RESEARCH

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Establishment and Evaluation of an Anterior Cruciate Ligament Injury Prevention Program

Rebecca Liebert

BACKGROUND: In female high school athletes, soccer continues to be a high-risk sport for sustaining an anterior cruciate ligament injury. Literature reviews indicate the best injury prevention programs (IPPs) focus on increasing core strength and proprioception in this age group.

PURPOSE: An IPP was created for a small Midwestern high school girls' soccer team. The goal of the study was to evaluate the effectiveness of the IPP on core strength and proprioception.

METHODS: The IPP incorporated functional movement applied science and exercises. Students were tested pre- and postseason. Results were analyzed using paired-samples *t* tests.

RESULTS: Statistically significant results in improved core measures were noted.

CONCLUSION: This IPP, which utilized functional movement and training, could be utilized by other teams for increasing core strength and proprioception of players, as well as adding to the body of literature utilizing functional movement.

Introduction

As young athletes become more and more competitive, the risk for lower extremity injuries increases as well. Injuries may be noted to the bony architecture, as seen in fractures and Osgood-Schlatter's disease, or may affect the ligaments and muscles. One of these ligaments, the anterior cruciate ligament (ACL), is a significant stabilizer in the knee, and an injury to this can be a devastating event for a young athlete. It has been noted that female athletes, particularly those in the postpubescent age, are at a three times greater risk for injury to the ACL than same-age male counterparts (Dharamsi & LaBella, 2013; Sutton & Bullock, 2013; Zazulak, Hewett, Reeves, Goldberg, & Cholewicki, 2007). The injury initially causes pain, followed by disability during the treatment and recovery phase (often lasting 9–12 months), may involve significant expense (\$17,000-\$88,000 per injury), and cause long-term consequences to the athlete (Dharamsi & LaBella, 2013; Mather et al., 2013). Risk factors erroneously thought to be the reasons these postpubescent female athletes were at risk included anatomical differences (narrow quadriceps [Q] angle, narrow intracondylar notch), hormonal changes (Griffin et al., 2000; Postma & West, 2013; Sutton & Bullock, 2013), lack of experience (Sutton & Bullock, 2013), and even poor coaching. Recently, studies have suggested the greatest risk for ACL injury is weak core strength and decreased proprioception, which are modifiable risk factors (Dharamsi & LaBella, 2013; Griffin et al., 2000; Postma & West, 2013; Sadoghi, vonKeudell, & Vavken, 2012; Sutton & Bullock, 2013; Walden, Atroshi, Magnusson, Wagner, & Hagglund, 2012; Zazulak, Cholewicki, & Reeves, 2008; Zazulak et al., 2007). If an injury prevention program (IPP) was designed to address core strength and proprioception, would the postpubescent female athlete have a decreased risk of an ACL injury?

Purpose

The purpose of this study was to evaluate an ACL IPP that was created on the basis of evidence of the best means of reducing these modifiable risk factors, that is, increasing core strength and proprioception. Exercises from functional and applied kinesthetic science were used as the basis for creating this program, as well as principles for creating success in a sports season with young female athletes, coaches, and athletic trainers. The problem statement for this study was as follows: "In female athletes participating in soccer (a noncontact sport), will participation in an ACL IPP increase core strength and proprioception over the course of a sports season?" The hypothesis was that participation in the IPP would increase core strength and proprioception at the end of the sports season. Independent variables were the measures of core strength and proprioception, determined by six tests. Dependent variables were preand postseason testing results.

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The author has disclosed no conflicts of interest. DOI: 10.1097/NOR.00000000000245

Literature Review

A literature search was conducted on CINAHL, MEDLINE, PubMed, and EBSCO utilizing delimiters of "peer reviewed," "anterior cruciate ligament," "female athlete," and "injury prevention." The focus of the search included evaluation of existing IPPs and studies predicting risk for ACL injury. In addition, searches from The Journal of the American Academy of Orthopaedic Surgeons and well as The Journal of Bone and Joint Surgery were conducted. The number of articles from all sources was narrowed to 149. Numerous articles were utilized from collaborating disciplines, such as physical therapy, strength and conditioning, research journals, and theory articles. Studies and articles were included if they were less than 6 years old, although some studies were reviewed for historical significance, because frequency of injury of the ACL in the female athlete has been documented in literature since the 1990s. Multiple Level 1 (strong evidence in randomized controlled trials, cohort studies) and Level 2 (prospective cohorts) studies were used, as well as several meta-analyses and systematic reviews.

ANATOMICAL DIFFERENCES

Compared with males, females have a narrower intracondylar notch, more narrow Q angle, hormonal fluctuations, and decreased quadriceps strength (Boden, Sheehan, Torg, & Hewett, 2010; Dharamsi & LaBella, 2013; Postma & West, 2013; Sutton & Bullock, 2013). In addition, female athletes were noted to have decreased core strength and proprioception (Zazulak et al., 2007). These areas of weakness cause the female athlete to land with an increased valgus stance, have poorer neuromuscular and quadriceps control in maneuvers, increased dependence on bones for landing technique versus muscle strength, and have weaker cores causing trunk instability with poor balance techniques (Boden et al., 2010; Dharamsi & LaBella, 2013; Griffin et al., 2000).

INCREASED RISK OF INJURY

The greatest increase of ACL injuries has been noted in the female soccer athlete, particularly between the ages of 16–18 years (some studies noted the ages of 15–19 years), and these females were at 3:1 increased risk of injury to the ACL compared with the same-age male athlete (Bien, 2011; Dharamsi & LaBella, 2013; Noyes, Barber-Westin, Tutalo-Smith, & Campbell, 2013; Sutton & Bullock, 2013). Ford, Shapiro, Myer, Van Den Bogert, and Hewett (2010) noted a significant increase in injuries in female athletes who have commenced puberty.

INJURY PREVENTION PROGRAM

In order for an IPP to be successful, several components must be present. First, the program must contain measures to strengthen the core and involve neuromuscular control (Bien, 2011; LaBella et al., 2011; Postma & West, 2013; Walden et al., 2012; Zazulak et al., 2007). Neither the meta-analyses nor the Level 1 studies were able to determine what the best specific exercises were. Second, the IPP needs to be between 15 and 20 minutes, which makes it easier to learn, and is more replicable in the off-season (Gilchrist et al., 2008; LaBella et al., 2011; Pfile et al., 2013). Third, a program should be low cost, with little equipment necessary, and easy to implement (Swart et al., 2014). For this IPP, functional science literature was examined for exercises to incorporate those exercises that would include functional movement, as sports occur in motion, versus static strengthening (Bien, 2011; Myer, Ford, Palumbo, & Hewett, 2005; Noyes et al., 2013; Reid, Birmingham, Stratford, Alcock, & Giffin, 2007; Zazulak et al., 2008).

Components of the IPP

On the basis of the aforementioned literature review, a 15-minute program was developed that involved no additional costs or equipment other than utilized by the soccer team already. The exercises chosen in this program were based on functional movement and consisted of five exercises: the common lunge matrix (see Figure 1), single leg hop, single leg deadlift, soccer ball toss, and shuttle run. Most of the exercises were simple to begin with and then progressed to an advanced level for the athlete ready to safely advance. The common lunge matrix, developed by Gary Gray of the Gray Institute (www. gravinstitute.com), has been rigorously tested for strength training. YouTube videos are available to learn how to perform these exercises (https://www.youtube. com/watch?v=hNdfemgY9KI). In addition, the researcher produced videos of these exercises for demonstration purposes for the participants. The common lunge matrix uses functional movement of lunges in the frontal, sagittal, and transverse planes (see Figure 1). These exercises were performed in a rotation, alternating right and left legs (Myer et al., 2005). With increasing strength, athletes could progress to a lunge hop. This rotation lasted about 5 minutes. The single leg hop (Myer et al., 2005) had athletes alternating hopping on each leg for 15-second intervals for 2 minutes. As athletes progressed, they could advance to hopping forward and backward, as well as lateral and rotational hops. A single leg deadlift (Bien, 2011) was performed for 3 minutes. Again, this exercise could be progressed to hopping, as well as using a water or sports bottle to lift as an added weight to increase core strengthening and stability. The soccer ball toss (Bien, 2011; Cowley & Swensen, 2008) was performed standing on one leg, which increased core stability while throwing. This exercise was done with a partner and lasted about 2 minutes. Finally, the team was divided into partners for a shuttle run incorporating forward/reverse/lateral and karaoke (also known as grapevine) running styles (https://www.youtube.com/ watch?v=maI6ZXtoYsA). This lasted approximately 3 minutes. These exercises involved only the student and inexpensive accessories-water bottles and soccer balls, both of which were an integral part of practice.

Theory

The Promoting Action on Research Implementation in Health Services (PARIHS) framework was utilized as the basis of this project. PARIHS puts evidence-based practice into action (Ciliska et al., 2011). Stetler,

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Soccer Exercises











Take a step with one foot and reach the opposite hand down past the knee that is moving. As you do this you should slide your hip to the side as shown in the orange arrows. Then you should return to the original starting position, by pushing up off of the mobile foot. This should be felt deep in the buttock muscles.

Left Anterior \rightarrow Right Anterior \rightarrow Left Lateral \rightarrow Right Lateral \rightarrow Left Rotational \rightarrow Right Rotational

FIGURE 1. Soccer exercises.

Damschroder, Helfrich, and Hagedorn (2011) developed a guide for use of this model. Their guide is task based, which was appropriate for this project. Evidence-based characteristics for this framework includes evaluating research and guidelines (literature reviews), evaluating the local environment for change (school and coaches were supportive), consideration of costs (none to minimal), and compatibility of the practice change. Contextual readiness for implementation included the culture, targeted group, and leadership support, which were sought by the athletic director, coaches, students, and school board. The researcher needed both expectations and activities to be discussed with the participants



Single LegBalance Deadlift:

You start by balancing on one legand touching the other toe just for balance as needed. Your opposite hand should be holding the water bottle and reaching down past your balancing ankle, and then up and back over your opposite shoulder. You should feel this in your buttook and hemstrings as you reach down and forward. Then you should feel it in your abdominals as you reach back over head.



Soccer Ball Toss:

Balancing on one leg or with the opposite toe down as needed, and throw the soccer ball back and forth with a partner. Catch it back over overhead and then use your abdominal musd esto help throw it back to your partner, like you would in an out of bounds throw in. Catch and throw it straight overhead and then back over each shoulder in order to work all of your abdominal musd es. This should work on your balance and abdominal musd es

(which included parents as well), availability on-site for interaction with others (both at practice and at games to answer questions of parents), and able to identify the purpose of this change. Finally, successful implementation of this model included development of the plan, including clinical interventions (development of the IPP), matching patient (increased core strength and proprioception), and organizational (decreased injuries) outcomes, with evaluation of their success (postseason testing) and remaining focused on interventions that will be evaluated prospectively, while examining strengths and weaknesses of the study during implementation as well as retrospectively.

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Methods

SAMPLE

A total of 49 subjects participating in soccer at a small Midwestern high school were asked to participate in the study. The sample was a convenience sample, including all students participating in soccer, as the IPP was going to become part of the practice warm-up. Educational information was given at team meetings for students and parents, allowing for question and answers. E-mail addresses and phone numbers of researchers were provided for students. Students were assured that failure to complete postseason testing would not affect their playing time in games. Students younger than 18 years had parental assent; those 18 years and older completed consents. The investigational review board of Graceland University of Independence, Independence, MO, approved the study. School board, athletic director, athletic trainer, and coach approval was sought before conducting the program. Confidentiality of participants was ensured, as each student was assigned a random number for testing. Demographic sheets with identifying information were only available to the primary researcher and kept off-site. Two students were injured preseason and unable to test. Sixteen more students were unable to complete postseason testing (two quit, two were not allowed because of academic performance, four had other injuries [head, arm, hip], and eight students were unable to attend the postseason testing sessions). Thirty-one students completed the program.

EDUCATION OF ATHLETES

The athletes were given educational material in multiple ways to ensure proper form of doing the exercises. The team captain was videotaped performing all the exercises, and these tapes were provided on the team social media page for review before and during the season. The athletic trainer was photographed doing the exercises, and a training sheet was given to the students as well as the coaches for referral. The primary and secondary investigators attended practice three times weekly the first 4 weeks and then once weekly to monitor the students' form during practice. The investigators made themselves available for questions of the students to ensure safety and competency during the exercises at practice, as well as at home games to meet with parents and answer questions if needed.

DATA COLLECTION

Data were collected pre- and postseason by the investigators of the study. The testing stations included validated exercises determined from the literature review as measures of core strength and neuromuscular control.

INSTRUMENTS

General Demographics

Each participant completed a demographic sheet (see Figure 2). Figure 2 noted name, assigned identification

number for confidentiality, birth date, parental assent or student consent, onset of menarche, and assessment of access to social media and educational materials. Figure 3 noted ID number, height, weight, body mass index, as well as testing measures described in the following text.

Functional Pre- and Postseason Testing

The Star Excursion "Y balance" test is considered a gold standard for neuromuscular control, as there is little room for testing error, it has proven reliability and validity, and it tests movement in multiple directions in a short amount of time (Bien, 2011; Plisky, Rauh, Kaminski, & Underwood, 2006). To increase reliability of these results, two individuals trained in proper testing, conducted both pre- and postseason testing. Additional tests included the single leg hop and hold (Reid et al., 2007), triple crossover hop (Lim et al., 2009; Mandelbaum et al., 2005; Reid et al., 2007), superman (Bien, 2011), and the shuttle run ("T" test) for speed and agility (Lim et al., 2009; Mandelbaum et al., 2005; Noves et al., 2013; Semenick, 1990). The measurement of hip internal and external range of motion was completed by the same investigator pre- and postseason to reduce risk of interrater reliability error (see Figure 3).

Likert Scale for Subjective Evaluation of Program

As this program was new to the school soccer program, student athletes were asked to evaluate the program using a Likert scale (see Table 1). The Likert scale ranged from 1 to 5, with 1 being "strongly disagree" and 5 "strongly agree." Components of this evaluation included ascertaining if the program was easy to learn, if the educational materials were helpful, and if this program would be replicable in the off-season.

DATA ANALYSIS

All data were analyzed using SPSS software (SPSS, Chicago, IL). Statistical methods included paired-samples t tests, evaluating pre- and postseason core measures.

Results

For all paired-samples *t* tests, the α level was .05. The total degree of freedom (*df*) was 30 (31 - 1 = 30). The critical value for the *t*-test statistic, two-tailed test equal $t = \alpha/df$, t = .05/30 = 2.042. Each measure of pre- and postseason testing was compared. A total of 25 pairs of data sets were evaluated. Samples from each test are included in Table 2.

Findings noted overall improvement of the athletes' core strength and proprioception. Abdominal strength improved as evidenced by the simple superman test (p = .01, mean improved 9 seconds; see Figure 4). Speed and agility improved as noted in the shuttle run test (p = .02), although the difference in time improvement for the test was less than 1 second. The single leg hop and hold had varied findings, with no significant improvement noted on the right (p = .29) or left

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Name	ID No
Birthday	Year in School: 9 10 11 12
Consent signed Assent s	igned
Have you ever had a knee injury b	pefore? Yes No
Right Left Bo	th
Have you begun menstruating? Yes what year did you star	rt?No
Check if you have access to the fo	llowing:
Internet YouTube	Facebook
Brochure received	

FIGURE 2. Participant demographic sheet.

(p = .23) single leg hop, or the right triple crossover and hold (p = .88). However, the left triple crossover and hold improved significantly (p = .01). Hip external and internal rotation improved in both hips significantly (all with p = .001, except right hip internal rotation p = .002; see Table 2). The Y balance test evaluates each leg in six directions each, for a total of 12 different findings (see Figure 5). Seven of 12 measures noted statistically significant improvement (p < .05). Of the five measures that did not show statistically significant changes, four of five applied to the right lower extremity (see Figure 6).

The students were asked to evaluate the program. Thirty-one students responded. As some students did not watch the social media videos, the number of respondents to those questions was less than 31 (see Table 1). Results from the student evaluation were positive, with scores ranging from 3.03 to 4.54 on the Likert scale. Evaluation of two main goals of this IPP, (1) that exercises were easy to learn and (2) the exercises would be replicable in the off-season, scored between "agree"

and "strongly agree" (scores >4.16). This indicated that these goals were achieved.

Discussion

The pre- and postseason scores noted improvement in many tests. Significance was noted in seven of 12 measures of the Y balance test. Hip internal and external rotation improved (p < .002), although the exercises focused on core strength and proprioception, not increased flexibility. This improvement may be attributed to the stretching exercises or overall improvement in fitness throughout the season. Times for the shuttle run improved (p < .028). The superman test was significant for change (p < .010), with time increasing from 80 to 89 seconds. The single leg hold and triple crossover improved for the left leg (p < .049 and p < .022) but not for the right leg (p < .189 and p < .073). The reason for this is not determined, but possibly as all exercises were performed bilaterally, more improvement was noted on the weaker leg.

ID # ______ Height _____ BMI _____ Pre-Season Date: _____ Post Season Date: _____

Y Balance / Star Excursion Test

Date:



	<u>Right</u>	<u>Left</u>	Average Score
Hip Internal Rotation			n/a
Hip external Rotation			n/a
Single leg hop and hold for distance test	1) <u>.</u> 2) <u>.</u> 3) <u>.</u>	1) . 2) . 3) .	
Triple Crossover hop for distance test	1) . 2) . 3) .	1) . 2) . 3) .	
Speed and Agility (seconds)			n/a
Superman (seconds)			n/a

FIGURE 3. Pre- and postseason exercise testing. BMI = body mass index.

As noted, components of an IPP, to be successful, must be replicable in the off-season, easy to learn, and inexpensive. This IPP required no tools or costs except a soccer ball (part of the team sport) and water bottles. The Likert scale evaluating the ability to perform in the off-season with coaching has a means of 4.35/5. Students felt the warm-up and practice time was appropriate (4.06/5) and the exercises were easy to learn (4.16/5).

Interestingly, the perception of challenge of these exercises was only 3.03/5, which may indicate more students could have advanced to more difficult levels of exercises as the season went on. Multiple methods of learning were provided for students. Social media was used for videos, but these had a poor response rate; the paper handouts were perceived better for learning. The IPP improved core strength and proprioception as evidenced

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TABLE 1. LIKERT SCORES OF ATHLETIC EVALUATION OF PROGRAM

ltem	Sample Size	Mean (SD)
The exercises were easy to learn	31	4.16
The exercises were challenging	31	3.03
I understood why we were doing this IPP	31	3.87
If I had questions, they were answered clearly	31	4.54
The paper handouts helped me learn the exercises	28	4.00
The videos on Facebook helped me learn the exercises	20	3.30
I feel like I could do this program in the off-season without someone coaching me	31	4.35
The time it took to do the warm-up/IPP seemed appropriate	31	4.06

Note. IPP = injury prevention program.

by nearly all measurements of pre- and postseason testing. Students found the program easy to learn and replicable in the off-season, but it could have been more challenging.

These results indicate that this program design is a means of increasing core strength and proprioception. During this sports season, one student was not able to participate in this program due to a hip injury. She experienced an ACL tear late season, but there is no direct correlation that this injury would have been prevented if she had been able to participate. Another student had a knee strain. Several others had arm and head injuries mid-season. Coaches indicated there were more injuries this season than most but perceived there to be fewer injuries to the knee and lower extremities. Historically, this school and its female soccer athletes are perceived to have had a low incidence of ACL injury but actual statistics of injuries have not been tabulated in past seasons.

Implications for future research for this school would be evaluating the incidence of ACL injury over time to determine if the number of injuries was reduced. Future doctorate of nursing practice students could correlate these findings over time to determine if this evidence-based practice has long-term success. Orthopaedic nurses could be involved with education of student athletes, coaches, and athletic trainers. Orthopaedic nurse practitioners may be able to evaluate core strength of patients with other lower extremity injuries to determine if core strength assists with other lower extremity injury prevention. As soccer is a sport that often begins at the age of 4 or 5 years, incorporating simple age-appropriate core strength and proprioceptive exercises at young ages may be beneficial as well.

This program could be replicated and tested in larger studies, or as part of a randomized study, comparing with other IPP, preexisting warm-up programs, or no IPP. Weakness of this study included participants limited to primarily White or northern European descent, middle class females in a rural town. The sample size was small, at 31 athletes. Studies evaluating functional movement as part of IPPs in soccer are limited. This will

TABLE 2. PAIRED-SAMPLES T TEST OF SELECT PRE- AND POSTSEASON TESTS							
Test	Name	Mean	SD	N	t	df	Р
Pair 1	P R HIR	38.74	6.57	31	-3.442	30	.002
	PO R HIR	42.16	5.21	31			
Pair 2	P L HIR	40.51	7.25	31	-4.652	30	.001
	PO L HIR	44.41	6.41	31			
Pair 3	P R HER	31.06	6.59	31	-5.294	30	.001
	PO R HER	36.54	5.40	31			
Pair 4	P L HER	31.51	4.50	31	-4.78925	30	.001
	PO L HER	38.09	3.627	31			
Pair 5	P R SLH	59.55	7.24	31	-1.078	30	.290
	PO R SLH	61.09	7.65	31			
Pair 6	P R TCH	163.89	27.65	31	-0.153	30	.880
	PO R TCH	164.81	35.27	31			
Pair 7	PLTCH	162.93	27.92	31	-2.575	30	.015
	PO L TCH	170.30	24.08	31			
Pair 8	P L SLH	59.61	7.96	31	-1.211	30	.235
	PO L SLH	61.27	7.86	31			

Note. HER = hip external rotation; HIR = hip internal rotation; L = left; P = preseason; PO = postseason; R = right; SLH = single leg hop and hold; TCH = triple crossover hop and hold.



FIGURE 4. Paired-samples *t*-test statistics Black bars = preseason; gray bars = postseason. (A) Superman. (B) Shuttle and agility run. PO SH = preseason shuttle and agility run; POSUP = postseason Superman; P SH = preseason shuttle and agility run; PSUP = preseason Superman.

add to the body of knowledge of functional movement, but more studies involving these types of movements are needed.

Future Implications

The framework for this project, PARIHS, may be used in the future, with similar programs with students participating in other sports such as volleyball or basketball. In addition, examining the students over time or multiple soccer seasons may provide additional data to determine if an overall decreased number of ACL injuries would be noted because of establishment or participation in a program similar to this.

Both the problem statement and hypothesis were answered, in that core strength and proprioception increased by participation in this particular IPP. Future studies may examine similar areas but may modify the IPP or the length/duration of a program. This will add to the body of knowledge for orthopaedic nurses, as well as physical therapists, athletic trainers, and functional sports science.



FIGURE 5. Paired-samples means for Y balance. black = preseason; L = left; LA = left anterior; LAL = left anterolateral; LP = left posterior; LPL = left posterior lateral; P = preseason; gray = postseason; PO = postseason; R = right; RA = right anterior; RAL = right anterior; RPL = right posterior; RPL = right poste



FIGURE 6. Paired-samples *t*-test significance for Y balance test. L = left; LA = left anterior; LAL = left anterolateral; LP = left posterior; LPL = left posterior lateral; P = preseason; PO = postseason; R = right; RA = right anterior; RAL = right anterolateral; RP = right posterior; RPL = right posterior lateral; Y = Y balance.

Conclusion

Injury prevention programs are necessary for athletes of all ages. Because of increasing numbers of ACL injuries in female high school athletes, in particular soccer players, it is important to prevent this costly injury with potential long-term complications. Incorporating exercises in motion, not just in static planes, has been shown to increase core strength and proprioception, which are known measures to decrease risk of ACL injuries.

ACKNOWLEDGMENTS

The author thanks Mathew Herbst, MSPT, MS3, for introducing knowledge of functional applied science and past experience to help create this injury prevention program, as well as assisting with all pre- and postseason testing.

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