Return to Sport Following Anterior Cruciate Ligament Reconstruction: Women's Soccer

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Soccer is largely recognized as the most popular sport in the world. It involves speed, agility and endurance, requiring its athletes to sprint, explode to the ball, change direction and maintain high thresholds of work for prolonged periods. In the United States, as many as 80,000 high school female athletes experience ACL injuries each year. Females tend to be more at risk for ACL injury for a multitude of reasons including biomechanical, neuromuscular activation patterns, strength imbalances and hormonal factors. Athletes and their families are becoming increasingly aware of this risk and the subsequent risk of not returning to their pre-injury level of play; thus, necessitating both preventative and post injury rehabilitation programs aimed at maximizing function and minimizing subsequent injury. A program that focuses on neuromuscular activation patterns, proprioception and balance training, functional strength, agility, landing techniques and quality of footwork is best for mitigating risk of ACL injuries in female soccer players. This post-surgical ACL reconstruction rehabilitation program for the female soccer player has been divided into five phases, each phase a progression and building upon its preceding phase. The phases range from early post-operative care to late stage, pre-clearance to return to sport guidance and have been constructed based on evidence informed guidelines focusing on maximizing function post operatively in a safe, efficient manner while minimizing risk for re-injury.

Soccer is largely recognized as the most popular sport in the world. Two teams of eleven players attempt to move a soccer ball into the opposing team's goal along a large grass or turf field without the use of their hands or arms. It involves speed, agility and endurance, requiring its athletes to sprint, explode to the ball, change direction and maintain high thresholds of work for prolonged periods. It has been played competitively and recreationally by ages young and old since the mid-19th century[1]. Throughout the last two hundred years, female participation has increased exponentially, most specifically within the United States where over 1.6 million female players are registered soccer players, ranking highest in participation globally[1].

Women's Football Member Associations Survey Report[2] discloses the global increase in female participation in soccer. As of 2019, the most recent survey revealed there were 13.36 million females playing organized soccer, 3.12 million registered female youth players under 18 years old and over 945,000 registered female adult players over 18 years old. There were over 63,000 female coaches (just over 7% of total coaches) and just over 80,000 female referees (10% of total referees).

Unfortunately, with this increase, there has been a marked increase in injuries, most notoriously, injury to the anterior cruciate ligament (ACL)[3]. Many groups have studied the incidence and epidemiology of ACL injuries in female soccer players. Silvers-Granelli's group reported nearly 250,000 ACL injuries occurring in the United States each year[4]. This incidence has nearly doubled over the last two decades[5].

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In the United States, as many as 80,000 high school female athletes experience ACL injuries each year, with most ACL tears occurring in soccer and basketball[6]. Females in the United States who play soccer year-round have a 5% change of tearing their ACL each year they participate, meaning a 4-year high school female soccer player has a 20% change of tearing her ACL[7]. Additionally, female athletes who do return to playing soccer following ACL injury have a 30% increased risk for sustaining a future ACL injury on either the operative or nonoperative knee[8, 9].

Injury mechanisms for ACL injuries in female soccer players have been shown to be primarily noncontact in nature[10,11,12]. ACL injuries sustained in NCAA women's soccer players have been shown to account for 15.9% of all injuries[13], with more injuries occurring in games than practices[14] and more commonly in college female soccer players (0.391) than high schoolers (0.131)[15]. ACL injuries accounted for 4.6% of all injuries and had an incidence rate of 0.09 per 1000 player hours in the Women's United Soccer Association (WUSA)[16].

Athletes of all ages and competition levels as well as their families are becoming increasingly aware of the risk and the subsequent risk of not returning to their pre-injury level of play following injury to the ACL[17], thus, necessitating both preventative and post injury rehabilitation programs aimed at maximizing function and minimizing subsequent injury.

Changing direction, jumping, landing, pivoting, sprinting and tackling place the sport of soccer at a unique disadvantage for being responsible for such a high-risk profile. It is well established in the literature that female's relative risk for suffering ACL injuries when compared to males is higher[18-20]. Females tend to be more at risk for ACL injury for a multitude of reasons including biomechanical, structural, hormonal, strength imbalances and neuromuscular activation patterns[21-28].

Most (70%) ACL injuries in female soccer players stem from non-contact injuries and typically involve either running and cutting sharply or landing with the knee(s) in extension.[29] Both result in significant forces on the ACL and can lead to catastrophic injury. For non-contact ACL tears, female soccer players usually injure their nondominant leg while men typically injure their dominant leg. Some studies using video analysis have demonstrated that most of all ACL injuries in soccer occurred while the player was playing defense, especially when tackling the opponent to gain possession of the ball[30]. Defending the ball and/or player requires increased forces throughout the lower quarter from lunging, stepping and reaching for the ball. Players tend to be more reactionary and off-balance while defending, as the nature of what the other player is doing with the ball is unpredictable. The cutting, landing from clearing the ball while heading and regaining balance after kicking the ball often results in ACL injuries. This data should influence prevention programs and return to play protocols in emphasizing the importance of including proper defending positioning and tackling techniques in their programs.

Effectively minimizing risk of ACL injury must include facets of rehabilitation beyond strengthening[31]. A program that focuses on neuromuscular activation patterns, proprioception and balance training, functional strength, agility, landing techniques and quality of footwork is best for mitigating risk of ACL injuries in female soccer players. This paper may serve as an evidence-informed protocol for returning safely and swiftly to sport while minimizing risk for injury or sustaining a subsequent ACL injury.

SPORT-SPECIFIC REHABILITATION PHASES

Post-surgical ACL reconstruction rehabilitation for the female soccer player has been divided into five phases, each phase a progression and build upon its preceding phase. The phases range from early post-operative care to late stage, pre-clearance to return to sport guidance. These phases have been constructed based on evidence informed guidelines focusing on maximizing function post operatively in a safe, efficient manner while minimizing risk for re-injury. Early post-surgical management does not vary widely from sport to sport, between genders or among various ages and so, the aim of this manuscript will be to provide soccer-specific guidance for the novice to experienced sport rehabilitation clinician.

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PHASE 1. 0-6 WEEKS POST OPERATIVELY: PROTECTION, INITIAL MOBILITY AND NEUROMUSCULAR ACTIVATION

The immediate goals of Phase 1 are to control edema, protect the repair and incision and monitor for any adverse reactions, specifically deep venous thromboses. Variations in graft type, surgeon preference and comorbidities will affect specific precautions and contraindications for each patient[32]. Additionally, brace and assistive device choice will depend on the above. During this acute phase, particularly within the first few days following surgery, careful care to educate the patient with goals and outcomes is necessary. Attention and assistance with quadriceps activation and isolation is critical as this serves as the foundation for future exercises and should be mastered during this acute phase.

As neuromuscular activation, range of motion, patellar mobility, cardiovascular fitness, and swelling are improving, the athlete will begin to shift focus onto initiating soccer specific challenging balance and proprioceptive demands. Soccer requires a complex strategy of static and dynamic postural control and thus, needs to be addressed from the beginning. Once appropriate neuromuscular control and strength are achieved, the athlete can begin to balance on her operative leg statically while using her non-surgical foot to initiate some simple ball touches, creating minor external perturbations that simulate soccer specific conditions.

Additional touches on the ball can ensue in a challenging seated position using a posterior lean onto the tailbone to increase demands on the core musculature while the athlete juggles the soccer ball with her non-surgical leg, suspending both legs in a tabletop position. Core strengthening can occur using the soccer ball to perform sit up ball tosses against a wall or with a teammate. Additional core and upper body strengthening exercises that do not place the athlete's surgical knee at risk should be initiated as well, including stability ball work, planking and resistance band periscapular exercises.

Criteria to Progress to Phase 2: See Table 1a

PHASE 2. 6-12 WEEKS POST OPERATIVELY: STRENGTHENING

The goals of Phase 2 include maximizing neuromuscular control and progressive strengthening into single leg demands to prepare the athlete for plyometric loads in future phases.

Female soccer players must have exceptional functional strength in their entire core: upper core, including neck and periscapular musculature to absorb forces associated with heading the ball, and lower core, including abdominals and gluteals to diffuse forces from contact at high speeds with other players. Progressive multi-plane core strengthening should continue, including increasing the difficulty of planks with movement in the limb(s) or an unstable surface for the feet, hands or forearms and initiating side planks. Progressing table-based lower extremity strengthening exercises can include clamshell and side lying abduction performed in a side plank position and straight leg raises performed in a reverse plank position. Soccer throw-ins using a light medicine ball can be combined with sit up ball tosses to meet core strength demands of the game. This can also be performed in a high kneeling position on the non-surgical limb.

Balance and proprioceptive activities should progress to include more dynamic stability. Single leg stance on the surgical leg while passing and kicking the ball can be initiated. Balance exercises during this phase should include use of a soccer ball and/or placing the athlete in her soccer cleats to create an unstable surface on which she is required to perform.

Criteria to Progress to Phase 3: See Table 1a

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Table 1a. Rehabilitation Protocol for Phase 1 and 2

	Phase 1	Phase 2
Time Frame	**0-6 weeks**	**6-12 weeks**
Goals	·Achieve full extension ·Achieve flexion of >130 ·Patellar mobility 3/6 all planes ·Trace to no suprapatellar effusion ·Normal gait mechanics ·Ready to initiate single leg strengthening	·LSI quad >80% (to be tested at 8 weeks) ·LSI glute med >80% ·LSI hamstring >70/80% depending on graft site, meniscal repair ·Motor control: ability to perform single leg step down with neutral hip and knee alignment ·Ready to initiate plyometrics
Exercise Recommendations	·Quadriceps/Hamstring/Glute progressive Strengthening ·DL to SL ·Ankle eversion/inversion with band ·balance/proprioceptive drills ·Lumbopelvic/core stabilization exercises ·Cardiovascular training: bike with minimal to no resistance, Upper Body Ergometer	·Progressive resisted SL strengthening exercises ·Standing ankle eversion/inversion with band – concentric/eccentric ·Progress SL balance exercises to simple/complex SL perturbation training (simulation of kicking ball with non-operated leg; passing back the soccer ball with non-operated leg)
Cardiovascular Recommendations	·Daily Stationary Bike 20-30 min with min to no resistance ·Upper Body Ergometer ·Airdyne Bike Arms only	·Stationary Bike 30-45 minutes with moderate resistance ·Elliptical at 8 weeks
Pool Program	·Gait Training at 4 weeks/once incision healed	·Kick board w/ straight leg kick ·Flexibility and ROM ·Simulated soccer drill (head)

(LSI, limb symmetry index; SL, single leg, ROM, range of motion)

PHASE 3. 12-20 WEEKS POSTOPERATIVELY: PLYOMETRICS

The goals of phase 3 include initiating plyometrics and change of direction or speed movements in preparation for soccer specific drills. This phase builds upon the previous two phases strengthening and proprioceptive focus while increasing the challenge in multiple planes and adding multitask and system charges.

Although plyometrics are initiated during this phase, careful attention to potential symptom provocation and joint effusion must be prioritized. Plyometric challenges may begin in a dual leg stance position in the sagittal plane and in a simple environment and progress to single leg challenges in coronal plane in a complex, unstable environment. These progressions should be carefully thought through and very gradually advanced based on the athlete's performance and mastery of each level of plyometric challenge. Criteria for progression is noted in **Table 1b**.

Return to jogging can begin once the athlete has demonstrated appropriate neuromuscular control with all single leg activities, including deceleration control, shock attenuation and proper landing mechanics. Additionally, she must not exhibit any signs of tibiofemoral or patellofemoral joint effusion, swelling or pain, nor should she show any signs of patellar tendinitis. Lastly, she must

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demonstrate at least 80% on the quadriceps limb symmetry index (LSI).

As the female soccer player completes her return to jogging program, outlined in **Table 2**, she may begin to initiate change of direction and change of speed challenges, with the goal of mirroring the specific challenges that soccer presents. External targets, like cones for hand or foot taps, vertical foam roller for knee taps and floor markers for where to change direction or speed can be helpful for both safety in exercise execution and compliance.

In this stage, the athlete should begin to use her surgical leg to perform ball touches, light passing, and shooting, juggling and simple dribbling moves with the soccer ball.

It is important to note that this can be a difficult stage for the athlete from a safety and protection standpoint. It is often during these weeks that the athlete does not feel pain and feels strong and stable. Externally, she "looks" recovered and coaches may view her ball touches and cardiovascular program participation as a greenlight to participate in more dynamic game-like situations. It is crucial to maintain communication with the team, coach, medical staff, family and athlete that she is still at high risk for re-injury at this phase despite presumed invulnerability.

Criteria to Progress to Phase 4: See Table 1b

PHASE 4. 5-7 MONTHS POSTOPERATIVELY: AGILITY, CUTTING, PIVOTING, SOCCER SPECIFIC SKILL DEVELOPMENT:

The goals of phase 4 is to maximize performance with running at different speeds, changing direction seamlessly and equally on each leg and refining non-contact soccer specific skills to prepare the female soccer player for contact drills in the next phase.

Running progressions should include tempo runs, endurance runs, change of speed and sprint intervals, change of direction, rotational and cutting activities and higher-level soccer specific drills. Agility ladders, running with obstacles, uphill trail runs and multi-directional, unpredictable dual task running challenges should be emphasized to mirror the demands of soccer.

Soccer specific drills should include passing with the instep, shoelaces, outside of the foot, progressing from close distance to full strikes of the ball covering longer distances; specific parameters are outlined in **Table 3**. Shooting the soccer ball should follow the similar progressions, resulting in corner kicks, free kicks and penalty kick precision, power and accuracy. Dribbling and juggling the soccer ball should focus on ball control with different parts of the foot, using each foot, varying speed, varying distance covered and obstacles present. Ultimately, the female soccer player should be able to effectively manipulate the soccer

ball with either foot, making both long rotations with the ball, sharp quick turns with the ball and sharp turns on receiving the ball.

Criteria to Progress to Phase 5 See Table 1b

PHASE 5. 7-9 MONTHS POSTOPERATIVELY: CONTROLLED CONTACT, RETURN TO PLAY

The goals of Phase 5 are to sharpen contact soccer drills to ready the athlete for situational soccer play and ultimate safe return to the pitch. This is the final preparatory phase before the female soccer player is back to full unrestricted contact soccer. Soccer specific drills should include defenders when working on offensive plays and movement of the ball, tackling techniques including slide tackling, heading the ball and short sided games of keep-away. Goalie specific training, per **Table 4**, should also be initiated during this phase.

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Table 1b. Rehabilitation Protocol Phases 3, 4 and 5

	Phase 3	Phase 4	Phase 5
Optimal Time Frame	12-20 weeks	5-7 months	7-9 months
Criteria Based Progression to advance to next phase	· LSI quad >90% · LSI glute med >90% · LSI hamstring >80/90% depending on graft site, meniscal repair · 60 second timed step- down test 80 bpm · 60 second timed Lateral leap 60 bpm · Single leg hop cluster (distance, triple, cross over, 6 m timed) >80% · Complete return to running program; initiate longer duration running (20-30min continuous) · Optimize soccer-specific motor control	· LSI quad >95% · LSI Glute med >95% · LSI Hamstring > 95% · 60 second timed step-down test 80 bpm excellent control · 60 second timed Lateral leap 60 bpm excellent control · Single leg hop cluster (distance, triple, cross over, 6 meter timed) >80% · Good acceleration, deceleration, change of direction control · Ready to initiate controlled contact · Ready to return to reduced soccer practice	· Same as Phase 4 · Final preparation for return to full contact soccer
Exercise Recommendations	· Continue progressive resisted strengthening from Phase 2 · Maintain ROM- no loss of extension, no increased effusion · Advance plyometrics from DL to SL, simple → complex · Squat jump, box jump, scissor jump, lateral jump, depth jump · Advance SL perturbation training · Linear change in direction drills · Lateral change in direction · Soccer-specific Drills (ball touches, passing, seated juggling, shooting)	· Running drills (straight line, zig zag, rotation, change in speed, change in direction · Rotational control drills · Agility specific: high knee for hip flexor strength for speed, uphill running for stride length, short sprint intervals to speed up leg turnover and stride frequency, ladders/obstacles for fast footwork · Soccer Specific Drills: Non-contact drills only, Passing, Ball work/touches/dribbling, standing juggling, Shooting)	· Initiate controlled contact (in air body contact, no ball progressing to ball) · Soccer Specific Drills: Contact drills, position specific training, Ball movement with defender, blocked shots, Heading, Slide tackling) · Goalie-specific training
Cardiovascular Recommendations	· Running forward, diagonal, backpedaling · Soccer specific training (interval, bike)	· Interval training · Tempo runs · Fartleks · Shuttle runs	· Same as Phase 4
Pool Program	· Water running		·

(LSI, limb symmetry index; DL, double leg; SL, single leg, ROM, range of motion)

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Table 3. Soccer Skill Progression [33]

	Running	Passing	Dribbling
Level 1	Straight Line · Endurance (time/distance) · Position specific (midfield/center forwards distances) · Shorter distances · Backpedaling · Gradually increase speed	· Static passing short distances <18yd · Static passing long distances >18yd · Gradually increase speed of ball	· Laces, control ball · Inside foot, ball control · Outside foot, ball control
Level 2	· Lateral, Diagonal Movement and Figure 8 runs · Longer distance shuttle run · Shuffling · Decrease distance, increase speed · Increase number of cuts	· Per above but add moving ball vs static/stationary ball · Begin with ball on turf, progress to ball in air/lifting ball · Static Volleys: inside foot, laces, outside foot · Dynamic volleys: moving feet/foot fires with alternating feet volleys inside/laces/outside	· Long distances · Short distances · Increasing speed · Change of direction
Level 3	· Zig Zag Runs · Long distance with long turn · Decrease distance between cones · Increase number of turns · Increase speed	· Dynamic passing, on the move with pressure <18yd · Corner kicks	· Per above, increase speed
Level 4	· Rotations · Without the ball · With the ball · Pass with the ball	· Dynamic passing, on the move with pressure >18yd · Free kicks and shooting: progress distance, force, speed	· Longer rotations with ball · Quick, sharp turns with ball, alternate to right and left · Sharp turns on receiving ball

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Table 4. Soccer Specific Skills

Passing (**Figure 1**) • Inside of foot pass (**Figure 1a**) against wall or with teammate, short and long distances; switching between right and left foot • Progress above to dribbling then pass • Outside of the foot (**Figure 1b**) "flick": pass short and long distances; switching between right and left foot • Progress above to dribbling then pass • Using instep for longer passing: strike ball with shoelaces, short and long distances; switching between right and left foot • Progress above to dribbling then pass
Ball Footwork (**Figure 2**) • Toe touches • Foundations • Foundations with roll over using cleats/bottom of foot, outside in or lateral to medial; switch feet • Foundations with roll over using cleats/bottom of foot, inside out or medial to lateral; switch feet • Foundations to pull back using cleats, switch feet • Foundations to "L" move, behind planted leg, switch feet • Foundations to "V" move, opening out laterally, switch feet • Foundations to "cut back" for change of direction (internally rotating at hip and cutting ball backwards toward other leg and changing directions), switch feet
Dribbling (**Figure 3**) • Dribble back and forth to cone 10 yards ahead 1. Outside of right foot to cone, outside of left foot back 2. Inside of right foot to cone, inside of left foot back 3. Combine: outside right, inside right, outside left, inside left to cone and back • Incorporate the above footwork exercises while moving to the cone and back • Progress the above by progressing speed • Dribble at speed with cone 20 yards away, keeping ball as close to your foot as possible, using each foot
Trapping (**Figure 4**) • Throw ball against wall or ask a teammate to throw the ball to practice trapping/settling the ball with 1. Chest 2. Thigh (switch thighs) 3. Foot (switch feet) • Progress by using a drag trap or moving trap, where you trap the ball using the above body parts toward the direction you want to go and immediately take off to dribbling at speed
Shooting (**Figure 5**) • Medial Foot • Instep • Lateral foot flick • Practice the above from different distances, against a wall, with a teammate, switch feet
Goalie specific drills (**Figure 6**) • Rotational lunge and reach: 1. Step out into a lunge with front leg at a 90 deg angle with arms overhead 2. Bend forward at hips to touch your chest to your front thigh reaching through your hands 3. Use your legs and push back up to a standing position 4. Switch legs and repeat 5. Repeat by lunging toward different directions **6.** Progress to catching the ball during above exercises
Single Leg Balance (**Figure 7**) • Firm surface • Uneven surface • Internal perturbations (arm swings, leg swings, trunk rotation) External perturbations (ball work juggling, passing)
Juggling (**Figure 8**) • Seated • Standing
Ball Movement Drills with Defender (**Figure 9**)

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Blocked shots (**Figure 10**) • On stable surface • Unstable surface • Blocking a shot with inside of foot • Blocking a shot with outside of foot
Slide tackling (Figure 11) • Practice mechanics without ball or opponent • Practice mechanics with ball only • Practice mechanics with ball and opponent
3x1, 5v2
Scrimmage

Figure 1a. Passing drills with inside of foot

Figure 1b. Passing drills with outside of foot

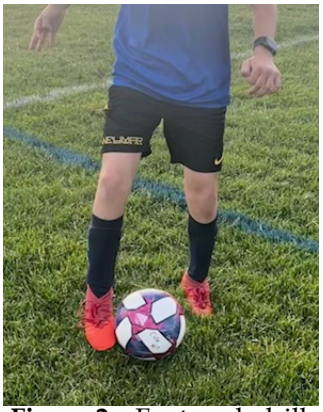

Figure 2a. Footwork drill in hip abduction, knee flexion, ankle plantar flexion

Figure 2b. Footwork drill using instep/shoelace with hip adduction and internal rotation

Figure 3. Ball touches with turns and rotational direction changes

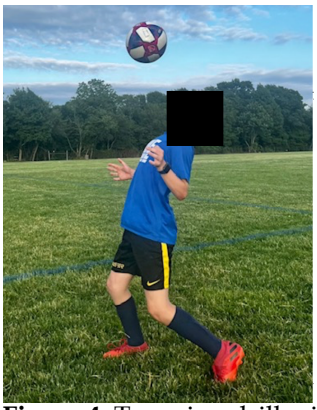

Figure 4. Trapping drill with lumbar and hip extension with knee flexion

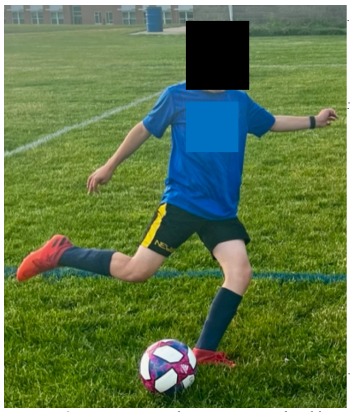

Figure 5. Shooting drill

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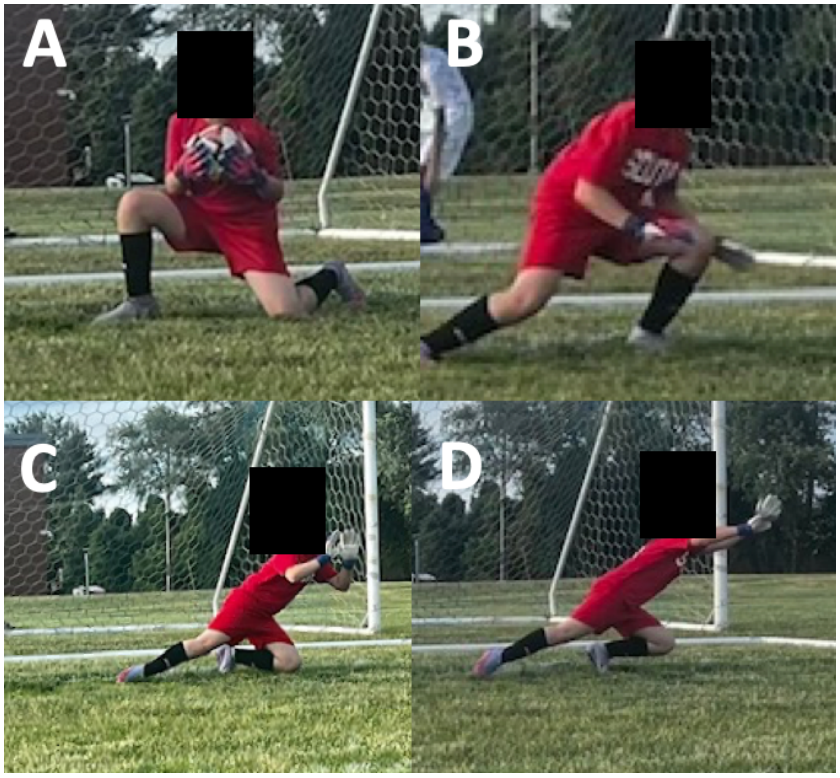

Figure 6. Goalie-specific drills include bending the knee to 90 degrees (A), 90 degrees at knee and hip (B), full pressure kneeling (C), rotational lunge and reach (D)

Figure 7. Single leg balance drill demonstrating lumbar extension with hip and knee flexion, and ankle plantarflexion

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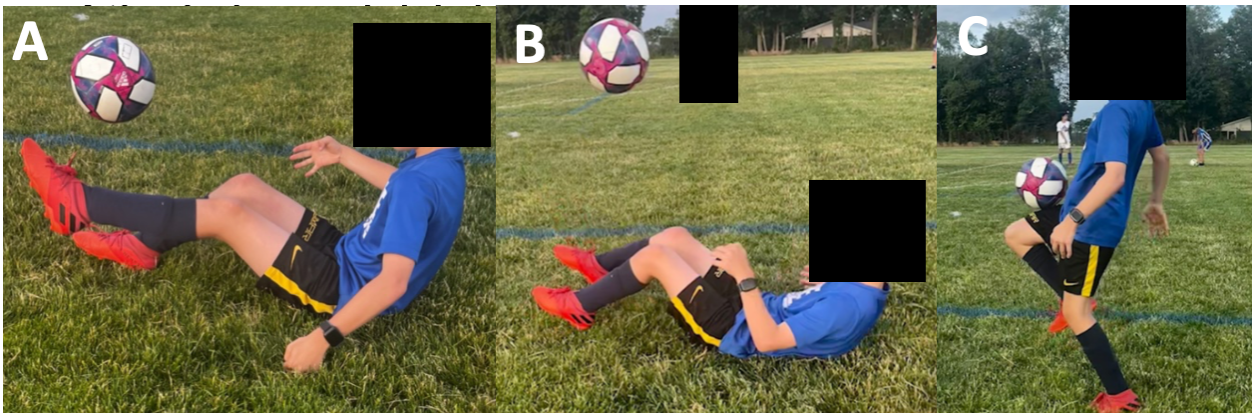

Figure 8. Juggling drills in seated (A, B) and standing (C)positions.

Figure 9. Ball movement drills with defender

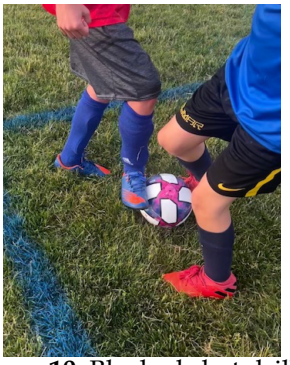

Figure 10. Blocked shot drills.

Figure 11. Slide tackling drill

Criteria to Discharge to Return to Playing Soccer

For clearance to full contact, unrestricted play, the athlete must meet the goals outlined in each of the five phases above, including soccer specific fundamentals, drills and goals. She must continue to demonstrate symmetry and mastery in each of the functional movement testing areas as well as have equally high scoring on her psychological readiness to return to sport subjective survey.

SUMMARY

Soccer will always play an integral role in the life of a female athlete. The female athlete is stronger and faster than ever before and potential external effects from training surface, year-round training, and lack of diversity in other muscle groups used places these athletes at an increased risk for ACL injury. Evidence supports a specific rehabilitation program aimed at the unique attributes that make up the female athlete as compared with her male counterpart; gender must be considered when developing this plan of care.

A program that focuses all phases of rehabilitation on mobility, neuromuscular control, strengthening, balance/proprioception, multi plane dynamic control and incorporates cognitive and psychological factors will set the female athlete up for a successful recovery and enable her to return to play safely.

This clinical commentary may provide a guided framework from which sports rehabilitative therapists can refer when working with female soccer players. Research that continues to focus on the individual characteristics of the female soccer player and her inherent and modifiable risk profile is needed.

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Conflict of Interest Statement
The author reports no conflict of interest with the contents of this manuscript.

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