IMPLEMENTATION OF AN ANTERIOR CRUCIATE LIGAMENT INJURY RISK REDUCTION PROGRAM IN NCAA DIVISION II WOMEN'S SOCCER

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BACKGROUND: Anterior cruciate ligament (ACL) injuries are a significant cause of performance limitation among female collegiate athletes, often resulting in lengthy rehabilitation and increased risk for long-term complications such as osteoarthritis. While multi-component injury risk reduction (IRR) programs incorporating plyometric, neuromuscular, balance, and strengthening exercises have shown promise, their efficacy in broad competitive populations remains unstudied. This study evaluated the effectiveness and feasibility of a six-week injury risk reduction program among NCAA Division II women's soccer players.

METHODS: A single-group pretest-posttest design was applied to 27 participants aged 18-21 from Nova Southeastern University during the Fall 2024 season. Baseline and post-intervention assessments included functional knee testing via the Single-Leg Squat, Lachman, and Lever sign, alongside injury tracking throughout the season. The program consisted of biweekly, supervised 15-minute sessions targeting specific muscles associated with knee stability through equipment-free exercises.

RESULTS: Results showed no statistically significant group-level improvements in squat test outcomes post-intervention; however, some individual athletes exhibited function gains in lower extremity control. Injury data revealed no ACL injuries during the season. Participant adherence was high, with 78% completing the program as planned, and the protocol was well tolerated with no adverse events. Analysis found no association between injury history and demographic or screening variables.

CONCLUSION: The findings demonstrated the feasibility and the potential for short, standardized IRR protocols to be integrated into collegiate athletic training, particularly in resource-limited areas. The program's equipment-free design and supervised delivery suggest scalability for teams without dedicated athletic trainers. Although further research with larger, controlled samples is warranted to optimize dosage and long-term outcomes, this study supports the implementation of complex ACL injury prevention programs as practical and promising strategies in women's collegiate soccer.

INTRODUCTION

The anterior cruciate ligament (ACL) is the primary restraint to forward tibial displacement on the femur. ACL injuries compromise stability and can be further debilitating due to the structure's secondary role in preventing excessive knee motion in the frontal and transverse planes. Most ACL injuries do not involve a direct blow to the knee but are non-contact or indirect in nature.[1] This can result in an athlete being out of play for at least 6-9 months due to potential surgery and subsequent rehabilitation. In addition, ligamentous lower extremity (LE) injuries can have long-term complications among those impacted, such as early onset osteoarthritis (OA). According to the Centers for Disease Control and Prevention (CDC), ACL injuries continue to rise annually, with an estimated 250,000 injuries and a cost of over $2 billion for ACL repair in the United States annually.[2]

ACL injury risk reduction (IRR) programs use a combination of plyometric, strengthening, technique, balance, and neuromuscular training exercises to influence the communication between the brain and musculoskeletal system.[3] These programs commonly take a multi-component training approach (including both an internal and external focus), which involves more than one type of exercise. However, previous IRR programs

demonstrated variability in exercise choices and dosage and are based on recommendations from existing literature, which are of questionable methodological quality and high risk of bias.[4] Subsequently, the author's choice of exercise dosage for the proposed study is based on exercise physiology as well as previous literature. It takes 6-8 weeks for the addition of protein filaments with resistance training. At least 1 set of 8-12 repetitions of a given resistance exercise is necessary to condition muscle groups. The recommended 8-12 repetitions are suggested to improve both muscle strength and endurance. Low-intensity exercise helps to improve muscle endurance. This type of exercise uses motor units consisting of slow-twitch fibers (fewer in number) at the onset of a task, lending to better control of movement. The longer the exercise persists, the body relies less on slow-twitch fibers and resorts to the use of fast-twitch muscle fibers necessary for higher intensity exercise. Fast-twitch fibers, while more numerous, lend less control of movement.

To date, the effectiveness of these programs has been evaluated in select populations such as high school or elite female athletes, but there is limited evidence regarding feasibility and outcomes in collegiate female soccer players, 18-21, thus representing a distinct and practically important population within competitive sports. Although well-established ACL IRR programs exist, including FIFA 11+, PEP, and Sportsmetrics, most require 20-30 minutes per session, specialized equipment, or trained personnel, which may limit the real-world adoption in some collegiate teams.[5,6] These programs are numerous and readily available, yet there continues to be a faster rise in ACL injury rates in the younger athlete population.[3] This prompts the researchers to question how well these programs are implemented in competitive youth sports as a form of injury prevention.

Despite the availability of validated programs, there remains a meaningful gap in the literature regarding short-duration and equipment-free protocols that are feasible for consistent implementation in collegiate female soccer teams. Rather, position statements (such as that from the National Athletic Trainers Association (NATA)) give generalized recommendations on the types of exercises to be utilized.[4] As such, an unmet need exists for such a program. Subsequently, the researchers aim to gain insight into the effectiveness and feasibility of implementing an ACL IRR program that involves a multi-component approach implemented among National Collegiate Athletic Association (NCAA) Division II women's soccer players. The results of this study will provide further insight into the effectiveness of such programs within the sport. Furthermore, with successful implementation the authors hope to advocate to expand this program around the country.

METHODS

Study Design

A single-group pretest-posttest design was utilized to evaluate the effectiveness of a six-week IRR program on ACL injury rates during a competitive college season. This study was conducted in a cohort of NCAA Division II female soccer athletes from Nova Southeastern University (NSU) in Fort Lauderdale, FL during the Fall 2024 collegiate season. Eligible participants were between 18 and 21 years of age and ranged from freshman to juniors, as senior athletes were unavailable due to scheduling conflicts and end of season commitments. Performance and injury data were collected both before (mid-August) and following (mid-February) the implementation of the program. The study was conducted in accordance with the ethical standards of the NSU Institutional Review Board for Research with Human Subjects.

Participant Recruitment

Participants for this study were recruited directly from the NSU women's soccer team using convenience sampling. Recruitment targeted eligible athletes who met the inclusion criteria outlined below.

Inclusion Criteria
- Female Division II soccer players
- Freshman to junior college classification
- Female gender
- 18 years of age and older
- Signed consent to participate
- Intact ACL

Exclusion Criteria
- History of more than two occurrences of ACL injuries or other ligamentous, tendon, meniscus, bone, or articular cartilage surgeries involving the hip, knee, or ankle bilaterally

- Active participation in structured LE physical rehabilitation programs such as physical therapy or athletic training

Baseline Assessment

Prior to the implementation of the IRR program, participants underwent baseline assessment by the primary investigator (PI). The athletes underwent the Single-Leg Squat (SLS) Test, which was scored as 'positive' for excessive knee valgus or loss of dynamic control and 'negative' for proper alignment and control, following the validated method described by Jamaludin et al. (2022).[7] Lachman's test and Lever sign were also performed to gauge LE functional control and integrity of the ACL bilaterally.[8,9]

Implementation of the Injury Risk Prevention Program

The IRR program was implemented over a six-week period. A total of 28 athletes were divided into four implementation groups, each group consisting of seven participants. Supervised sessions were conducted immediately prior to scheduled team practices to integrate the intervention seamlessly into the athletes regular training, ensuring consistency and feasibility. Timing was chosen to reflect the real-world implementation while minimizing interference with practice. Each group completed the fifteen-minute sessions under direct supervision. Two research team members supervised three groups, while the PI directly oversaw the remaining group to maintain consistency and program fidelity. All members of the research team reviewed and were familiar with the IRR program to maintain consistency when directing and correcting the athletes during implementation.

Participants in all the groups performed the prescribed exercises listed in Figure 1. Each athlete completed a single fifteen-minute session twice per week for six weeks, for a total of 30 minutes weekly. Exercises were selected to target quadriceps, hamstrings and ankle stabilizers, based on evidence from neuromuscular and plyometric ACL prevention programs.[10,11] Selection criteria included feasibility, equipment free execution, and proven functional relevance to soccer related movements. Exercises were completed in sequential order as outlined in Figure 1 to ensure consistency across the groups.

Objective Measures of Progress

At the conclusion of the 6-week IRR program, participants repeated the SLS test and were graded by the PI. Results were compared to baseline values to assess for changes in LE function and symmetry.

Injury Tracking

Injury data for participants was tracked using NSU's athlete management software (SportsWare). This data included injuries sustained during the most recent Fall soccer season as well as historical injury data from prior seasons. Tracking focused on ACL injuries and other LE injuries relevant to the study.

Statistical Analysis

Descriptive statistics were calculated for all relevant demographic variables, including age, height, and weight, and are reported as means ± standard deviations. A total of twenty-seven female collegiate soccer players were included in the initial correlation analyses. Correlations were used to examine the relationship between ACL tear history and each pre-test screening measure as well as demographic variables. Additionally, paired samples t-tests were conducted to evaluate the effectiveness of a 6-week rehabilitation program, by comparing pre- and post-test squat outcomes for the right and left legs. Only athletes who completed both the pre- and post-intervention assessments were included in this comparison (n = 21). A significance level of $p < 0.05$ was used for all analyses and was conducted via. SPSS version 29 (IBM, New York).

RESULTS

Twenty-seven (20.1 ± 1.6 years, 166.0 ± 6.8 cm, 62.2 ± 6.6 kg) division II collegiate women's soccer players were used for this study. There were no statistically significant correlations between ACL tear history and any pre-test screening measure, including the Lachman, Lever, and Squat tests (all $p > 0.05$). Likewise, no significant relationships were observed between injury history and demographic variables (age: $r = -0.11$, $p = 0.57$; height: $r = 0.06$, $p = 0.77$; weight: $r = 0.10$, $p = 0.61$). The chi-square test comparing year in school and ACL injury history was also non-significant ($\chi^2 = 11.42$, $p = 0.723$). Pearson correlation analysis across all demographic and screening variables revealed no statistically significant inter-variable relationships ($p \geq 0.05$), although moderate associations were noted between height and weight ($r = 0.581$, $p = 0.001$). No

ACL injuries occurred during the study period. Table 1 presents the correlations between ACL tear history (prior injuries) and participant demographics and screening measures.

Additionally, 21 (19.9 ± 1.5 years, 166.4 ± 6.8 cm, 62.6 ± 7.2 kg) athletes completed both pre- and post-intervention squat assessments. Paired-samples t-tests revealed no statistically significant change in squat test outcomes following the 6-week rehabilitation program. Right-leg squat scores remained unchanged at the group level (t = 0.44, p = 0.666), as did left-leg scores (t = 0.44, p = 0.666). However, individual-level analysis revealed that a small number of athletes showed improvement by transitioning from a positive (0) to a negative (1) outcome, suggesting that some individuals benefited from the intervention despite no significant group-level effect.

Figure 1. Injury risk reduction program exercises

Table 1. Pearson correlation coefficients and p-values between key variables

Variable 1	Variable 2	R	P
weight	height	0.581	0.001*
height	squat left	-0.299	0.130
height	squat right	-0.299	0.130
age	height	0.257	0.197
year	weight	-0.238	0.240
age	Squat right	0.247	0.214
age	Squat left	0.247	0.214
year	height	-0.067	0.746
year	squat left	-0.006	0.978
year	Squat right	-0.006	0.978
age	year	-0.158	0.431
age	weight	0.081	0.689
weight	Squat left	0.058	0.793
weight	Squat right	0.058	0.793
height	year	-0.067	0.746
ACL tear history	year	0.123	0.540
ACL tear history	weight	0.103	0.608
ACL tear history	Squat left	-0.120	0.562
ACL tear history	Squat right	-0.120	0.562
ACL tear history	height	0.059	0.770
ACL tear history	age	-0.114	0.572

*Significant p ≤ 0.05

Table 2. Paired t-test results for pre- versus post-squat tests

Test	T value	P value
Right Leg Squat	0.44	0.666
Left Leg Squat	0.44	0.666

DISCUSSION

The primary objective of this study was to evaluate the effectiveness of a six-week IRR program as it relates to ACL injury prevention. 27 female collegiate soccer players were analyzed, and no significant correlations were found between ACL injury history and any demographic or screening variable. The duration of collegiate participation was not significantly associated with injury status. However, significant correlations were observed between height and weight.

In the subset of 21 athletes who completed both the pre- and post-intervention testing, no statistically significant changes were observed in squat test scores following the 6-week program. While not statistically significant at the group level, several individual athletes demonstrated improvement. The program was well tolerated, with no adverse events reported, and most participants (78%) completed the protocol as planned. Despite the lack of significant findings, these results support the practicality and feasibility of implementing IRR programs in collegiate athletics, although the lack of measurable group-level change limits drawing conclusions regarding program efficacy and suggests that any potential benefit may be confined to individual variation rather than a consistent training effect.

Interpretation of the SLS Test Results

To assess the efficacy of the IRR program, the SLS test was utilized as both a pre- and post-program evaluation tool. Improvements in the SLS test can serve as indicators of enhanced knee function.[12] A positive SLS test indicates excess knee valgus angulation and LE functional weakness, whereas a negative test demonstrates proper dynamic control and a lower risk of injury.[13]

Two participants who initially had positive SLS tests demonstrated negative results post-intervention, reflecting improved LE control. However, three of the four participants who initially exhibited negative SLS tests bilaterally showed positive results post-intervention.[14] While this could indicate a decline in knee function, no injuries were reported. These mixed findings highlight the limitations of the SLS test as a standalone risk assessment tool, particularly given its inherent subjectivity, intra-rater variability, and dependence on visual evaluation. Confounding factors such as evaluator subjectivity and athlete fatigue, especially given that post-tests occurred after full practice sessions, may explain the inconsistent results.[15]

No ACL injuries were reported during the study period. Although causation cannot be conclusively attributed to the IRR program, the absence of injuries limits the ability to determine whether the intervention had any protective effect during the observation window. The IRR program targeted key muscle groups vital for soccer performance and knee stability: quadriceps, hamstrings, and ankle stabilizers. Exercises such as depth jumps, squat and hold, forward lunges, and Romanian deadlifts targeted quadriceps and hamstrings, while lateral bounds, plyometric A-skips, and L-hop drills aided in ankle stabilization. It should be noted that ACL injury rates for the team as a whole in prior seasons were not collected as part of this study, limiting comparison to historical risk. While the absence of injuries during the study is encouraging, without baseline seasonal incidence data, it is unclear how much of this outcome reflects the effect of the IRR program versus the inherent risk profile of this cohort. Additionally, although the IRR program primarily targeted quadriceps, hamstrings, and ankle stabilizers, the exercises indirectly engaged hip abductor and external rotator muscles which play a role in correcting dynamic knee valgus and reducing ACL injury risk.[16] Future studies should explicitly measure hip strength and incorporate it into program evaluation to better contextualize neuromuscular adaptation and potential injury prevention effects.

Participant Adherence and Implementation Challenges

Of the 27 participants, six dropped out, mentioning that they believed the program was not relevant to their specific positions on the field. Weather delays postponed data collection by one week. Attendance varied due to extrinsic factors such as conditioning differences based on field position. Out of the 12 scheduled sessions, data were collected for nine sessions. Session attendance ranged from full participation to missing up to five sessions per athlete.

Despite the variations, the program demonstrated good overall adherence and was well-tolerated. Its short 15-minute session and bodyweight design make it practical for collegiate environments. Supervision by research staff ensured consistency, supporting its potential scalability to teams lacking dedicated athletic training personnel. The protocols' structured design

and standardized procedures could allow implementation with minimal specialized staff, relying instead on remote supervision or automated monitoring systems. This adaptability makes the program feasible for institutions with limited access to on-site athletic trainers, promoting broader adoption and consistency in training and injury prevention.

Supplementary Post-Test Evaluation

In the post-testing phase, the Subjective Knee Value (SKV) test was added to evaluate knee function.[17] This validated single-question tool assesses perceived knee function as a percentage of normal (100%). The SKV correlates strongly (p<0.0001) with established ligament-specific instruments such as the Lysholm Knee Score.[18] However, because SKV was only collected post-intervention, pre-/post comparison could not be made. Therefore, the mean post-intervention score of 88.6% cannot be interpreted as definitive improvement without a baseline comparison.

Feasibility and Practicality

Positive feasibility indicators were evident throughout the study. High adherence rates were achieved, with 78% of participants completing at least 8 of 12 sessions and no adverse events reported. High compliance in IRR programs has been associated with an 88% reduction in ACL injuries.[19]

This program's equipment-free and easily supervised design supports scalability and adoption in resource-limited athletic programs. It may be feasible for coaches or senior athletes to administer this type of program in future applications. Comparative dose response studies evaluating interventions of six weeks or longer, particularly those spanning 8 to 12 weeks and administered two versus three times per week, are warranted to establish the minimal effective dose and enhance participant adherence.[3]

Limitations

Although sessions were supervised, participant effort varied due to factors such as game schedules and prior workouts. Conducting the IRR before morning practice may have limited exertion during the program to conserve energy for subsequent training.

Pre-and post-screening measures were subjective despite validated assessments like the SLS, Lachman, and Lever tests. Importantly,

reliance on the SLS as the primary or sole indicator of ACL injury risk presents limitations, as the test captures only one dimension of risk and is influenced by evaluator subjectivity. Without the use of objective measurements, such as laboratory-based valgus angle quantification, it is difficult to determine whether the observed improvements represent true biomechanical change.

The small sample size (n=27) and the absence of any ACL tears during the observation period further limit the ability to evaluate the predictive value of the IRR. Additionally, although two athletes demonstrated improved SLS performance, three demonstrated declines, and overall changes were not statistically significant, further reducing the practical interpretability of the findings. Together these factors underscore the limited ability of this dataset to draw conclusions regarding injury prevention benefit or clinical relevance.

Baseline testing occurred two weeks before the program initiation, and post-testing was delayed approximately 17 weeks after the interventions due to scheduling conflicts and weather-related closures. This substantial delay could have reduced internal validity, as neuromuscular adaptations may regress during the off-season, masking true effects. Conversely, regular-season conditions could have artificially inflated improvements.

Future studies should conduct post-tests within 1 to 2 weeks of program completion or include a short maintenance phase to mitigate detraining effects.

Future Directions

Workload Management and Neuromuscular Control

While combining plyometrics, strengthening, technique, balance, and neuromuscular training exercises is the cornerstone of ACL risk reduction, other evidence-based measures can further lower injury rates. Sudden increases in high-speed running and high loads with changes in velocity increase ACL injury risk.[20] Soccer is a sport that is subject to such changes. Thus, implementing a progressive workload monitoring program could potentially reduce the risk of ACL injury. This principle has already demonstrated significant improvement in knee function in acute ACL rehabilitation studies, as seen in Eitzen et al. 2010, and could aid in prevention.[21]

Lower Limb Symmetry

Asymmetries in the lower limbs have been considered risk factors for knee injuries.[22] It has been shown that few athletes, irrespective of ACL injury history, demonstrate greater than 90% lower limb strength symmetry.[23] Importantly, evaluating lower limb strength symmetry is essential for identifying and correcting such deficits. Implementing focused exercises to improve symmetry before beginning the IRR program could help prevent ACL injuries. This targeted approach would address a modifiable risk factor, potentially enhancing the protective effect of neuromuscular training.

Footwear Optimization

Soccer shoe ergonomics influence comfort and injury risk.[24] Incorporating supportive features such as arch support and flexible sole materials may reduce stress on the foot and lower limb.[25] Future IRR programs should consider footwear standardization or ergonomic recommendations.

Menstrual Cycle Considerations

The menstrual cycle may influence an athlete's performance in varying ways depending on the activity type. Some research indicates that physical strength may be enhanced during the follicular phase, while other studies reveal no definitive pattern. Aerobic performance generally appears unaffected, but intermittent endurance may experience slight improvements during specific phases.[26] Due to the inconsistent findings, further research is necessary to gain a clearer understanding of how the phases of the menstrual cycle impact female athletic performance. When looking at the direct effect of the menstrual cycle on anterior knee laxity of female athletes and non-athletes, those with oligomenorrhea had higher knee joint stiffness compared to those with regular cycles. Genu recurvatum, possibly influenced by estradiol, also appeared to increase during the late follicular, ovulatory, and luteal phases.[27] These findings suggest hormone fluctuations may affect joint mechanics. As a result, more research is needed to explore how this impacts injury risk in female athletes.

CONCLUSION

Although no statistically significant group-level findings were observed, this study demonstrated that a structured six-week ACL IRR program is both feasible and well-tolerated among NCAA Division II female soccer players. Individual-level improvements in LE control were noted, suggesting that even short-duration, low-equipment interventions may enhance neuromuscular coordination in select athletes.

The high adherence rate, absence of adverse events, and smooth integration of the protocol into regular team training highlight the practicality and scalability of such programs in collegiate sports environments. Given the high prevalence and economic burden of ACL injuries in female athletes, these findings underscore the value of feasible, time-efficient prevention strategies that can be seamlessly adopted by coaches and athletic trainers.

While limitations, such as delayed post-testing and variable participant effort, may have influenced the results, the observed improvements and zero ACL injuries during the study period suggest a promising preventative potential. The multicomponent approach targeting quadriceps, hamstrings, and ankle stabilizers aligns with current evidence emphasizing comprehensive neuromuscular conditioning as a cornerstone of ACL injury prevention.

Future research should build upon these findings through larger controlled studies designed to optimize exercise dosage, refine implementation timing, and assess long-term retention of neuromuscular adaptations. Ultimately, this study supports the practicality of implementing multi-component IRR programs and contributes meaningful insight toward establishing standardized, accessible, and evidence-based ACL injury prevention protocols in women's collegiate athletics.

Conflict of Interest Statement
The authors declare no conflicts of interest with the contents of this study.

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