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THE EFFECT OF AN INTRODUCTORY STRENGTH TRAINING PROGRAM ON ACL INJURY RISK FACTORS

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ABSTRACT

The purpose of this study was to examine both objective and athlete perceived biomechanical outcomes of Block Zero training thought to be associated with ACL injury risk potential. There were two specific aims of this study. The purpose of Aim 1a of this study was to examine the extent to which Block Zero training increased knee:ankle ratio during the performance of the Drop Jump Screen Test. Thirteen female high school athletes from girls' volleyball, basketball, softball, and soccer comprised the sample. A paired t-test indicated participants demonstrated increases in knee:ankle ratio and increases in strength from pre to post test. Spearman's correlation indicated there was a strong positive relationship between increased strength gains and increased knee:ankle ratio. Aim 1b examined the perceived benefits of Block Zero training through an exploration of knee symptoms and an ability to perform certain tasks during sport participation in past participants of Block Zero. Twenty-four survey responses comprised the sample. Results from McNemar's Test for correlated proportions indicated participants reported positive perception of Block Zero training. The purpose of Aim 2 was to compare injury data from the host high school to three area high schools to determine if athletes who participated in Block Zero were less susceptible to ACL injury than those who did not participate in Block Zero. While results were not statistically significant, injury rates revealed, with the exception of girls' volleyball, the host school experienced lower injury rates. These preliminary positive results suggest that Block Zero training should be studied in the future as one potential way to provide protection against ACL injury.

Keywords: Block Zero Training, anterior cruciate ligament, injuries, team sports, strength and conditioning, injury prevention

INTRODUCTION

As early as 1983, research indicated a rising trend in anterior cruciate ligament (ACL) injuries where eighty percent of injuries are caused by non-contact mechanisms (Noyes, Mooar, and Matthews, 1983). A sixteen-year epidemiological study (1988-2004) presented by the National Collegiate Athletic Association (NCAA) showed that female gymnasts suffered an incidence of ACL injuries in .33 per 1000 athlete exposures and that three of the four sports with the highest incidence of ACL injuries were female sports: gymnastics, basketball, and soccer. A more recent eight-year epidemiological study from 2004-2005 to 2012-2013 indicates that when compared to male soccer players, females have .10 rate of injury (per 1,000 exposures) compared to males which is a .03 rate of injury (Agel et al, 2016). Similar results were found for basketball where females have .22 rate of injury compared to .08 for males, and for lacrosse where females have a .23 rate of injury compared to .13 for males (Agel et al. 2016).

The high incidence of ACL injury and the increased rate of injury for females has led researchers to develop ACL injury prevention programs that focus on neuromuscular and biomechanical risk factors, as they are considered modifiable risk factors (Voskarian, 2013). A key risk factor associated with non-contact ACL injuries in females that these programs have targeted is knee valgus. Hewett, Myer, Ford, and Heidt (2005) conducted an injury surveillance study and found that subjects that suffered non-contact ACL injuries demonstrated significant increases in lower extremity valgus and knee abduction. In a video analysis of 39 basketball ACL injuries, Krosshaug, Nakame, Boden, Engebretsen, Smith, Slauterbeck, Hewett, and Bahr (2007) found female basketball players demonstrated a 5.3 times higher relative risk of sustaining a valgus collapse at the time of injury when compared to male basketball players. Injury prevention programs that have focused on neuromuscular and biomechanical risk factors have documented success in reducing the rate of non-contact ACL injury (Hewett, Lindenfeld, Riccobene and Noyes, 1999; Mandelbaum, Silvers, Watanabe, Knarr, Thomas, Griffin, Kirkendall, and Garrett, 2005; Myer, Ford, Palumbo and Hewett, 2005).

Despite the efforts of current ACL injury prevention programs to address neuromuscular and biomechanical risk factors, a gender difference in ACL injury rates still exists for females when compared to males. Stanley, Kerr, Dompier, and Padua (2016) indicate females remain two times as likely to sustain an ACL injury when compared to males that compete in the same sport. Noyes and Westin (2012) suggest a variety of ACL injury prevention programs have been developed to address ACL injuries, however, the components of intervention programs vary. Noyes and Westin (2012) found programs typically include plyometrics and agility exercises; however, only three programs implemented strength training: *Sportsmetrics*, *PEP*, and the *FIFA 11* (Noyes and Westin, 2012) (Table 1, Table 2, & Table 3).

Table 1. Sportsmetrics. Hewett et al. (1999)

Phase 1 Wall Jumps Tuck Jumps Broad jumps stick (hold) Landing Squat Jumps Double legged cone jumps 180 degree jumps Bounding in place	**Week 1** 20 Sec 20 Sec 5 Reps 10 Sec 30sec/30 Sec 20 Sec 20 Sec	**Week 2** 25 Sec 25 Sec 10 Reps 15 sec 30sec/30sec (side to side and back to front) 25 sec 25sec
Phase II: Fundamentals Wall Jumps Tuck Jumps Jump, jump, jump, vertical Jump Squat Jumps Bounding for distance Double legged cone jumps Scissors jump Hop, hop, stick landing	**Week 3** 30 Sec 30 Sec 5 reps 20 sec 1 run 30sec/30sec 30 sec 5 reps/leg	**Week 4** 30 sec 30 sec 8 reps 20 sec 2 runs 30 sec/30 sec (side to side and back to front) 30 sec 5 reps/leg
Phase III: Performance Wall Jumps Step, jump up, down, vertical Mattress jumps Single-legged jumps distance Squat jumps Jump into bounding Hop, hop, stick landing	**Week 5** 30 sec 5 reps 30sec.30sec 5 reps/leg 25 sec 3 runs 5 reps/leg	**Week 6** 30 sec 10 reps 30 sec/30 sec (side to side and back to front) 5 reps/leg 25 sec 4 runs 5 reps/leg

Table 2. Prevent Injury and Enhance Performance. Gilchrist et al. (2008)

Warm Up	Jog to line of soccer field, shuttle run, backward running
Stretching	30seconds x 2 reps each: calf stretch, quadriceps stretch, inner thigh stretch, hip flexor stretch
Strength	Walking lunges (20 yard x 2), Russian Hamstring (3 x 10), Single toe-raise (30 Reps ea. Side)
Plyometrics	Lateral hops over 2 to 6 inch cone, forward/backward hops over 2 to 6 inch cone, single leg hops over 2 to 6 inch cone, vertical jumps w/ headers, scissors jump
Agilities	Shuttle run with forward/backward running (40 yards), diagonal run (40 yards), bounding run (45-50 yards)

Table 3. FIFA 11+. FIFA (2007)

I. Running exercises, 8 minutes (opening warm up, in pairs; course consists of 6-10 pairs of parallel cones)	
Running straight ahead	x 2
Running hip out	x 2
Running hip in	x 2
Running circling	x 2
Running and jumping	x 2
Running quick run	x 2
II. Strength, plyometrics, balance, 10 minutes (one of three exercise progression levels each training session)	
The Plank:	
Level 1: Both Legs	3 x 20-30 seconds
Level 2: Alternate legs	3 x 20-30 seconds
Level 3: one leg lift	3 x 20-30 seconds
Side Plank:	
Level 1: Static	3 x 20-30 seconds (each side)
Level 2: Dynamic	3 x 20-30 seconds (each side)
Level 3: with leg lift	3 x 20-30 seconds (each side)
Nordic Hamstrings:	
Level 1	x 3-5
Level 2	x 7-10
Level 3	x 12-15
Single Leg Balance	
Level 1: holding ball	2 x 30 seconds (each leg)
Level 2: throwing ball to partner	2 x 30 seconds (each leg)
Level 3: testing partner	2 x 30 seconds (each leg)
Squats:	
Level 1: with heel raised	2 x 30 seconds
Level 2: walking lunges	2 x 30 seconds
Level 3: one leg squats	2 x 10 (each leg)
Jumping:	
Level 1: vertical jumps	2 x 30 seconds
Level 2: lateral jumps	2 x 30 seconds
Level 3: box jumps	2 x 30 seconds
III. Running exercises, 2 minutes (final warm up)	
Running over pitch	x 2
Bounding run	x 2
Running and cutting	x 2

Intensity and duration of programs range from 15 to 120 minutes and programs have been implemented during the season and prior to the start of the athletic season (Noyes and Westin, 2012). Yoo, Lim, Ha, Lee, Oh, Lee, and Kim (2010) conducted a meta-analysis on the effect of neuromuscular training on the prevention of ACL injuries in female athletes and found that while a certain combination of neuromuscular and biomechanical components could not be verified, plyometric and strength training are necessary factors for a prevention program. However, a recent systematic review indicated that injury prevention programs often do not employ common strength training guidelines such as progressive overload (Taylor et al., 2015). Furthermore, Davies, Reimann, and Manske (2015) indicated the most significant contraindication to plyometric training is exposing the athlete to plyometrics before a foundational strength base is developed.

Current ACL injury prevention programming that has included strengthening and plyometrics are reported to be effective in reducing ACL injury rates (Voskanian, 2013); despite the fact the programs do not employ suggested strength training guidelines or the development of relative strength. If strength training is a critical element of these programs, developing programs that adhere to progressive overload and the development of foundational strength prior to plyometric training, as well the development of relative strength should yield more effective injury reduction.

Purpose Statement

The purpose of this program evaluation was to examine both objective and athlete perceived biomechanical outcomes of Block Zero training thought to be associated with ACL injury risk potential. The central hypothesis, which was based on prior strength training literature and observational experiences with Block Zero, was that athletes who increase strength in response to their Block Zero training will increase knee separation distance (a 2-dimensional measure of bi-lateral knee valgus collapse) during the high impact landing of the Drop Jump Screen Test, and that athletes who have participated in Block Zero in the past will report that Block Zero has had a positive impact on jumping mechanics, and will report fewer ACL injuries than athletes that did not participate in Block Zero. The rationale for this study was that demonstrating the implementation of proper strength training protocols which may positively impact knee valgus, future ACL prevention programs will be more effective at reducing the sex-disparity in ACL injuries. Block Zero is a widely implemented program in collegiate and high school strength settings, however, Block Zero has yet to be studied. The *specific aims* were:

Aim 1a: Examine the extent to which Block Zero training increased knee:ankle ratio during the performance of the Drop Jump Screen Test. The working hypothesis was that Block Zero training would increase knee separation during the performance of the Drop Jump Screen test landing from pre- to post- test.

Aim 1b: Determine perceived benefits of Block Zero training through an exploration of knee symptoms and an ability to perform certain tasks during sport participation in past participants of Block Zero. It was hypothesized that past participants of Block Zero would have a positive perception of Block Zero concerning knee symptoms and certain maneuvers during sport participation

Aim 2: To conduct an exploratory analyses of injury data to determine if athletes who participated in Block Zero were less susceptible to ACL injury than those who did not participate in Block Zero. The working hypothesis was that athletes that did not participate in Block Zero would incur more ACL injuries than athletes who participated in Block Zero.

METHODS

Aim 1a

The sample for the study were 9th grade female athletes from multiple sports. All freshmen athletes received Block Zero training. It seemed unwise, and possibly unethical, to use a control group in which an athlete would not receive Block Zero training before more is known about this type of training. Prior to beginning the program, participants were given parent permission forms and consent forms approved by the Universtiy Institutional Review Board (IRB). Only those with parent permission and consent forms were included in the results of the study. Block Zero serves as a foundational strength training program, therefore, these subjects were chosen due to their novice experience in strength and conditioning. The sports represented were girls volleyball, girls softball, girls basketball and girls soccer. There were a total of 13 subjects included in the reporting of results.

Block Zero Training

The Block Zero program utilized in this study was derived from Coach Joe Kenn (2016). The eight week program follows periodization guidelines defined by the National Strength and Conditioning Association (NSCA). Periodization cycles are defined as macro (typically a year), meso (several weeks to several months), and micro (one to four weeks) (Baechle and Earle, 2008). The Block Zero program represents an eight week mesocycle that is divided into two four week microcycles (Table 4, Table 5). The athletes participated for 45 minute sessions three days per week. The daily program was divided into four areas: athletic position, jumping mechanics, stabilization, and relative strength. The eight-week program was divided into two four week phases.

Table 4. Block Zero Cycle 1. Kenn (2008)

Day 1	Day 2	Day 3
	Athletic Position	
Athletic Position Hold x 30 Seconds x 3	Athletic Position Hold x 30 Seconds x 3	Athletic Position Hold x 30 Seconds x 3
Athletic Position to Squat x 5	Athletic Position to Squat x 5	Athletic Position to Squat x 5
Athletic Position to Goodmorning x 10	Athletic Position Lateral Lunge x 3e	Athletic Position to Abduction/Adduction x 10
	Jumping Mechanics Circuit--3 Rounds	
Athletic Position Snap Down x 6	Athletic Position Snap Down x 6	Athletic Position Snap Down x 6
Athletic Position to VJ w/ Stick x 6	Athletic Position to Long Jump w/ Stick x 6	Altitude Drop from 6inch Box w/ Stick x 6
	Stabilization Circuit--3 Rounds	
Back Extension Hold x 30sec	Back Extension Hold x 30 Sec	Back Extension Hold x 30 Sec
Counter Balance Squat x 30sec	Lunge Hold x 15sec. Each Leg	Lateral Lunge Hold x 15sec. Each Leg
Chin Up/Inverted Row Hold x 15 Sec	Push Up Hold x 15sec.	Chin Up/Inverted Row x 15sec.
Front Plank x 30s	Front Plank x 30s	Front Plank x 30s
	Relative Strength Circuit--3 Rounds	
Back Extension x 10	Reverse Lunge x 6e	Russian Hamstrings x 8
Counter Balance Squat x 10	Counter Balance Squat x 10	Counter Balance Squat x 10
Chin Up/Inverted Row x 10	Push Up x 10	Chin Up/Inverted Row x 10
Double Leg Hip Hinge x 10	Flat Footed Sit Up x 10	SL Hip Hinge x 10e

Table 5. Block Zero Cycle 2. Kenn (2008)

Day 1	Day 2	Day 3
	Athletic Position	
Athletic Position Hold x 30 Seconds x 3 Athletic Position to Squat x 5 Athletic Position to Goodmorning x 10	Athletic Position Hold x 30 Seconds x 3 Athletic Position to Squat x 5 Athletic Position Lateral Lunge x 3e	Athletic Position Hold x 30 Seconds x 3 Athletic Position to Squat x 5 Athletic Position to Abduction/Adduction x 10
	Jumping Mechanics Circuit–3 Rounds	
AP to Long Jump then Vertical w/ Stick x 3 Altitude Drop from 12 inch box w/ stick x 6	AP to VJ then LJ w/ Stick x 3 Altitude Drop from 12 inch box w/ stick x 6	AP to Three Jump w/ Stick x 2 Altitude Drop from 12 inch box w/ stick x 6
	Stabilization Circuit–3 Rounds	
Back Extension Hold x 1 min Counter Balance Squat x 30sec Chin Up/Inverted Row Hold x 30 Sec Front Plank x 30s	Band Goodmorning x 12 Monster Walk x 10e Push Up Hold x 30 sec. Front Plank x 30s	Back Extension Hold x 1 min Lateral Lunge Hold x 30 sec. Each Leg Chin Up/Inverted Row x 30 sec. Front Plank x 30s
	Relative Strength/ General Strength Circuit--3 Rounds	
Rotational Back Ext x 6e Pause Goblet Squat x 10 Chin Up/Inverted Row x 12 Russian Hamstrings x 10	Goblet Reverse Lunge x 6e Counter Balance Squat x 10--3 Sec. Pause @ Bottom Push Up x 12 OH Sit Up x 15--10lb. Plate	Russian Hamstrings x 10 Goblet Split Squat x 10e Chin Up/Inverted Row x 12 SL Hip Hinge w/ Pause x 10e

Phase two progressed in intensity reflecting the principle of progressive overload. Exercises increased in repetitions or by adding time. The athletic position aspect area of the program placed an emphasis on the power position and landing position. During the jumping mechanics portion of the program, athletes were introduced to low intensity plyomtetrics. Prescription of repetitions for plyometrics were well below the recommendations set forth by the NSCA for novice athletes (3 sets of 6 for a total of 18 foot contacts). Stabilization involves isometric strength. Participants of Block Zero performed upper and lower body exercises and held the isometric contraction for prescribed time

The final area, relative strength, placed the athlete through upper and lower body exercises without an external load. Intensity was manipulated through reps, time, and tempo. Athletes performed five isometric exercises for time during pre and post training to measure increases in isometric strength: chin up hold, isometric push up, isometric single leg glute bridge, isometric split squat, and isometric squat.

Drop Jump Screen Test

Before an athlete could complete the Drop Jump Screen Test, she had to first understand how to perform it. The test itself required each athlete to step onto a 12-inch plyometric box. Next, the athlete stepped off the box, landed on both feet and immediately performed a vertical jump. Athletes were allowed to practice the Drop Jump Screen Test and demonstrate the ability to perform the test prior to evaluation.

Video recording of the Drop Jump Screen Test was used to analyze knee:ankle ratio during the landing of the test. Prior to Block Zero training, athletes performed the Drop Jump Screen Test. Athletes also performed the Drop Jump Screen Test at the conclusion of the eight-week Block Zero training cycle. To account for a learning effect, each athlete performed the jump three times for both pre and post testing. Each athlete was recorded using an iPad. An average was determined from all three jumps. Video was uploaded to ImageJ software downloaded from https://imagej.nih.gov/ij/. Once the video was uploaded, a still image was used depicting the Drop Jump Screen Test at the lowest point of the landing to assess the knee:ankle ratio. To determine the knee:ankle ration during the landing, the box size was measured in pixels on the screen and compared to the actual size of the box. Then, it was compared to the distance between knees and distance between ankles in pixels; then the pixels were correlated to inches. The distance between the knees was divided by the distance between the ankles to determine the knee:ankle ratio.

Strength Testing

Four isometric exercises were tested pre and post intervention: single leg (SL) hip bridge for both legs, single leg (SL) lunge for both legs, body weight squat, and chin up hold. All exercises were performed for maximum time. The use of isometric strength exercises stems from the use and research regarding flex arm hang, which is utilized by the Fitnessgram and the United States Military as an assessment of upper body strength. Clemons et al. (2004) found the flex arm hang, or chin up hold, to be a reliable test to measure weight-relative strength. The results of the flex arm hang, an isometric contraction, as a viable method to develop relative strength supports the use of bodyweight exercises in Block Zero. The use of isometric contractions to measure strength is further supported by Earl and Hoch (2011) who used isometric core holds for time to measure core strength and isometric contractions to measure hip adduction and abduction strength.

Aim 1b

This portion of the study required athletes within the last three years that have gone through Block Zero training to fill out a survey. Girls soccer (GSOC), girls volleyball (GVB), and girls basketball (GBKB) head coaches called team meetings with tenth through twelfth graders. The principle investigator attended the meetings and explained the purpose of the survey. For athletes that were interested in doing the survey, the investigators sent home a letter of consent for their parents to give the athletes permission to fill out the survey. Once the athletes were chosen based on parental consent, the investigators distributed the survey through email and asked surveys to be returned within two weeks.

Survey and Data Collection

The Knee Outcome Survey (KOS) Sport Activity Scale (SAS) was utilized to survey past participants on how symptoms affect sport activity and how the knee affects the ability to perform certain tasks during sport activities (Table 6). The first survey was completed for current perceptions of Block Zero. For further analysis, subjects were asked to complete the survey a second time recalling knee symptoms prior to starting Block Zero training. The survey has a total of 11 questions with 6 possible responses. From left to right response values are 5 (not difficult at all), 4, 3, 2, 1, 0 (unable to do). The point values are added together and divided by 55 and multiplied by 100 for the SAS score. Differences between each survey scores were calculated to determine a total number of positive, negative, or no change scores.

Table 6. Knee Outcome Sport Activity Scale. Irrgang et al. (1998)

	Never Have	Have, but does not affect my sports activity	Affects sports activity slightly	Affects sports activity moderately	Affects sports activity severely	Prevent me from all sports activity
Pain	○	○	○	○	○	○
Grinding or Grating	○	○	○	○	○	○
Stiffness	○	○	○	○	○	○
Swelling	○	○	○	○	○	○
Slipping or partial giving away of knee	○	○	○	○	○	○
Buckling or full giving way of knee	○	○	○	○	○	○
Weakness	○	○	○	○	○	○
Functional Limitations with Sport Activities: How does your knee affect your ability to: (click one answer on each line)						
	Not difficult at all	Minimally difficult	Somewhat difficult	Fairly difficult	Very difficult	Unable to do
Run straight ahead	○	○	○	○	○	○
Jump and land on your involved leg	○	○	○	○	○	○
Stop and start quickly	○	○	○	○	○	○
Cut and pivot on your involved leg	○	○	○	○	○	○

Aim 2

Data Collection of ACL Injury Rates.

To determine the effect of Block Zero on incidence of ACL injuries compared to past ACL injury incidence rates on those not trained with Block Zero, data collection occurred in three different sports. The principle investigator worked with the athletic training staff at the host high school to gather ACL injury data on teams that had been trained with Block Zero over the last four years: girls basketball (GBKB), girls volleyball (GVB), and girls soccer (GSOC). The total number of athletes for each sport for each year were also requested. Email correspondence was sent to three area high school athletic trainers asking for permission to use ACL injury data for GBKB, GVB, and GSOC, as well as the total number of athletes for each year **or sport.** Permission was granted and a request was sent to school administration to use unidentifiable information for ACL injury data.

RESULTS

Aim 1a

Aim 1a examined the difference in knee:ankle ratio during the initial landing of the drop jump screen test from pre to post intervention and measured the difference in isometric strength movements from pre to post intervention. A paired t-test was used to demonstrate change in knee:ankle ratio and strength changes from pre- to post-intervention. Spearman's correlation was used to estimate strength of association between strength gains from SL hip bridge for both legs, SL lunge for both legs, and body weight squat with changes in knee separation for both pre- and post-intervention. To account for a learning effect of the Drop Jump Screen test, each athlete performed it three times and an average was calculated for the three jumps.

For Aim 1a, results indicated a statistically significant difference in knee:ankle ratio from pre to posttest; $t(12)=-4.543$, $p<.001$ (Table 7). On average, knee:ankle ratio increased from pre (.887) to post (1.148). Only one subject did not increase knee:ankle ratio from pre (1.013) to post (0.987). Strength was also measured from pre to post intervention. On average, each exercise tested increased from pre to post (Table 6). Single leg lunge increased from 22.615 seconds to 31.385 seconds on the left leg ($t(12)=-13.658$, $p<.001$) and 24.308 seconds to 33.462 seconds on the right leg (t(12)=-11.338, p<.001). Single leg glute bridge increased from 23.077 seconds to 32.846 seconds on the left leg (t(12)=-11.834, p<.001) and 25.308 seconds to 36.000 seconds on the right leg (t(12)=-11.956, p<.001). An increase from 33.000 seconds to 44.077 seconds was observed for the body weight squat hold (t(12)=-12.000, p<.001).

For Aim 1a, the relationship between increases in knee:ankle ratio and increases in strength were calculated. For each exercise tested, the correlation was statistically significant at the .001 level (Table 8).

Aim 1b

To support Aim 1a, the Knee Outcome Survey (KOS) Sport Activity Scale (SAS) was used to determine perceptions from athletes that had previously participated in Block Zero. Participants were asked to complete the survey twice. The first survey was completed for current perceptions of Block Zero. The second survey was completed asking the participants to recall perceptions prior to starting Block Zero. Even though these were recall data, they were deemed interesting in support of Aim 1a results. McNemar's test for correlated proportions was used to test for differences between positive and negative changes in survey responses.

A total of 33 responses were recorded from the first survey distribution. There were twenty four responses from the second survey distribution. For the purposes of statistical analysis, only subjects that responded for both survey distributions were used, a total of twenty four. Sixteen subjects reported a positive perceived benefit (66.6%), six reported a negative perceived benefit, and two reported no change. Statistical analysis indicated participants were more likely to report a positive effect of the program (p=0.026).

Aim 2

Aim 2 utilized confidence intervals to compare ACL injury rates at the host high school with injury rates at three area high schools among girl's basketball, girl's volleyball, and girl's soccer (Table 9). Confidence intervals for injury rates from each sport at the three area high schools compared to the host school showed that the proportion could be either higher or lower, therefore, it cannot be concluded statistically that the proportion of injuries at the host school would be higher than the other three schools. However, injury rates were consistently higher at the other three schools regardless of sport except girl's volleyball, where two schools reported zero injuries (Table 10).

Table 7. Descriptive Statistics and T-Test Results for Knee:Ankle Ratio and Strength Exercises

	Pretest		Postest			95% CI for Mean				Sig.
	Mean	SD	Mean	SD	n	Difference		t	df	(2-tailed)
Knee:Ankle Ratio	0.887	0.175	1.148	0.124	13	-0.387	-0.136	-4.543	12	0.001
Left Leg Isometric Lunge	22.615	3.330	31.385	3.927	13	-10.168	-7.370	-13.658	12	0.000
Right Leg Isometric Lunge	24.308	2.428	33.462	4.332	13	-10.913	-7.395	-11.338	12	0.000
Left Leg Isometric Glute Bridge	23.077	5.251	32.846	5.242	13	-11.568	-7.971	-11.834	12	0.000
Right Leg Isometric Glute Bridge	25.308	7.123	36.000	7.106	13	-12.641	-8.744	-11.956	12	0.000
Isometric Bodyweight Squat	33.000	6.468	44.077	6.184	13	-13.088	-9.066	-12.000	12	0.000

Table 8. Spearman Correlation of Difference in Average Knee:Ankle Ratio and Difference in Average of Strength

		Difference in Average Knee:Ankle Ratio	Difference in Average Left Leg Isometric Lunge
Difference in Average Knee:Ankle Ratio	Correlation Coefficient	1.000	.976**
	Sig. (2-tailed)		0.000
	N	13.000	13.000
Difference in Average Left Leg Isometric Lunge	Correlation Coefficient	.976**	1.000
	Sig. (2-tailed)	0.000	
	N	13.000	13.000

** Correlation is significant at the 0.01 level (2-tailed).

		Difference in Average Knee:Ankle Ratio	Difference in Average Right Leg Isometric Lunge
Difference in Average Knee:Ankle Ratio	Correlation Coefficient	1.000	.906**
	Sig. (2-tailed)		0.000
	N	13.000	13.000
Difference in Average Right Leg Isometric Lunge	Correlation Coefficient	.906**	1.000
	Sig. (2-tailed)	0.000	
	N	13.000	13.000

** Correlation is significant at the 0.01 level (2-tailed).

		Difference in Average Knee:Ankle Ratio	Difference in Average Left Leg ISO Lunge
Difference in Average Knee:Ankle Ratio	Correlation Coefficient	1.000	.974**
	Sig. (2-tailed)		0.000
	N	13.000	13.000
Difference in Average Left Leg Isometric Glute Bridge	Correlation Coefficient	.974**	1.000
	Sig. (2-tailed)	0.000	
	N	13.000	13.000

** Correlation is significant at the 0.01 level (2-tailed).

		Difference in Average Knee:Ankle Ratio	Difference in Average Right Leg Isometric Glute Bridge
Difference in Average Knee:Ankle Ratio	Correlation Coefficient	1.000	.943**
	Sig. (2-tailed)		0.000
	N	13.000	13.000
Difference in Average Right Leg Isometric Glute Bridge	Correlation Coefficient	.943**	1.000
	Sig. (2-tailed)	0.000	
	N	13.000	13.000

** Correlation is significant at the 0.01 level (2-tailed).

		Difference in Average Knee:Ankle Ratio	Difference in Average Isometric Body Weight Squat
Difference in Average Knee:Ankle Ratio	Correlation Coefficient	1.000	.732**
	Sig. (2-tailed)		0.004
	N	13.000	13.000
Difference in Average Isometric Body Weight Squat	Correlation Coefficient	.732**	1.000
	Sig. (2-tailed)	0.004	
	N	13.000	13.000

** Correlation is significant at the 0.01 level (2-tailed).

Table 9. Confidence Intervals Comparing Injury Rates at Host School to Area Schools

	Confidence Interval	
Girls Basketball	Lower	Upper
Host School School 2	-0.0456	0.0537
Host School School 3	-0.0313	0.0757
Host School School 4	-0.0368	0.0705

	Confidence Interval	
Girls Volleyball	Lower	Upper
Host School School 2	-0.0234	0.0396
Host School School 3	-0.0172	0.0696
Host School School 4	-0.0117	0.0765

	Confidence Interval	
Girls Soccer	Lower	Upper
Host School School 2	-0.0158	0.0632
Host School School 3	-0.0249	0.0403
Host School School 4	-0.0219	0.0515

Table 10. Injury Ratios

	Host School	School 2	School 3	School 4
Girls BB	0.018	0.020	0.037	0.031
Girls VB	0.007	0.000	0.027	0.000
Girls Soccer	0.011	0.030	0.018	0.022

Ratios were calculated based on injured athletes of athletes over a four year period and the total number of athletes over a four year period for each sport. The host school demonstrated a 0.018 ratio of ACL injury in girls basketball compared to school two (.020), school three (.037) and school four (.031). Girls soccer ratios were also higher at school two (.030), school three (.018), and school four (.022) compared to the host school (.011). The injury ratio for volleyball at the host school (.007) was lower than school three (.027), however, both school two and school four reported zero ACL injuries for girls volleyball over the last four years.

DISCUSSION

Aim 1a

Results of this program evaluation indicate that participants experienced increased knee:ankle ratio separation from pre to post test, as well as increased relative strength from pre to post test. Correlational evidence indicates that a positive increase in strength may result in a positive increase in knee:ankle ratio. Prior research indicates that females are at greater risk of ACL injury due to decreased flexion and an increase in knee valgus (Campbell et al, 2014). Video analysis conducted by Krosshaug et al. (2007) found that female basketball players demonstrated a 5.3 times higher relative risk of sustaining a valgus collapse at the time of injury when compared to male basketball player. While a direct casual effect cannot be established due to the lack of a control group, results suggest that Block Zero may have had a positive impact on knee:ankle ratio and a positive impact on strength.

In a study designed to examine the effects of a strengthening program on patellofemoral pain syndrome (PFPS), Earl and Hoch (2011) found that strengthening and improving neuromuscular control of the hip and core musculature improved hip and core strength, as well as reducing the knee abduction moment. Subjects in the Block Zero program participated in various exercises that focused on the development of relative strength of the hips and core musculature. Findings indicated that a strong linear positive relationship exists between increased strength gains from the exercises measured and increased knee:ankle ratio (Figure 1, Figure 2, Figure 3, Figure 4, Figure 5). These results address Aim 1a and are supported by Earl and Hoch (2011) with increased knee:ankle ratios and increases in relative strength, however, due to the nature of this study, future research is needed to confirm this relationship between relative strength and knee:ankle ratio using larger groups of subjects.

Aim 1b

The results of the KOS SAS indicated Block Zero may have had a positive effect on perceived biomechanical outcomes based on participant responses. Participants who completed the KOS SAS on average reported positive perceptions of Block Zero training. Eisner, Elder, Sinclair-Elder and Kelly (2014) examined the importance of strength and conditioning on increased athletic performance in college athletes through the use of a survey. Results of this study indicated athletes believed strength and conditioning was important to the overall development of athletic performance. This included a perception that strength and conditioning helped prevent injuries. Low motivation to implement injury prevention programs is a common barrier reported by Bogardus (2013). Kiane et al. (2010) reported thirty six coaches declined to implement injury prevention programs due to skepticism about the effectiveness of the programs. These test results and positive perceptions toward strength and conditioning having a positive effect on injury prevention may be a positive step in offering a reason for strength professionals and coaches to experiment with implementing a Block Zero training program.

Aim 2

Results addressing Aim 2 suggest the host school demonstrated a lower injury rate with the exception of girls volleyball compared to other schools. These results were not calculated using the standard of strictly comparing ACL injuries to athlete exposures as used in previous studies (Agel, Rockwood and Klossner, 2016; Hootman, Dick, and Agel, 2007; Renata et al., 2011). Due to the unavailability of data, the total number of athletes for each sport over a four year period compared to the number of ACL injuries over a four year period was utilized to calculate a ratio of ACL injuries. While results addressing Aim 2 were not significant, they do suggest that athletes at the host school may have experienced a lower ratio of ACL injuries as compared to the other schools. Further research is warranted using existing ACL injury rate exposure from various schools comparing those that use Block Zero training versus those that use other forms of training.

CONCLUSION

If the results of this study hold true in future studies, Block Zero training could have an impact on reducing pain and suffering for numerous female (and possible male) young athletes by reducing the rate of ACL injury. Curbing the rate of ACL injury can also impact the financial burden associated with ACL injury (Hewett and Johnson, 2010). ACL injuries can have devastating effects on athletes: loss of playing time, loss of scholarships, season ending injuries, and the onset of osteoarthritis (Hewett and Johnson, 2010). Block Zero training might impact the way in which strength and conditioning professionals train younger athletes, therefore, alleviating or curbing the devastating effects of ACL injuries.

Figure 1. Difference Average Knee:Ankle Ratio to Difference Pre-Post Strength for Left Leg ISO Lunge

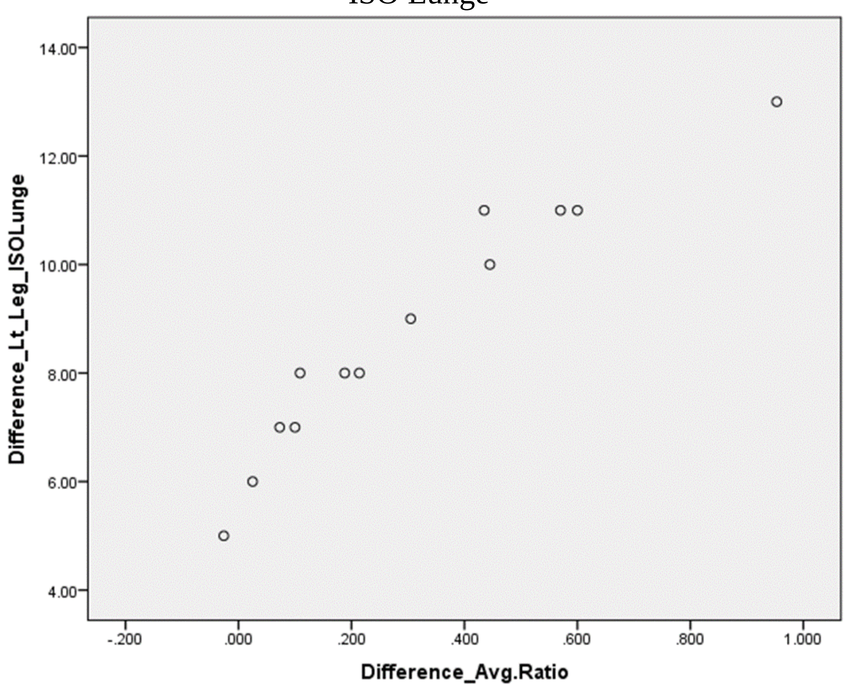


Figure 2. Difference Average Knee:Ankle Ratio to Difference Pre-Post Strength for Right Leg ISO Lunge.

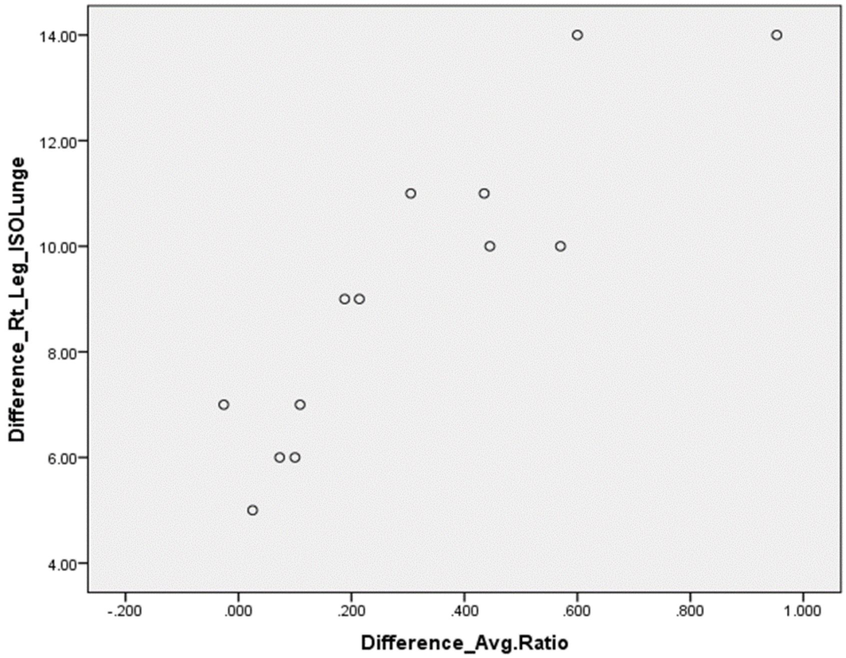


Figure 3. Difference Average Knee:Ankle Ratio to Difference Pre-Post Strength for Left Leg ISO Glute Bridge

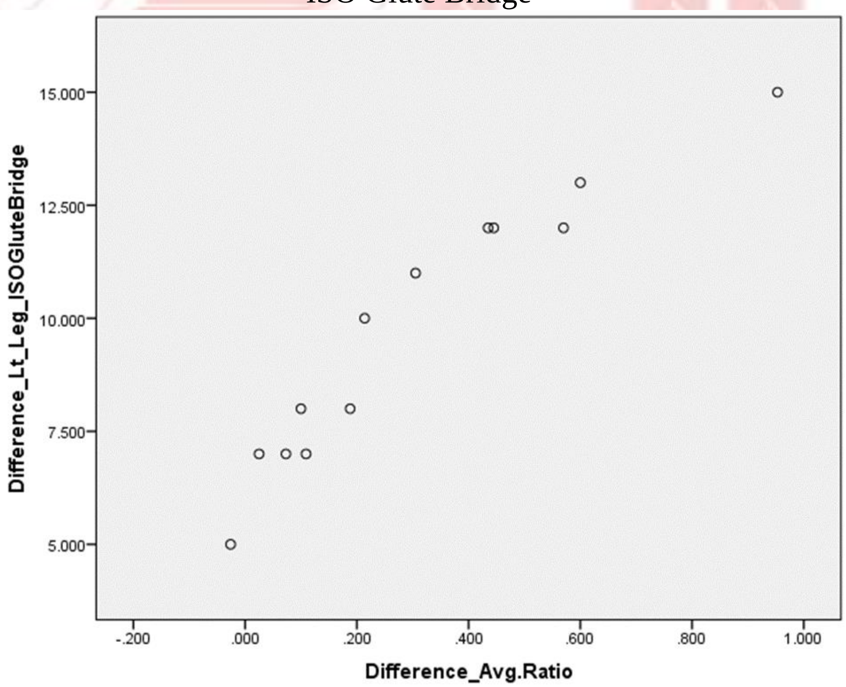


Figure 4. Difference Average Knee:Ankle Ratio to Difference Pre-Post Strength for Right Leg ISO Glute Bridge

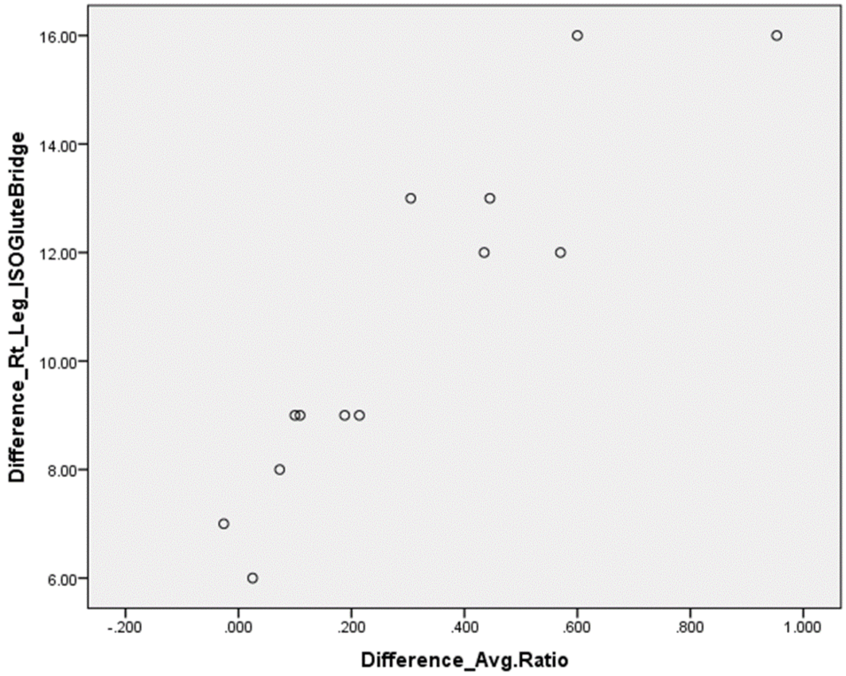
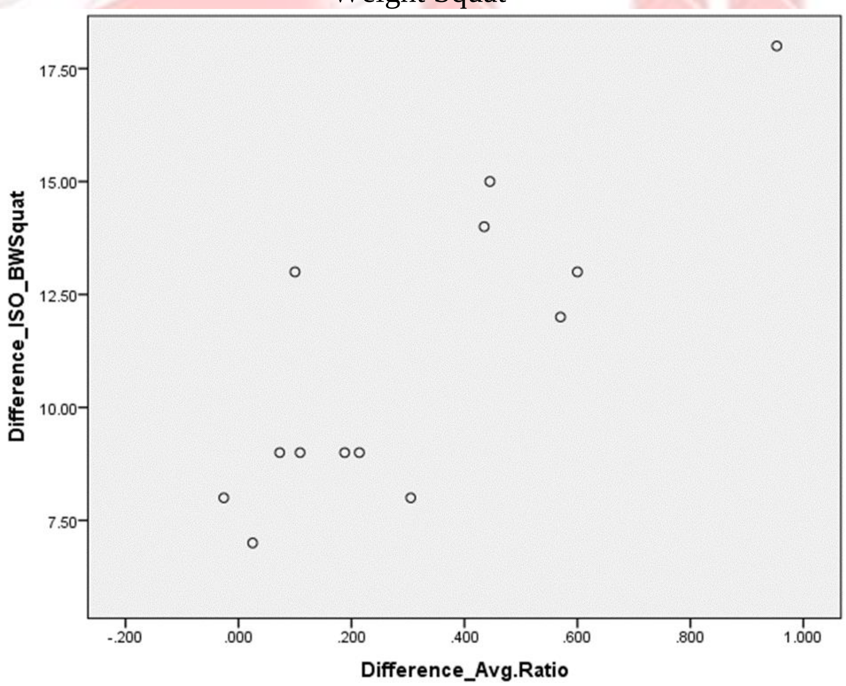


Figure 5. Difference Average Knee:Ankle Ratio to Difference Pre-Post Strength for ISO Body Weight Squat



Conflict of interest declaration

The authors have no conflict of interests.

Ethics

Institutional Ethics Research Committee approval was obtained for the study procedure. The study conformed to the provisions of the Declaration of Helsinki.

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