on lower extremity power tasks.

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LITERATURE REVIEW

Injuries due to Balance

Lower extremity injuries, such as a torn anterior cruciate ligament (ACL), have become a common problem for active individuals^{4, 38-41}.

Considered to impose one of the longest recovery times and devastating influences on patient activity levels and quality of life, ACL ruptures are major injuries^{38, 42-44}. Individuals that are ACL-deficient and/or had ACL-reconstructed knees due to previous injuries are at an increased susceptibility to second injuries such as meniscal tears and early development of osteoarthritis^{38, 45-47}.

Each year in the United States, 30,000 women and girls suffered from non- contact ACL injuries with costs exceeding more than \$650 million annually, making it one of the most costly injuries^{2, 48}. This is a 4- to 6-fold greater rate than seen in male counterparts participating in comparable high-risk sports⁴⁰⁻⁴¹. Female and youth sport enrollment has also increased over the past few years, leading to higher incidences of injury^{9, 38}. Soccer, the most commonly played sport, reports 0.06 to 3.7 ACL injuries per 1,000 hours of active playing^{38, 49}.

While increased playing time can account for this increase of injury, other mechanisms can influence the rate of ACL injury. Valgus positioning of

the lower extremity, hormonal imbalances, genetic predispositions, anatomical indices, unbalanced weight distributions and altered neuromuscular control of sport movements may contribute to an increased risk of injury in females^{2, 38-40}. Proprioceptive core deficits could also contribute to the decreased muscular control of the lower extremity causing increased strain on knee ligaments⁵⁰⁻⁵⁴. Therefore, researchers have begun to design and implement injury prevention strategies to reduce the incidence of ACL injuries. Some have reported that prophylactic knee braces reduced injury while others suggest that training programs provide the best preventative means^{38, 55}. Researchers have experimented with modifications of adequate hamstring/quadiceps ratios, stretching, plyometric training, proprioception training and core/trunk control³⁸. Postural control has also been advocated as an establishing determinant of neuromuscular performance injury⁵. Consequently, changes in core/trunk control could prevent other lower extremity injuries and eliminate exclusive prevention to just the ACL.

Other injuries could be prevented for those with low back pain (LBP) and those recovering from unihemispheric strokes with limited balance^{6, 19}. LBP can occur due to excessive fatigability of lumbar paraspinal muscles, which may easily injure the painful, passive structure of the lumbar spine¹³,

^{20, 56-58}. LBP comprised 25% of the injuries among elite male rowers and 15.2% among elite female rowers¹². This percentage only increased over a span of 20 years, increasing to 32% of all intercollegiate rowers with LBP¹². In unihemispheric patients, complex systems involved with balance are most usually disrupted and can impact function of trunk musculature^{6, 59}. Other injuries include neurological diseases such as lumbar discectomy, multiple sclerosis, and amyotrophic lateral sclerosis¹⁵. Because balance ability is closely related to functional status among these patients, core stability is considered a prognostic clinical tool for functional recovery. Therefore, researchers have begun to explore the effects of core strength on prevention of lower body injuries.

Core Stability and Balance

The body's core encompasses passive structures of the thoracolumbar spine and pelvis with active contributions from trunk musculature¹⁻². Moreover, its stability is conditional upon neuromuscular control of trunk muscles in response to internal and external perturbations on distal body parts and segments². Core stability is necessary to maintain body position, remain stable while changing positions, sustain mobility and for everyday activities^{6, 60}. A more precise definition concludes core stability as a foundation of trunk control that allows for "production, transfer, and control

of force and motion to distal segments of the kinetic chain³⁻⁴.”

Biomechanically, the function of trunk muscles is a necessary component for balance, transfers of weight, and gait. When weight is shifted into any plane, the trunk must counteract with a movement to restore the center of balance⁶.

While balance is a complex interaction of vestibular, visual, proprioceptive, musculoskeletal and cognitive systems, it can be characterized as either static or dynamic⁵⁻⁶. Static postural control entails maintenance of a base of support while minimizing movement of one's center of mass or body segments⁷. It can further be defined as the ability to maintain position while standing in a unilateral or bilateral stance⁵. Most often this characteristic is assessed by measuring center of pressure changes or sway area⁵. Dynamic postural control can be described as performance of purposeful movements in completion of a prescribed task without compromising a stable base of support⁷. These tasks usually involve one's center of mass to be displaced outside the base of support and require proper integration of proprioception, range of motion and strength^{5,7}. Such examples include running, jumping and cutting.

Core stability has a profound effect on lower-body injuries. Lack of adequate trunk stability may impair postural control, lower extremity balance and function, and result in poor task mechanics and injury⁴. Oliver

and colleagues ⁹ deduce that core stability could lead to more efficient use of the kinetic chain and ultimately decrease the insufficiency that results in injury or dysfunction. Because core musculature activity precedes lower extremity activation in temporal sequence of many athletic activities, even more injuries can ensue. Zazulak et al. ² continue by stating that increased error in core proprioception is associated with risk of knee injury due to altered valgus positioning, ligament strain and increased knee abduction and torque; while Cholewicki et al ¹⁰, discovered that delayed trunk muscle reflexes predicted low-back injuries in college athletes. Furthermore, it was determined that even mild weakening of trunk muscles in unihemispheric stroke patients interfered with balance and stability, increasing susceptibility to injury ⁶. However, improving musculature may improve stability and ease the reeducation of limb use. Overall, current evidence indicates that compromised neuromuscular function of the trunk musculature may contribute and underlie a multitude of injuries.

Measurements of Core Musculature

Strength, endurance and speed are typified measurements of musculature function. Of these, muscular endurance- the capacity of a muscle to sustain effort and produce force over time- exercises have been found by McGill and colleagues to be the safest and most mechanically

justifiable approach to enhance stability¹². Trunk muscle recruitment during isometric endurance tests most commonly parallels injury occurrence and thus is the best method to utilize in measuring core strength¹¹⁻¹⁵. Moreover, isometric endurance measurements have proven to be a reliable method to assess trunk muscle strength with an abundance of literature to validate measures¹⁴⁻¹⁸.

Recent work has suggested that the balance of endurance measurements between the torso flexors, extensors and lateral musculature be tested due to their stabilizing effect on the spine during virtually any task¹⁸. From research collected by McGill and Cholewicki¹⁰, it was demonstrated that the quadratus lumborum was “architecturally best suited to be the major stabilizer of the lumbar spine.¹⁴” Therefore, varieties of exercises were designed and implemented to assess this muscle. The best determinate of the optimal functionality of the quadratus lumborum was the “side bridge,” which minimized load on the lumbar spine¹⁴. However, as this assessment gained exposure, clinicians and researchers desired normal values for flexor, extensor, and lateral flexion endurance times and ratios to determine training targets to use when assessing isometric endurance tests for rehabilitation. Ultimately, research has validated and shown high reproducibility²¹ for the following three stabilizing core endurance exercises

for trunk functionality: the Biering-Sorensen Back Extension, isometric flexion, and lateral flexion tests.

Biering-Sorensen Test

In an attempt to provide longitudinal evidence for standardized physical examinations for low-back trouble, Fin Biering-Sorensen examined over 900 individuals over a period of one year using anthropometric measurements, flexibility of the back and hamstrings, and tests for trunk muscle strength and endurance ¹⁹. From this study, she became recognized for her back extensor isometric endurance test. This exercise required individuals to keep the unsupported upper part of the body (from the anterior superior iliac spine) parallel to the floor while placed prone with the ankles fixed to the table by a strap and the arms folded across the chest. The exercise was evaluated by measuring the seconds an individual could maintain the position and/or an individual reached a limit of tolerance of symptoms of fatigue¹⁹. From his test, she discovered that endurance time was longer for women than men in all age groups and those who could not complete the test complained of pain in the lower-back, legs and abdomen¹⁹.

In an effort to prove or disprove Biering-Sorensen's method of the isometric extension exercise, many completed follow-up studies to validate

his procedure. One such study conducted by Nicolaisen and Jorgensen²⁵, paralleled Biering-Sorensen's findings contributing lower isometric endurance to patients with severe low-back pain as compared to normal controls with significantly higher isometric endurance. Similar findings were found again by Latimer et al., when participants were asked to perform the exact test as done in 1983. Again, patients with low-back pain performed more poorly on the endurance test than healthy controls.

In another study performed by Coorevits et al., both hip and back extensor muscles were measured through electromyographic analysis during the Biering-Sorensen test and normalized median frequency slope (NMF_{slope}) was determined. From the data collected, it was concluded that both the back and hip muscles fatigued and NMF_{slope} values correlated with endurance time. However, the only limiting portion of the test stemmed from the fatigue of the back musculature proving the validity of the Biering-Sorensen test for measuring only back muscle fatigue⁶¹. These studies demonstrate the effective isolation of the back extensor musculature as the sole reciprocator and limiting factor when performing the Biering-Sorensen isometric core endurance exercise.

Intraclass correlation coefficient (ICC), which defines the reproducibility of measures and has been recommended for tests of

reliability was observed in a test completed by Paalanne, et al ¹⁵. Repeating the same test within 30 minutes after completing the first test, this study found that the ICC of isometric extension endurance to be 0.93, showing very high reproducibility. When performed by Latimer et al., an ICC of 0.83 was discovered²⁰. These studies demonstrate the validity and reproducibility of the Biering-Sorensen test support its use in the testing of back extensor strength.

Isometric Flexion Endurance

McGill et al., describe the procedure of the isometric flexion endurance test. It is required that the individual begin in a sit-up position with the back resting on a wedge angled at 60° from the floor²¹. While both knees and hips are flexed at 90° and arms are crossed against the chest, the wedge is pulled back 10cm and the individual begins the timed isometric test²¹. This test concluded once a participant fatigued beyond comfort or body fell below 60°. Women tend to perform worse than men at flexion, as compared the better scores achieved by women than men in the Biering-Sorensen test. When interrater reliability was tested by Paalanne et al., an ICC of .87 was found for the flexion isometric endurance test¹⁵. In addition, McGill, found a reliability coefficient of .93 for an 8-week 5-day period¹⁴. The

isometric flexion endurance test is a reliable measure of trunk flexor strength.

Isometric Lateral Flexion

The isometric lateral flexion endurance, or side bridge tests, mandate that participants lay on their sides with legs extended with their top foot placed in front of the lower foot. Hips are then lifted upward, off the mat to attain a straight line over their full body length, while supported with one elbow and both feet¹⁴. The unsupporting arm was held across the chest and the hand placed on opposite shoulder. This test concluded when an individual fatigue beyond comfort or when the hips returned to the mat. Both left and right arms should be tested as bases of support. The ICC for this test was .84 with a reproducibility coefficient of .96 for the right side bridge and .99 for the left side bridge during a period of 8-week 5-day repeated sessions¹⁴⁻¹⁵.

Endurance Ratios

Examination of the trunk flexion-extension torque ratio may be useful in determining what proportional influence of muscles to stability are needed for proper functionality¹⁷. It provides a comparative measure of strength between muscle groups. McGill et al., resolved that extensor

endurance is diminished relative to flexors in those with lower-back problems, and therefore are weaker strength individuals⁶². It is thought that muscle strength imbalances may be a better indication than strength deficits in any one test⁶²

Quantifying Static Balance

Because static postural control entails maintenance of a base of support while minimizing movement of one's center of mass or body segments⁷, the postural sway accompanying this movement of mass can be defined more precisely; it is the deviation from the mean center of pressure (COP) of the foot⁶³. While tests such as the modified Romberg test can be implemented to quantify static control in patients with concussions; they may not be appropriate for testing healthy individuals⁶⁴. For research purposes, the use of stabilometry and force plates provides significant details of COP excursion during balance tasks. When postural stability is impaired, a respective increase COP excursion velocities and path lengths ensue^{17, 65}. Subjects are typically asked to stand as still as possible on a force plate with their eyes opened or eyes closed. Trials are conducted for various lengths of time from 10-30 seconds. Testing can be performed in double-legged stance or single-legged stance^{17, 25}. Tests where the individual loses balance, touches one leg to another or removes the hands from their waist are repeated²⁵.)

While numerous studies compare proprioceptive balance training and a decrease in postural sway, no general conclusion has been made showing such results^{23, 63, 66}. One study completed by Tsukagoshi et al of this year with a similar design to ours found that participants with strong cores presented no improvement in COP static balance³⁶. Few studies have examined postural control in healthy individuals, but rather make comparisons between injured and uninjured participants^{17, 65}. Numerous studies have validated the use of COP-based measures with ICC = .35 - .80^{17, 67}. Single-legged quiet stance is a valid and reliable means to assess postural sway and static balance function.

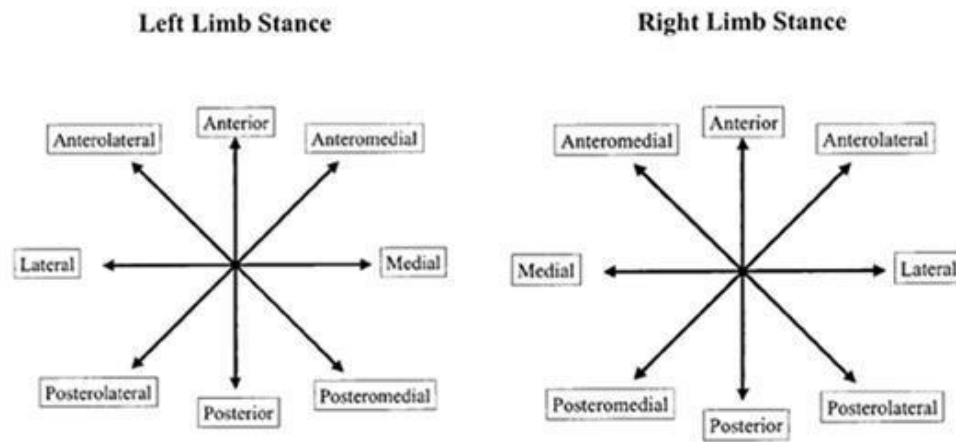
Quantifying Dynamic Balance

Due to the defining characteristics of dynamic balance such as: performance of purposeful movements in completion of a prescribed task without compromising a stable base of support and involves one's center of mass to be displaced outside the base of support. It requires proper integration of proprioception, range of motion and strength^{5, 7} and may be a more exact method of detecting neuromuscular deficiencies. Two tests have emerged as valid, reproducible means to evaluating dynamic postural function of the lower-extremity.

Star Excursion Balance Test

The Star Excursion Balance Test (SEBT) is a reliable measurement (ICC = 0.81 – 0.86)²² of dynamic balance consisting of 8 directional reaching tasks spaced 45° apart as shown in Figure 1.

Figure 1: Left and Right leg view of 8 directions of SEBT



Participants were instructed to reach with their non-weight bearing leg while keeping hands on their hips and minimizing transfer of body weight to the reach leg without compromising the base of support, and then return the reaching leg back to the starting position^{5, 7, 23-24}. This position was marked by the same examiner each time to produce accurate results. For the purposes of this study, only 3 of the 8 possible reach directions were utilized. Those directions used were: anterior, posteromedial, and posterolateral. Recent work proved that the 8 directions could be paired down to 3 due to

redundancy across reaching directions because all reach directions were significantly correlated^{7, 22}. Moreover, kinematic patterns of the stance limb were redundant across directions, thus 3 directions was suffice to generate enough sensitivity to measure dynamic postural control^{7, 24}.

One study conducted by Kahle et al., found that maximum excursion distances demonstrate significant increases across 3 reach trials⁷. In order to achieve stable reach distances, practice trials are necessary. Robinson et al., discovered that 4 practice trials would suffice to produce reliable reach distances²⁴. Efficient dynamic balance testing using the SEBT requires movements in three different directions and requires four practice trials to provide valid and reliable data²².

In order to quantify this in a measurable and comparable way between participants, it was necessary to normalize the results with respect to the participants' leg length. Therefore, the 3 maximal reaches are typically averaged then divided by the participant's leg length and expressed as %LL. In this way, maximal reaches could easily be compared among participants as a percentage⁶⁴.

Recent work completed by Tsukagoshi et al. discovered that an increased SEBT performance was observed in participants demonstrating

greater core endurance in the front and side bridge planks³⁶. It can be suggested that the increased core strength impacted the functionality of the lower limb when completing tasks similar to the SEBT.

Single-Legged Hop

Hop testing is a practical, inexpensive means incorporating minimal equipment as a means to measure lower-limb function. Performance on this outcome measure reflects integrated effects of neuromuscular control, strength, and confidence in lower-extremity³¹⁻³². Movement principles such as direction change, speed, acceleration, deceleration and rebound demand dynamic knee stabilization, which ultimately require core stabilization³². This hop test is also an appropriate means to identify patients who may endeavor future problems due to knee injury⁶⁸. Thus implementation of this task may better assess the functional role of core stability on lower-extremity functionality and possibly predict the potential for injury. To date, no research has explored the relationship between core strength and single-legged hop performance.

In order to complete this outcome measure, participants were required to place the tip of their toes behind the start of the tape and then participants were instructed to jump as far as possible³⁰⁻³². There were no

restrictions placed on the movement of the arms during this jump. To classify a jump as successful, the participant had to maintain the landing for 2 s and could not do the following: touch down with the contralateral lower extremity, lose balance and/or perform an additional hop upon landing³². Just as with the SEBT test hop distance are normalized to leg length (%LL) for comparison between subjects.

Conclusion

Although research has linked core strength to lower extremity injury rates, minimal research has been conducted to compare the relationship between core endurance strength and balance, both static and dynamic. There is also no research exploring the relationship between core strength and hopping tasks. In order to better understand the relationship between lower extremity injury and core strength, research needs to be conducted to explore the relationship between core strength and the performance of lower-extremity balance and functional tasks.

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APPENDIX A: (QUESTIONNAIRES):

GENERAL HEALTH SCREEN



Title of Project: Core Strength and its Relation to Dynamic and Static Balance

Principal Investigator: Sayers John Miller, PhD, PT, ATC

Co-Investigator: Giampietro L Vairo, MS, ATC

Research Assistant: Anne Fisler

Screening Checklist: Healthy College-Aged Participants (18-35 years old)

Participant Identification Number _____

As a general health screen, you must be able to answer 'YES' to the following questions.

1. Are you between 18 to 35 years old? **Yes** **No**

2. Do you speak English? **Yes** **No**

3. Are you generally healthy (BMI¹ under 30 and a non-smoker or non-consumer of nicotine products)?
 Yes **No**

As a general health screen, you must be able to answer 'NO' to the following questions.

1. Do you have a history of musculoskeletal or neurological injury to the low-back or lower body within the last six months? **Yes** **No**
2. Do you have a history of low-back or lower body surgery? **Yes**
No
3. Have you sustained a concussion within the past six months? **Yes**
No
4. Have you followed a formal physical rehabilitation program in the last six months? **Yes** **No**
5. Do you have any low-back or lower body pain described as above '1' on a 10-point scale? **Yes** **No**
6. Are you diabetic or suffer from peripheral neuropathy? **Yes**
No
7. Do you currently have any lower body joint swelling? **Yes** **No**
8. Are you pregnant? **Yes** **No**

[1]United States Government. (2010) Defining Overweight and Obesity. Center for Disease Control and Prevention. June.

CLINICAL EXAM

Participant ID _____

Core Strength's Relation to Balance

Age_____

Height_____cm

Weight_____

Right Leg Length_____cm

Left Leg Length_____cm

Dominant Leg_____

STAR BALANCE TEST

	Dominate			Best	Nondominate			Best
Front								
Opposite Side Diagonal Back								
Same Side Diagonal Back								

SINGLE LEG HOP

Dominate			Best	Nondominate			Best

CORE STRENGTH

Back Extension	Flexion	Left Lateral Plank	Right Lateral Plank

STATIC BALANCE

	Dom Eyes Open			Dom Eyes Closed			Nondom Eyes Open			Nondom Eyes Closed		
Path Length												
Unit Path												
Path/Area												
Vx Min												
Vx Max												
Vy Min												
Vy Max												
V Avg.												

RECRUITMENT SESSION SCRIPT

PENNSTATE



Title of Project: Core Strength and its Relationship to Static and Dynamic Balance

Principal Investigator: Sayers John Miller, PhD, PT, ATC

Co- Investigator: Giampietro L Vairo, MS, ATC

Research Assistant: Anne Fisler

Script: Healthy College-Aged Participants(18-35 years old)

Hello, my name is Sayers John Miller and I work with the Athletic Training Research Laboratory at Penn State. I am currently looking for research volunteers and was wondering if you would be interested in participating or at least hearing more about this study. I am looking for a group of participants who are 18 to 35 years old, have no history of lower body or low-back injury in the past six months and no related surgeries. Participants in this research study should be in good general health, not overweight and non-smokers. Participants cannot be pregnant at the time of the study. If you are undergoing physical therapy or sports rehabilitation under the supervision of a physical therapist or athletic trainer you will not be eligible to participate. I will be examining how core strength relates to balance. If you are interested in participating, you would be required to come to the Athletic Training Research Lab in 21D & E Recreation Building for one testing session lasting approximately one hour. During the testing session we will measure core strength through three tests and your postural control abilities as you will be asked to perform three balancing exercises. As a participant we will be happy to provide you with your specific data results. If you have any questions or need to get in touch with me for any reason, my phone number is 814-865-6782 and my e-mail is sjm221@psu.edu. Thank you.

RECRUITMENT FLYER



Research Volunteers Needed

*Are you interested in learning more about
core strength and balance performance?*

*If so, you may be interested in participating in our research study at
Penn State.*

Measurements: Core strength as well as static and dynamic
single-leg balance

Purpose: To study the relationship between core strength and
balance

One 60-minute session at the Athletic Training Research
Laboratory in 21 D & E Recreation Building

Requirements:

- Men and women ages 18 – 35 years old
- Good general health
- Non-smoker or consumer of nicotine products
- Not overweight

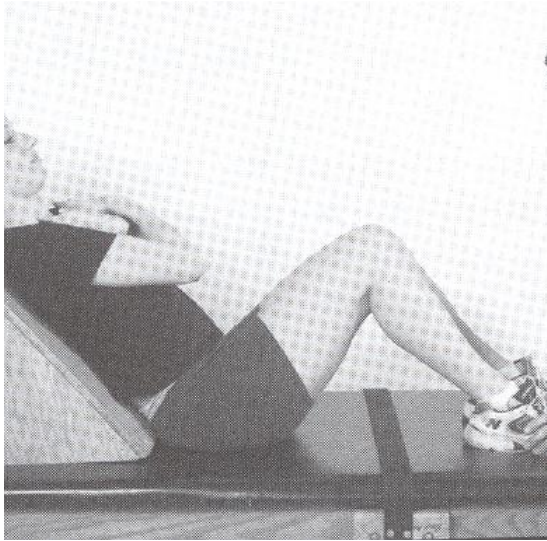
Dr S. John Miller, John Vairo and Anne Fisler
Department of Kinesiology

For more information, contact John Miller at
sjm221@psu.edu or 814-865-678

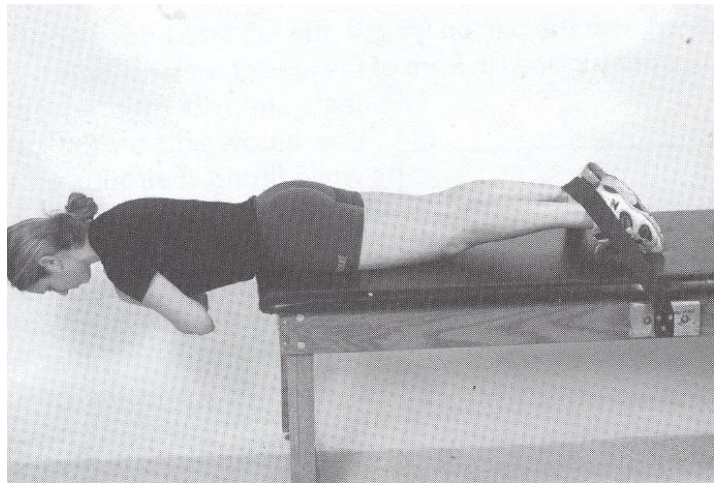
APPENDIX B (FUNCTIONAL TEST PHOTOS):

CORE ENDURANCE TESTS:

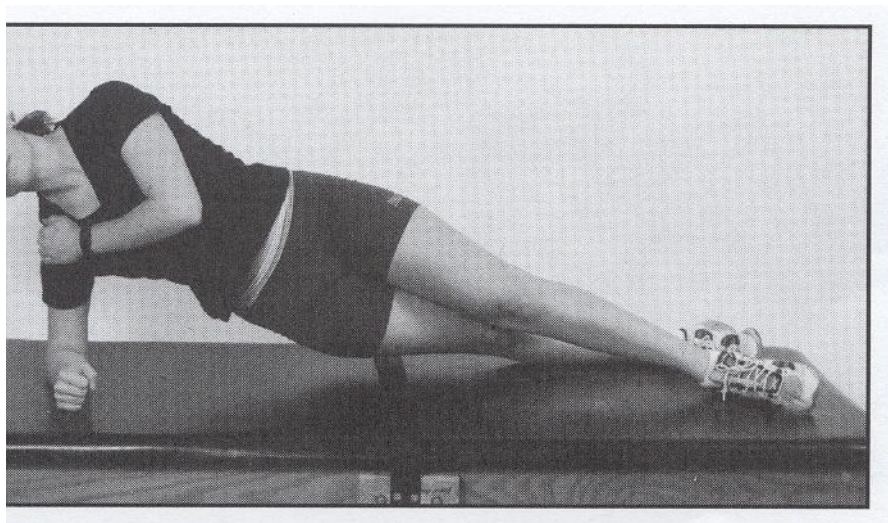
Abdominal Flexion



Back Extension



Lateral Plank



STAR EXCURSION BALANCE TEST



SINGLE-LEG HOP TEST



QUIET STANCE SINGLE-LEG BALANCE



APPENDIX C: INFORMED CONSENT



Informed Consent Form for Biomedical Research The Pennsylvania State University

HEALTHY COLLEGE-AGED PARTICIPANTS

(18-35 years old)

ORP OFFICE USE ONLY

DO NOT REMOVE OR MODIFY

IRB# 35177 Doc. #1001

The Pennsylvania State University

Title of Project: Core Strength and its Relationship to Static and Dynamic Balance

Principal Investigator: S John Miller, PhD, PT, ATC
Assistant Professor of Kinesiology
Department of Kinesiology
146 Recreation Building
University Park PA 16802
sjm221@psu.edu
814-865-6782

Co-Investigator: Giampietro "John" L Vairo, MS, ATC
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Research Assistant:

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Schreyer Honors College Undergraduate Student

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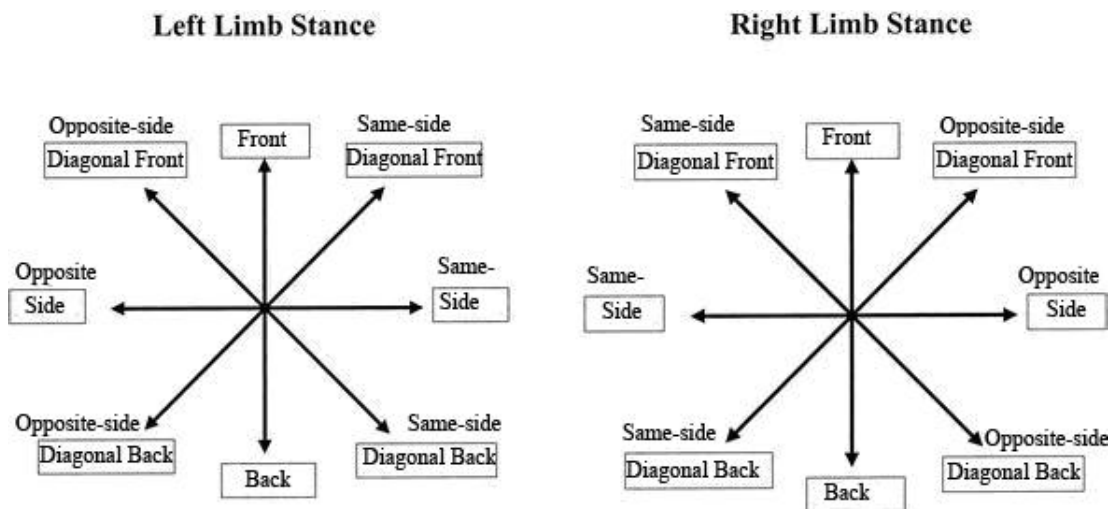
814-865-4303

- 1. Purpose of the study:** The purpose of this research is to study the effects of core strength and endurance on balance both dynamic and static. A total of 26 people between the ages of 18-35 years old will be taking part in this study.
- 2. Criteria for inclusion of participants:** You are being invited to participate in this research study because you are healthy, physically active and between the ages of 18-35 years old. You have no history of lower body or back injuries within the last six months and have never undergone surgeries for injuries to these areas. You are also not diagnosed with diabetes, peripheral neuropathy or epilepsy.
- 3. Procedures to be followed:** If you chose to participate in this research study, you will be asked to perform the following procedures:

Procedures

- A. We will begin the study by measuring your height, weight, and length of one leg. We will also determine your dominate leg by asking you to kick a soccer ball.

- B. We will also ask you to perform three abdominal exercises thereafter. One exercise will require you to do static sit-up, another will require back extension and lastly, you will be asked to do a lateral plank. All will be measured to maximum hold and rests will be held between each measurement.
- C. Following the warm-up, you will be asked to perform a single-leg balance stance task. You will be standing barefoot on one leg with your arms crossed over your chest while bending your knee on the opposite leg. You will be asked to keep balance for 10 seconds. We will ask that you complete three trials with your eyes open and then three trials with your eyes closed. Your balance performance will be measured by a force platform, which stays still on the floor and is electronically hooked up to a computer. You will be asked to perform the single-leg balance stance task for both of your legs.
- D. You will then be asked to perform a single-leg balance reach task. You start the single-leg balance reach task by standing in place on one leg in the middle of an asterisk drawn on the floor. You then reach as far as possible with your other leg in each of the following directions: front, opposite-side diagonal back, same-side diagonal back. A picture of the single-leg balance reach task is below.



You will be asked to complete three trials in each direction. You will be given practice trials and rest between each trial. You will be asked to perform the single-leg balance reach task for both of your legs.

- E. For your last measurement, you will be asked to do a maximum single-leg hop. Using one leg you will be asked to hop as far as possible. You will be given practice and then three hops will be measured with the best hop recorded into the data.

- 4. Discomforts and risks:** The discomforts and risks with participation in this type of research study are minimal. The tests used are within expected ranges for physically active people. To lessen the chance of injury, you will also be shown how to properly perform every task in the experiment. Possible discomfort may consist of delayed onset muscle soreness 48 to 72 hours following testing. As with any research study, it is possible that unknown harmful effects may happen. However, the chance for injury in this type of research study is minimal and includes muscle strains, ligament sprains and bone fractures. We will take every possible effort to watch for and help prevent against any discomforts and risks.
- 5. Benefits:** There is no direct benefit to you from participating in this research study. The benefits to society include recognizing potential advantages core strength training on balance performance in healthy college age people.
- 6. Duration/time of the procedures and study:** The testing session will last about one hour and will include taking height and weight measures, trunk strength tests, balance tests and a single-leg hop test. All testing takes place in the Athletic Training Research Laboratory in 21E Recreation Building on Penn State's University Park Campus.
- 7. Alternative procedures that could be utilized:** There are no known alternative procedures used to answer the research questions of this study.

- 8. Statement of confidentiality:** Your participation in this research study is strictly confidential. All research records from your participation in this study will be kept confidential similar to medical records at your doctor's office or hospital. All records will be secured in locked file cabinets at the Athletic Training Research Laboratory. A unique case number will indicate your identity on research records. In the event of any publication resulting from this research study, no personally identifiable information will be disclosed. Penn State's Office for Research Protections, the Institutional Review Board and the Office for Human Research Protections in the Department of Health and Human Services may review records related to this research study. Penn State policy requires that research records be kept for a minimum period of three years at the end of the study. Three years following the end of this research study all records will be appropriately destroyed.
- 9. Right to ask questions:** Please contact S John Miller at (814) 865-6782 with questions, complaints or concerns about this research. You can also call this number if you feel this study has harmed you. If you have any questions, concerns, problems about your rights as a research participant or would like to offer input, please contact Penn State University's Office for Research Protections at (814) 865-1775. The Office for Research Protections cannot answer questions about research procedures. Questions about research procedures can be answered by the research team. Referral information for those who wish to seek additional assistance includes the following:
- Penn State University Health Services
- Student Health Center
- University Park PA 16802
- 814-863-0774
- 10. Voluntary participation:** Your decision to be in this research study is voluntary. You can stop at any time. You do not have to answer any questions you do not want to answer. Refusal to take part in or withdrawing from this research study will not involve penalty or loss of benefits you would receive otherwise. You may be removed from this

research study by investigators in the event you cannot complete the testing procedures.

11. Injury Clause: In the unlikely event you become injured as a result of your participation in this research study, medical care is available. If you become injured during testing procedures the investigators listed on this informed consent form will provide you with appropriate first aid care and instruct you on proper steps for follow-up care. If you were to experience any unexpected pain or discomfort from participating in this research study after leaving the Athletic Training Research Laboratory please contact S John Miller immediately at (814) 865-6782. If you cannot reach S John Miller please leave him a voicemail and contact your doctor.

If you are a Penn State student and cannot reach S John Miller or your doctor, please leave them voicemails and contact Penn State University Health Services at:

Student Health Center

University Park PA 16802

814-863-0774

It is the policy of this institution to provide neither financial compensation nor free medical treatment for research-related injury. By signing this document, you are not waiving any rights that you have against The Pennsylvania State University for injury resulting from negligence of the University or its investigators.

12. Abnormal Test Results: In the event that abnormal test results are obtained, you will be made aware of the results in three days and recommended to contact your private medical provider for follow-up consultation.

You must be 18 years of age or older to take part in this research study. If you agree to take part in this research study and the information outlined above, please sign your name and indicate the date below.

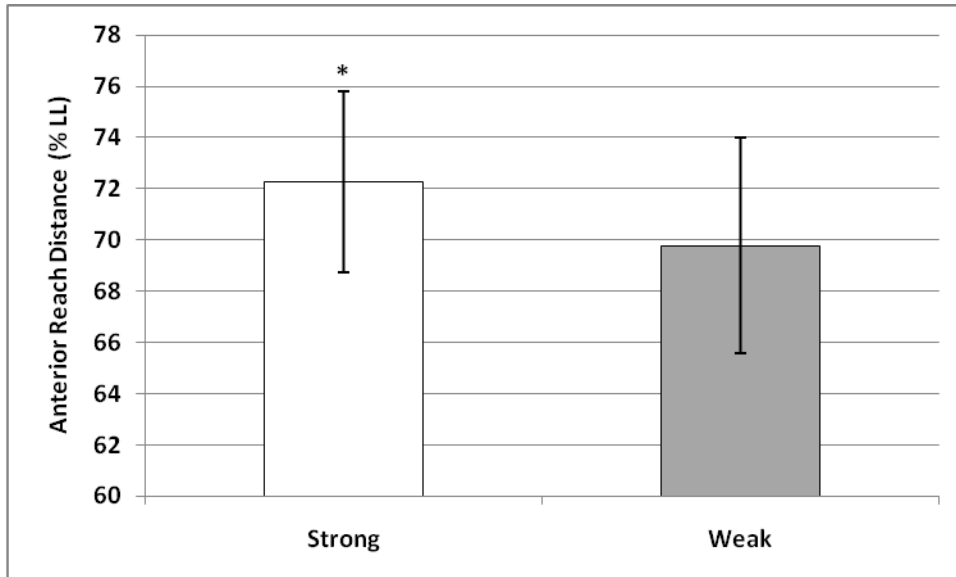
You will be given a copy of this signed and dated consent form for your records.

_____	_____
Participant Signature	Date

_____	_____
Person Obtaining Consent	Date

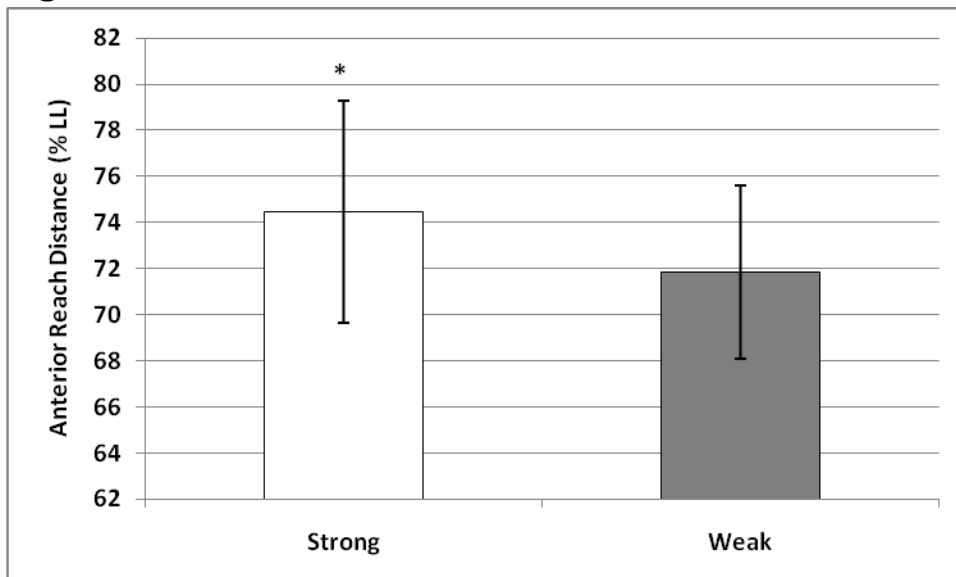
APPENDIX D (DATA FIGURES)

Figure 1: Balance Reach Task Distance Measures for the Dominant Leg



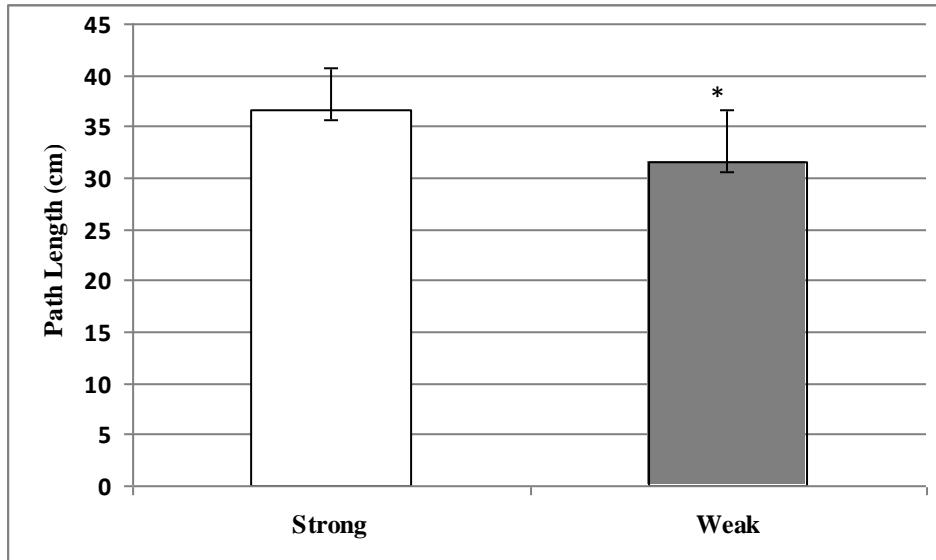
*Denotes statistical significance ($P \leq 0.05$).

Figure 2: Balance Reach Task Distance Measures for the Non-Dominant Leg



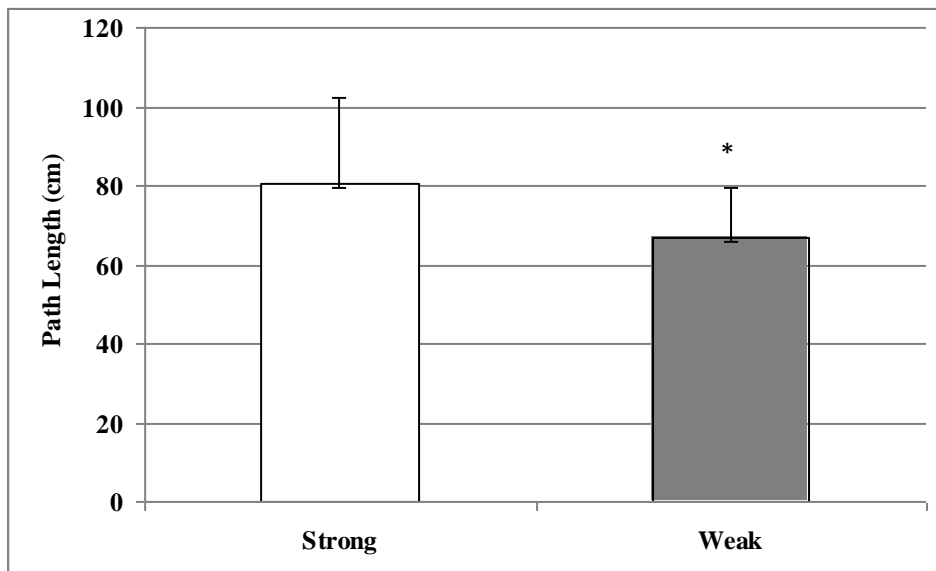
*Denotes statistical significance ($P \leq 0.05$).

Figure 3: Path Length Differences for Dominant Leg with Eyes Open



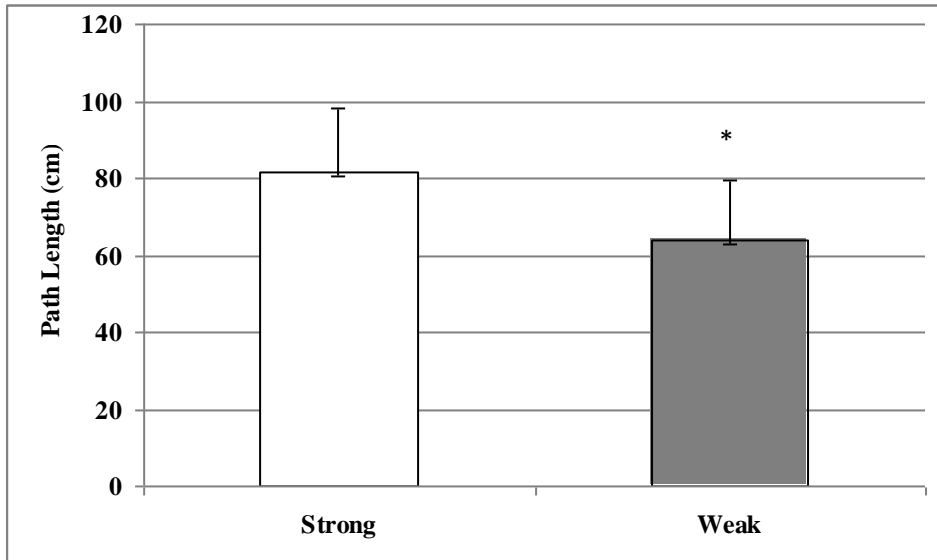
*Denotes statistical significance ($P \leq 0.05$).

Figure 4: Path Length Difference for Dominant Leg Eyes Closed



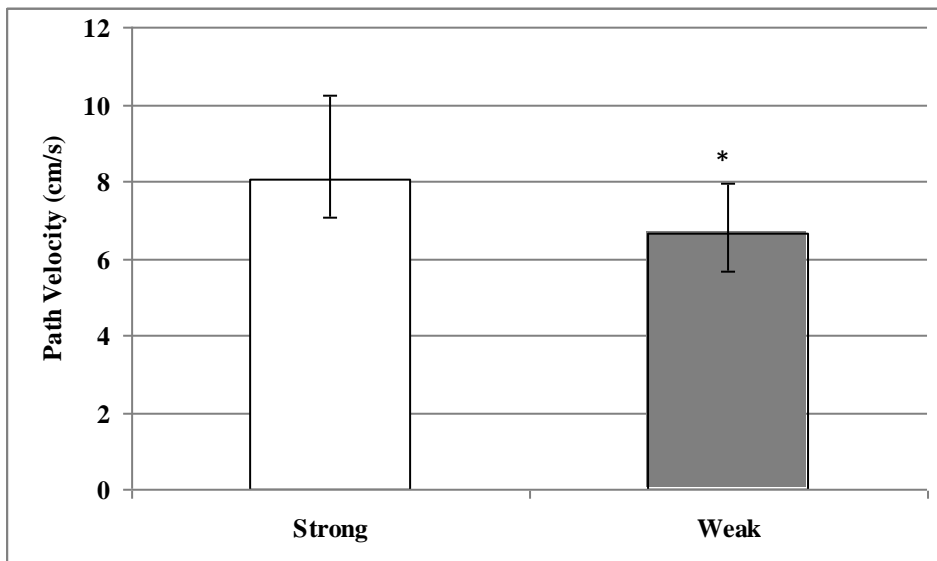
*Denotes statistical significance ($P \leq 0.05$).

Figure 5: Path Length Difference for Non-Dominant Leg Eyes Open



*Denotes statistical significance ($P \leq 0.05$).

Figure 6: Center of Pressure Avg. Velocity for Dominant Leg Eyes Closed



*Denotes statistical significance ($P \leq 0.05$).

ACADEMIC VITA of Anne E. Fisler

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Permanent Address

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Washington, PA 1530

Email: fisler@psu.edu

Education:

Bachelor of Science in Kinesiology, Penn State University, Spring 2011
Honors in Kinesiology
Thesis Title: Core Strength's Relation to Static and Dynamic Balance
Thesis Supervisor: Sayers John Miller
Studied Abroad in Florence, Italy, Spring 2010

Related Experience:

Lemont Physical Therapy
Supervisor: Amy Flick
Summer 2009
Bradley Physical Therapy
Supervisor: Dennis Strosko
Summer 2010
Physical Therapy Institute
Supervisor: Cristy Carnahan
Summer 2010
The Washington Hospital
Supervisor: Jennifer Leichliter

Awards:

Schreyer Ambassador Travel Grant, Fall 2009
Dean's List, every semester
Phi Kappa Phi Honor Society

Presentation/Activities:

Sigma Alpha Professional Agriculture Sorority
Penn State Dance MaraTHON
- FOTO Special Interest Student Organization
Kinesiology Club
Health & Human Development Student Council Homecoming Chair,
2009