



Pediatric ACL Injury Prevention: Improving Strength and Performance with a Prevention Program

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Introduction

Pediatric anterior cruciate ligament (ACL) injury prevention programs have become increasingly noteworthy in recent years, due in large part to the ever-increasing incidence of ACL injury in young athletes.¹⁻⁴ Increased sports participation, intensity of training and competition, participation on multiple teams, heightened awareness, and improved methods for diagnosis have all been cited as contributing factors to the growing frequency of ACL injuries in children and adolescents.^{1,2}

Females are also known to have a greater risk for ACL injury than males.⁵⁻⁸ The gender-based discrepancy may be caused in part by differing neuromuscular activation patterns in females, resulting in increased genu valgum and tendency towards injury in the landing position.⁶ Given the special challenges faced in the treatment of pediatric ACL injuries, prevention programs are of special importance in not only reducing rates of injury but also increasing athletic strength and performance.

Background

Several studies of high school female athletes have shown comprehensive, off-field injury prevention programs focusing on stretching, plyometric jump training, and weight training to decrease the incidence of ACL injuries^{9,10} and increase strength and performance.¹¹⁻¹³ Such programs often impose demanding schedules with sessions lasting up to ninety minutes in duration and occurring three times per week over the course of several weeks, ultimately resulting in poor compliance.^{9,10} In contrast, prevention warm-up programs allow for focused training to occur over a ten to twenty minute period as a team activity at a convenient time before practices or games, offering the theoretical benefit of improved compliance.^{14,15}

A two-year prospective evaluation of the Santa Monica Prevent Injury and Enhance Performance (PEP) warm-up program led to a reduction in ACL injuries in adolescent female soccer players.¹⁶ However, the few research studies evaluating the effect of warm-up programs on strength and physical performance have reported conflicting

findings. In this article, we review pediatric ACL injury prevention warm-up programs and discuss the philosophy behind employing a pre-participation program to improve athletic ability and decrease injury risk.

Literature Review and Discussion

The available evidence in the current literature regarding the impact of an ACL injury prevention warm-up program on strength and performance is limited and provides mixed results. Two prior studies failed to find a beneficial effect. Vescovi *et al* assessed linear sprinting, counter-movement jump height, and agility performance in adolescent female soccer players completing a twelve-week PEP program.¹⁷ The five components of the twenty minute PEP program are warm-up, stretching, strengthening, plyometrics, and agility.¹⁶ The authors found small and transient improvements and concluded little benefit of the PEP program on overall performance. Similarly, Steffen *et al* reported on a ten-week injury prevention warm-up program called "11."¹⁸ Designed as a structured warm-up program targeting the most common soccer injuries, the "11" is a fifteen minute, ten exercise program focusing on core strength stability, neuromuscular control, eccentric hamstrings strength, and agility.¹⁹ The authors did not observe gains in linear sprinting, jumping, or strength in adolescent female soccer players.

Both Vescovi *et al* and Steffen *et al* pointed to the lack of intensity of the exercise drills and low volume as the likely explanation for their poor outcomes. They posited that the ultimate purpose of the prevention program is to reduce noncontact ACL injuries and not to enhance performance.

Other studies, however, support the notion that prevention warm-up programs have a positive impact on strength and performance. Lim *et al* assessed an eight-week modified-PEP program, called the Sports Injury Prevention Training Program.¹⁵ The six parts of the twenty minute program were warm-up, stretching, strengthening, plyometrics, agilities, and alternative exercises. The authors evaluated high school female basketball players and found significant gains in maximum knee extension

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Table 1. *Ready. Set. Prevent.* is a lower extremity injury prevention program developed by physicians and physical therapists at the Sports Medicine and Performance Center at The Children's Hospital of Philadelphia. The fifteen to twenty minute warm-up program is conducted prior to each practice or game and consists of dynamic stretching, strengthening, and plyometrics. The strength and plyometrics programs have two phases. Phase one is conducted from weeks one through four and is designed to provide a framework for proper form development. Phase two is conducted from weeks five through the end of the season and is more challenging. A more detailed program guide can be found at www.chop.edu/export/download/pdfs/articles/sports-medicine/ready-set-prevent-field-sheet.pdf.

Weeks 1-4:

Warm-up, dynamic stretching, initial strength & plyometric exercises

Weeks 5-end of season:

Warm-up, dynamic stretching, progression strength & plyometric exercises

Warm-up:

Shuttle Run – 10-15 yards, 2 laps each

-Forward/Backward Shuttle Run

-Side Shuffles and Carioca

Dynamic Stretching: (10s rest between each exercise)

Inchworm Stretch (hamstring, calves) –5 reps

Spider Stretch (hip flexors, hip adductors, quadriceps) – 5 reps each side

Straight Leg March – 10 kicks total

Leg Cradle – 10 cradles total

Strength Exercises: (10s rest between each exercise)

Initial: Weeks 1-4

Progression: Weeks 5-end of season

Double-leg Squat	20 reps	Single-leg Squat	10 reps per leg
Alternating Lunge	20 reps	Side Lunge	10 reps per leg
Double-leg Bridge (ball or ground)	20 reps	Single-leg Bridge (ball or ground)	10 reps per leg
Side-lying Plank	10s, 3 x each side	Side Plank	15s, 3 x each side

Plyometric Exercises: (10s rest between each exercise)

Initial: Weeks 1-4

Progression: Weeks 5-end of season

Wall Jump	15 reps	Single-leg Squat	10 reps per leg
Squat Jump	15 reps	Jump	
Double-leg Low Cone Hop (side-to-side)	15 reps	The Single-leg Cone Hop	10 reps per leg
180° Jump	10 reps	Lunge Jump	10 reps per leg
Jump, Jump, Vertical Jump	5 reps	Single-leg Forward Hop	5 reps per leg

torque and hamstring-quadriceps ratio as well as in flexibility and biomechanical markers. DiStefano *et al* also found significant improvements in balance and vertical jump height after a nine-week integrated injury prevention warm-up

program in youth male and female soccer players.²⁰ The ten to fifteen minute program consisted of a dynamic warm-up, static flexibility, balance, strengthening, agility, and plyometric exercises on both limbs.

Our Program

Ready. Set. Prevent.

ACL pre-practice programs have the potential to enhance an athlete's strength and performance and, consequently, reinforce the neuromuscular activation patterns necessary to modulate knee and hip biomechanics to diminish risk of injury, particularly in females.^{6,21,22} The most advantageous prevention warm-up program, however, remains unclear, although components such as dynamic warm-up, stretching, strengthening, and plyometric exercises are all reasonable to include.

Our sports medicine group at the Children's Hospital of Philadelphia has developed a warm-up program called *Ready. Set. Prevent.* (Table 1). For patients undergoing ACL reconstruction at our institution, we have incorporated these regimens into the postoperative protocol for the affected knee to reduce the chance of re-injury and for the contralateral, unaffected knee to address potential future injury.

Prevention warm-up programs benefit both athletes and parents. Athletes can find motivation from working with teammates and the competition that ensues to increase one's strength and performance. Parents can potentially avoid excessive costs and time commitments on off-field programs since pre-participation programs occur on scheduled days of practices and games. Most importantly, all involved wish to avoid injury and the need for management of an ACL injury as well as the long-term rehabilitation process required for recovery.

Conclusions

We believe that an injury prevention warm-up program has the capacity to improve strength, flexibility, and biomechanical properties associated with ACL injuries in pediatric and adolescent athletes to lower their risk of future injury. Increasing evidence for augmented strength and performance in athletes may lead to greater desire by coaches to implement ACL injury prevention warm-up programs and to better compliance among participating athletes. Future prospective large-scale studies are still necessary to clarify the most appropriate protocol to maximize strength and performance while reducing noncontact ACL injuries utilizing pediatric ACL injury prevention programs.

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