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

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Competitive women's field hockey has evolved through the years, making it a fast-paced sport, requiring high levels of strength, endurance, and cardiopulmonary demands. While the sport of field hockey continues to grow, so does the number of ACL injuries. Research is lacking in return of female athletes to the sport of field hockey post ACL reconstruction. Rehabilitation guidelines addressing field hockey specific ACL injury must include building lower extremity muscular strength, optimizing neuromuscular control, and improving cardiopulmonary endurance. The field hockey athlete is required to sprint, pivot, cut, and change directions quickly, while mainly in a squat-like position. The challenge for the clinician is to incorporate sport specific elements into the rehabilitation and training to maximize function for return to play, while minimizing risk of reinjury for the field hockey athlete. This guideline will provide a criterion-based rehabilitation progression with early integration of field hockey specific exercises to assist in the athlete's multiplanar neuromuscular control and success in return to sport.

Field hockey is one of the world's oldest sports dating back to depictions found in 500BC Greece. The sport is governed by the International Hockey Federation, known as hockey in most countries and is equally played by both men and women. In United States and Canada, the sport is referred to as field hockey and is primarily played by women. Competitive women's field hockey has evolved over the years with over 60,000 high school athletes[1]. As the sport of field hockey continues to grow, so does the number of injuries. It is important for the treating clinician to understand the game of field hockey and the physical requirements of the field hockey athlete.

The game of field hockey has evolved through the years, making it a fast-paced sport, requiring high levels of strength, endurance and cardiopulmonary demands. Experts have found that 20% of the game is played in a high intensity state of sprinting, cutting and pivoting, resulting in significant stresses on the neuromuscular system[2]. A field hockey player is required to change speed and direction quickly while in a squat-like position. The sport consists of 10 field players and a goalkeeper, and is played on a 100 by 60 yard turf or grass field/pitch. At each end, there is a 7 feet high by 12 feet wide goal/net with a 16 yard semi-circular area known as the circle. Players are typically divided into offense, mid-fielders and defense. The exact number of each is dependent upon the type of offense or defense approach played by the team. Players can only use the flat side of the curved end of the field hockey stick, made of wood, carbon fiber, fiberglass, or some combination thereof to hit a hard, plastic ball into the net. The goalkeeper is the only player who can touch the ball with their body and stick, while all others can only touch the ball with the flat side of their stick. If a player touches the ball with their body, and it advances the game of play, it is considered a foul. If a whistle is blown by the referees, the game is stopped and the opposing

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team is given a free hit. The game lasts between two, 25–35-minute halves (depending on the level of play), and the team who scores the most goals by the end of the game wins.

Field hockey is one of the most competitive, non-contact, team sports currently played[2]. Analyzing a decade of injuries in both high school and collegiate field hockey athletes, knee injuries occurred frequently, second to hip and facial injuries[1]. Anterior cruciate ligament (ACL) tears in field hockey athletes are mainly non-contact and the rate of rupture during competition occurs more than double the rate during a practice[1,3,4]. Female college athletes are at the highest risk of first-time non-contact ACL ruptures[5]. This shows that increased level of competition is synonymous with increased injury rate[5]. According to the 2004-2014 injury surveillance program, the rate of ACL tears was 21 per 10,000 athletic exposures, approximately the same in women's soccer athletes[3]. It was found that in unanticipated cutting maneuvers in field hockey athletes, there is a higher ground reaction force and medial lateral peak force which is a major contributing factor to ACL injury[6].

Multiple clinical guidelines for ACL reconstruction rehabilitation exist, but very few with late phase return to sport recommendations. Besides the gold standard of physiological healing time for return to sport participation, clinical criteria remains variable[7]. Functional testing, such as hop testing, Y balance test (YBT), isokinetic testing and running programs have been advocated to determine patient's return to sport, but the late phase rehabilitation process remains inconsistent[8,9]. Research is lacking in return of female athletes to the sport of field hockey post ACL reconstruction.

Rehabilitation guidelines addressing field hockey specific ACL injury must include targeted exercises for lumbopelvic, hip and trunk control for cutting and pivoting in a squat like position. Dynamic stability is required for dual tasks such as lunging passes, running passes or dribbling. Multiplanar and cardiopulmonary training are essential for safe return to play and reduce the risk of re-injury[1,2]. The challenge for the clinician is to incorporate sport specific elements into the rehabilitation and training to maximize function for return to play, while minimizing risk of reinjury for the field hockey athlete. The final key to successful athletic rehabilitation is collaboration with athlete, surgeon, athletic trainer and coach.

SPORT-SPECIFIC REHABILITATION PHASES

Post-operative rehabilitation is typically divided into five main phases. Each phase is a criterion-based progression to help individualize treatment and optimize outcomes with respect to healing timelines[7,10–12]. The purpose of this manuscript is to help guide clinicians in the late phase of post-operative ACL rehabilitation for the field hockey athlete. Therefore, an overview will be given for phases 1 and 2. Field hockey specific considerations will be given primarily in phases three through five.

PHASE 1: PROTECTION AND MOBILITY

Phase 1 should focus on edema control, pain management, range of motion, patella mobility and quadricep strength. The operative report should be read for any patient specifications of concomitant injuries and/or surgical procedures, precautions and contraindications. In addition to exercises for the surgical knee, maintaining cardiovascular fitness and core and upper body strength is recommended to prevent deconditioning and improve mental state[10,13] (**Table 1**).

Suggested Rehabilitation Program for Phase 1:

Athletes who achieve goals of phase 1 easily, can initiate sport specific field hockey training. A squat involves triple flexion and extension of the lower limbs while maintaining optimal trunk control and is the defense position for most field hockey players. It is important the athlete demonstrates symmetrical load in bilateral lower extremities in order to prevent poor outcomes, secondary to lack of strength, balance, proprioception or graft maturity[14,15]. Stick work can begin once the patient demonstrates adequate strength and control during a partial squat with equal weight-bearing in bilateral lower extremities. The athlete can begin stick work with a ball in the front and sides of the body with weight-shifts from right to left in a squat position to simulate ball control prior to a pass (**Figure 1**).

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Figure 1. Field hockey squat position with stick and ball work (Photo courtesy of Emily Chichester)

It is important to consider the graft healing timeline and that more than a 60 degree squat can increase anterior tibial translation[10]. Therefore, cueing the athlete to stay within 60 degrees of knee flexion at this stage is recommended. Lumbopelvic strengthening is an essential part to eliminating distal injury, meeting the demands of field hockey, and should include planks, dead bug and Pallof press. Initiating stationary biking for developing return of previous cardiovascular fitness is recommended once surgical knee range of motion measurements are achieved for rotation around the bike[13].

Criterion to Progress to Phase 2:

Full surgical knee extension range of motion compared to contralateral knee within 10 degrees of knee flexion range of motion compared to contralateral knee, good patella mobility in all directions, straight leg raise (SLR) without extension lag, minimal knee pain, trace to no effusion, can perform a squat without asymmetries and restoration of normal ambulation without assistive device or abnormalities.

PHASE 2: STRENGTHENING

Phase 2 is primarily focused on building muscular strength, optimizing neuromuscular control and improving cardiopulmonary endurance. Strength should be progressed throughout the rehabilitation to enhancing endurance, maximizing strength and optimizing function[10]. An example of emphasizing lower extremity endurance would be keeping the weight low on the leg press and increasing repetition or duration of the exercise to improve proper muscle motor function without significant fatigue to prepare for the demand of the sport. For the women's field hockey athlete, emphasis should be placed on multiplanar strengthening of the lumbopelvis and lower extremity in closed chain positions to simulate dribbling down the field and passing. Monitoring limb alignment with functional tasks is important to ensure the knee can withstand loading demands. It is recommended to initially restrict high load functional exercise(i.e. lunges, leg press, squats) to less than 90 degree knee flexion to reduce patellofemoral joint stress[15].

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Table 1. Rehabilitation Protocol for Phase 1 and 2

	Phase 1	Phase 2
Suggested Time Frame Based on Healing Timelines	0-6 weeks	6-12 weeks
Criteria Based Progression to advance to next phase	· Achieve full extension · Achieve flexion of >130 degrees · Patellar mobility 3/6 all planes · Trace to no suprapatellar effusion · Straight leg raise without extension lag for 10 repetitions · Normal gait mechanics · Squat with good form · Single leg standing for 30s without loss of balance	· Full knee range of motion · No knee pain · No knee effusion · 1x body weight on SL leg press for 8-10 repetitions · 2x body weight on DL leg press for 8-10 repetitions · Perform 10 pain-free single leg squats with good form and control · Lower extremity strength 5/5 on MMT or use HHD requirements below · YBT LSI for anterior reach > 80% · Good neuromuscular control with 60-second timed step-down test · Quadriceps LSI >65% by 8 weeks and >80% by end of phase · Hip Abductor LSI >80% · Hamstring LSI >70/80% · (Depending on graft site or concomitant procedures) · Q:H ratio 0.8-1
Exercise Recommendations	· Progressive Quadricep/Hamstring/Glute Strengthening · DL to SL balance and proprioceptive drills · Lumbopelvic/core stabilization exercises · Field hockey stick work in squat positions	· Progressive resisted SL strengthening · Progress SL balance exercises to simple/complex SL perturbation training · Field hockey passing while in lunge position
Cardiovascular Recommendations	· Stationary bike with minimal to no resistance, 20-30 minutes daily · Upper body ergometer · Airdyne® bike with arms only	· Stationary bike with moderate resistance, 30-45 minutes · Elliptical beginning at 8 weeks
Pool Program	· Gait training at 4 weeks or once incisions healed	· Kick board with straight leg kicking · Aqua jogging 10-20 minutes · Lower extremity strengthening

(DL=Double Limb, SL= Single Limb, YBT: Y balance test, HHD: Hand-held dynamometer)

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Suggested Rehabilitation Program for Phase 2:

Balance and Proprioception

Balance exercises should be progressed from static to dynamic to reactive. Single limb training should incorporate unstable surfaces with ball and stick work to improve neuromuscular control. This not only improves motor control strategies but also enhances a positive mental state for the rehabilitating athlete[12]. Wohl and colleagues found increased visual input for lower extremity motor control following ACL injury. Therefore, it is important to challenge balance with sensory reweighting with visual perturbations, such as eyes closed on foam and visuocognitive tasks for enhanced motor control required in competition[16]. Some examples of this would include single leg standing on foam while balancing an object with their arm and/or looking up to call out colors.

Strengthening

Squat progressions can aid in foundational strength and can vary from squat, wall squat, goblet squat, back squat, front squat and overhead squat with progression in load, timed holds and repetitions[15,17]. Double limb squats should be progressed to single leg squats because they are the foundational movement prior to running, required throughout the game of field hockey. It has been advised by Buckthorpe et al. to perform a leg press nearly 100% body weight to have the necessary strength to perform a body weight single leg squat[15]. Having good dynamic knee control with forward, backward, lateral, diagonal and rotational body movements is needed to mimic passing. In field hockey, one may pass while on the run or lunge forward with one leg to perform a pass. This requires proper stabilization of the lower extremity in multiple planes of movement whether the surgical leg is the forward moving leg or stabilizing leg. Therefore, performing lunges in all directions with and without trunk rotations will assist in this multiplanar stabilization[12]. Progressing this to task-based, such as lunging in multi-directions while passing with stick and ball, should be based on movement quality[15]. The trunk rotation is key, as the athlete does not want to give away to the defender where they are passing the ball. For example, a field hockey player will most likely keep their legs moving forward and twist their trunk and upper body to the right to make or fake a pass. The patient can continue with squat stick and ball work from phase 1 and progress to passing during this phase. Practicing free hits, as one would do after a whistle or at the top of the circle for a scoring opportunity, is permissible at this time as it is shifting weight in a double limb stance. Other examples of single limb strengthening in this phase include step-ups, resisted side stepping, and single leg deadlifts. See Dribbling and pulls video.

Lumbopelvic Strengthening:

These exercises can be advanced from one phase to the next to emphasize neuromuscular control and lower extremity strength. Planks in all positions are an important full body proximal strength exercise[18,19]. Core strengthening utilizing arm and leg coordination would be an added skill such as dead bug and super-mans. These can be progressed by performing planks with perturbations, super-mans on a theraball or Pallof press while in a lunge position or while standing on foam.

Cardiopulmonary Fitness:

Multiple studies have shown that the majority of reported non-contact ACL tears occur at the end of a game, demonstrating fatigue plays a role in the neuromuscular control of the lower extremity[2,4,20]. Therefore, continuation of increased time of biking, elliptical and UBE can increase cardiopulmonary fitness. Within 4 weeks of de-training, vascular changes impair muscular perfusion and oxygen delivery. It is important to off-set cardiorespiratory changes with a slow and steady return to cardiovascular exercise[13]. If the patient has demonstrated good quadricep strength and control, the patient's cardiopulmonary fitness can be tested using the Wingate Test[13]. The Wingate Test has been found to be a reliable assessment of an athlete's anaerobic conditioning on a stationary bike ergometer for 30 seconds against a resistance of 7.5-8.9% of the athlete's body mass. Normative values have been established for female athletes[13]. At this time, with good incisional healing, pool activities (strengthening exercises), swimming (no breast-stroke due to tibial external rotation at the knee), kickboard with straight leg kicking, water jogging in deep end with belt and water treadmill walking

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can be initiated with minimal loading on the knee joint[13].

Criterion to progress to Phase 3:

The athlete must demonstrate full knee range of motion, no knee pain or swelling, greater than 80% on quadricep limb symmetry index (LSI), 1x body weight on single-leg leg press for 8-10 repetitions, 2x body weight on leg press for 8-10 repetitions, Q:H ratio 0.8-1, single leg standing for 30s without loss of balance, lower extremity strength 5/5 on MMT, greater than 80% anterior reach on YBT and perform 10 pain-free single leg squats with good form and control[7,10–12,21,22].

PHASE 3: PLYOMETRICS

This phase is a continuation of the strengthening phase with combination of neurocognitive tasks specific for the field hockey athlete. Plyometric exercises have been known to be superior to more traditional resistance training for developing power, speed, strength, and proprioception by utilizing eccentric muscle contraction followed by a quick concentric contraction[15]. While plyometrics are initiated during this phase, one must pay close attention to signs and symptoms of knee pain, effusion or instability. It is recommended bilateral landing exercises are initiated prior to running to ensure that the knee can accept ground reaction forces[15].

Proper landing and stabilization is best seen on a shuttle in a controlled de-weighted device starting with double limb jumps then to single limb jumps[10]. Once she can demonstrate landing with adequate knee flexion for shock absorption, she can progress to land jumping. Plyometrics should be progressed from double-limb to single-limb in both horizontal and vertical jumping. The clinician should place emphasis on landing technique with plyometric jumping, progressing from double to single limb activities. The agility ladder can also be added during this phase to improve coordination, motor control and speed of lower extremities.

It is important to note to avoid an adverse joint response, plyometrics should not be performed on consecutive days. Gradual progression of musculoskeletal conditioning in respect to frequency, duration, sets and repetitions will allow proper stress and strains along the knee joint to prepare the athlete for return to field hockey. Once athletes can perform jumping and running without swelling, pain or limitations in knee range of motion, consecutive training days can occur[7].

During this phase, running may begin. It is recommended that the patient initiate a return to run program slowly increasing distance to allow for muscular and joint loading response[13,15,22]. Effective implementation of running can ensure good quality of gait, while developing strength and neuromuscular control to ground reaction forces[15,22].

Once return to run is completed, the athlete can initiate specific field hockey conditioning. Running should vary in distance, speed and surface in order to simulate the game environment and functional muscular strength. An exercise can include running up to a ball, then dribbling forward and varying directions of dribbling (running with stick and ball) [12].

Later in this stage, the athlete can begin increased sport specific exercises in controlled environments. This includes receiving a pass while running, shooting and wall balls to improve eye-hand coordination. All plyometric progressions should occur gradually with attention to the patient's symptoms and challenging the athlete by varying speed and direction.

The athlete may be cleared for drills as a stationary player for passing and shooting drills. Communication and education with athlete, coach, athletic trainer, parents and surgeon are key for safe return to specific drills with verbalized understanding of restrictions.

Suggested Rehabilitation Program for Phase 3

Balance and Proprioception

Balance exercises should continue to be advanced from dynamic to reactive with visuocognitive or dual-task training[23]. Examples would include double limb squat on bosu ball or rocker board while tossing a ball against a trampoline, squat position on foam with defense tackles and jabs, lunge position on foam with stick and ball passing and balancing on unlevel surfaces with eyes closed while performing a math problem. Balance activities that are utilizing the mind will

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prepare the patient for game-like situations where the athlete can't focus on their lower extremity alignment or balance.

Strength Exercises:

These exercises continue to focus on single limb strength and power based on strength measurements via hand-held dynamometry (HHD), isokinetic machine or manual muscle testing (MMT)[15,17]. Some examples include walking lunges in various directions, curtsy lunges, rear-foot elevated split squats. Single leg squats, step-ups, resisted side stepping and single leg deadlifts, can be challenged by adding a slide board, unilateral weight, increasing the weight, resistance bands or performing on unlevel surfaces (BOSU, foam, rocker board) [7,15,17,20].

Lumbopelvic Strengthening:

Incorporating core and lower extremity strength and endurance, such as chops, lifts and Pallof press in a lunge position can also further increase power and force with agile changes in direction, passing and shooting. Since the sport is played while holding the stick to the right of your right foot in a squat position, chops and lifts are essential core strengthening exercises to assist with this position.

Plyometric Exercises:

Plyometric exercises include body weight jump squats and forward jumping. Bilateral landing trains eccentric control of the quadriceps to receive ground reaction forces and prepares the neuromuscular system for single limb acceptance such as running. It would be important for this to be performed prior to running, as bilateral landing is 1.5-2 times your body mass compared to single limb landing, like running, which is 2-3 times body mass[15]. As neuromuscular control and confidence in the surgical leg improves, these can be progressed to jumps up and down from a box. The clinician can use the lower extremity scoring system (LESS) to assess motor control and aberrant movements in the trunk and lower extremity with jumping tasks[24]. Using the LESS can assist in determination of when it is appropriate for the athlete to progress to single limb jumping and/or running based on motor control compensations. Double leg plyometrics can be progressed to single-leg plyometrics with single leg jump for vertical height, single leg jump for distance and from a box[7]. Observation on surgical knee flexion acceptance to jumping is an essential aspect of absorbing forces up the kinetic chain and functional performance[15]. Single leg hops can then be progressed to lateral hops and diagonal hops, continually on one leg and then from one leg to the other. An example of this would be lateral leap and catch. Neuromuscular control can be challenged with forward, backward and lateral running against a sport cord[7,10]. Plyometrics focusing on eccentric quadricep strength for deceleration of the lower extremity for changes in play is an important aspect of the game of field hockey (ball taken from offensive player, that player must go on defensive).

Cardiopulmonary Fitness

After plyometric and running conditioning is completed without knee pain, instability or edema, field hockey specific cardiovascular training can begin. This would include forward and backward running, shuffling and middle-distanced speed work such as 400 meters, 800 meters, and timed mile[7,25].

Functional Movement Assessment/Return to Sport Testing

In addition to lower limb strength testing every 4-6 weeks, neuromuscular functional testing can be initiated. This includes the single leg hop test for distance, the triple hop test for distance, the crossover hop test and the timed 6-meter hop test. Three trials of each limb are performed for each test with a median score. Limb symmetry index is taken for each score with the goal to be more than 80% of non-surgical leg. Repeated neuromuscular tests include the timed single step down test and timed lateral leap test[7,11,15,18,21].

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Table 2. Rehabilitation Protocol for Phase 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	· Quadriceps LSI > 90% · Hip abductors LSI > 90% · Hamstring LSI > 80/90% (depending on graft site or concomitant procedures) · Q:H ratio 0.8 or greater · Good neuromuscular control with 60-second timed step-down test · Good landing mechanics with 60 second timed lateral leap and catch · Good landing mechanics with single leg hop cluster (hop for distance, triple hop, crossover, 6m timed) > 80% of uninvolved limb · Y Balance Test: LSI > 90% · Running pain-free without abnormality at athlete's jogging pace based on 1-2 minutes slower per mile than prior to surgery	· Quadriceps LSI > 90% · Hip abductors LSI > 95% · Hamstring LSI > 95% · Q:H ratio 0.9 or greater · Y Balance Test: LSI > 95% · Good neuromuscular control with 60-second timed step-down test · Good landing mechanics with 60- second timed lateral leap and catch · Good landing mechanics with single leg hop cluster (hop for distance, triple hop, crossover, 6m timed) > 90% of uninvolved limb · Good acceleration, deceleration, change of direction motor control · Ready to return to reduced field hockey practice · Yo-Yo Intermittent Recovery Test · Completion of ACL-RSI	· Quadriceps LSI > 95% · Hip abductors LSI > 95% · Hamstring LSI > 95% · Q:H ratio close to 1 · Excellent neuromuscular control with 60-second timed step-down test · Excellent landing mechanics with 60-second timed lateral leap and catch · Excellent landing mechanics with single leg hop cluster (hop for distance, triple hop, crossover, 6m timed) > 95% of uninvolved limb · Excellent acceleration, deceleration, change of direction control · Participated in reduced field hockey practice, completing final preparation for return to full field hockey practice and games · Completion of ACL-RSI
Exercise Recommendations	· Continue with progressive resisted strengthening from Phase Two · Maintain Knee range of motion · Advanced plyometrics from double to single leg, from simple to complex · Advance single leg perturbation training to unlevel surfaces, anticipated and unanticipated perturbations · Linear change in direction drills · Lateral change in direction drills · Field Hockey specific drills, ladder drills, passing, shooting, stick work: jabbing, tackling, dribbling, running with stick skills around cones, weaving in/out of cones at high speeds	· Running drills (straight line, zigzag, rotation, change in speed, change in direction as if there is a turn-over of the ball during play, backpedaling) · Field Hockey specific drills: passing and receiving the ball while running, dodging, and cutting defenders with ball and stick, passing, and receiving while running and corners.	· Field Hockey specific drills, including: dodging and cutting defenders while at full speed, playing 3v3 towards the circle, receiving a ball while dodging a defender then taking a free hit at the top of the circle, etc.

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Cardiovascular Recommendations	· Field Hockey specific cardiovascular training · Longer runs (20-30 minutes in duration)	· Interval Training · Tempo Runs · Fartleks · Shuttle Runs (can perform with and without stick and ball) · Sprinting on field/turf similar to yo-yo test	· Same as Phase 4
Pool Program	· Water Jogging	· Water Jogging · Swimming can be used for non-impact cardiovascular training as deemed appropriate	· Swimming can be used for non-impact cardiovascular training as deemed appropriate

Criteria to Progress to Phase 4:

In order to progress to phase 4 the athlete must demonstrate LSI greater than 90% on quadriceps, hamstrings, and hip abduction strength measurements, LSI of greater than 80% on single leg hop testing, and good motor control for 60s on single leg step down and lateral leap test[7–9,15,21,22,25]. She should be able to run for 20-30 minutes without any adverse knee response. Finally, the athlete should be able to demonstrate safe and stable acceleration and deceleration movements with both forward and lateral movements prior to starting phase 4. If the athlete demonstrates poor motor control while performing these tests, even if LSI is greater than 80%, the clinician is advised to not progress to phase 4. Quality of neuromuscular control without adaptation strategies is more than quantitative data[16]. If these deficits remain, it is important for the treating clinician to develop a targeted plan to address these impairments in order to continue to the return to sport.

PHASE 4: CUTTING, PIVOTING, SKILL DEVELOPMENT

Progression of previous strengthening should continue in this phase with an emphasis on combining sport-specific plyometric, agility and conditioning exercises. Introduction to cutting and pivoting will occur during this phase. However, it is important for the clinician to remember that multidirectional movements at high speeds place greater torque at the knee and it is important to gradually increase complexity of exercises[15,20]. Therefore, initiating two directions with a slight pause between can allow for safe introduction of cutting with good body mechanics. Speed, direction and resistance can be varied to prepare the athlete for return to field hockey. Single leg hops can be progressed by increasing the height of the box, varying the distance of the hops and the speed[7]. A gradual progression to more challenging exercises involving higher speeds, multi-directions and visual-motor requirements to improve movement quality, reactive movements and single limb motor control[15].

Suggested Rehabilitation Program for Phase 4:

<u>Balance and Proprioception</u>

Balance exercises should continue to be reactive and on single limb to prepare the athlete for increased proprioception for shifting weight onto the lower extremity when changing direction. This can include single leg standing on foam with tossing the ball against the trampoline or skaters with stick in hand and PT variably picking speeds or stop and go to alter the amount of force/weight placed on lower extremity as in game-like situations. Advancing balance activities that are utilizing the mind will prepare the patient for game-

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like situations where the athlete can't focus on their lower extremity alignment or balance[23].

Strength Exercises:

Collaboration with the school's athletic trainer and strength and conditioning specialist is always encouraged at this stage in rehabilitation to develop a program addressing the needs of the field hockey athlete for return to play. Increasing weight and repetitions and unilateral weight with double limb squats, single limb squats and variety of lunges will improve muscular strength and endurance required by the field hockey player. Similar to phase 3, increasing the height of step-ups and changing the surface that the exercises are performed on, such as bosu ball, slide board and rocker board, can provide aspects of multi-directional stability to the knee.

Sport-Specific Activity:

A field hockey athlete changes directions approximately every 5 meters in order to challenge a defender and make it up the field towards the goal. Cutting should be at a 90 degree angle to limit the stress and strain placed on the knee with new movement training[15]. Some drills include dribbling with a ball up to a cone, pulling past the cone, and then dribbling in another direction. This drill would then transition to being performed at higher speeds and then past a moving defender or the direction is called out by the physical therapist after the athlete has accelerated. Practicing sprinting to a ball in one direction, dribbling in a different direction and then taking a shot, would challenge the athlete in acceleration, deceleration and planting while on the move, similar to game-like play. Combining various exercises such as quick-feet, squatting, cutting, accelerating and decelerating can be performed in a rapid sequence to simulate a game environment[12]. These can also be progressed to be performed with the stick in hand, to simulate squat playing position. Clinician can also add sprints into squat holds to simulate running after the ball, then into defensive position for stick tackling. See Video receiving ball with defender and pull around defender video.

Cardiopulmonary Fitness

High intensity interval training, according to Seehafer et al., has been found to be effective at improving lower extremity power, speed, HR, VO2max and muscular endurance as effectively or to a greater extent than traditional aerobic training and in a shorter amount of time[13]. Therefore, the athlete should practice performing tempo runs, sprinting the verticals and jogging the horizontals on the field, fartleks and HIIT's with strengthening component (burpees, body weight squats, jumping lunges) can prepare the athlete for return to play. It is also recommended the athlete complete the Yo-Yo intermittent recovery test. This test involves running from back and forth between two markers, placed 20 meters away. The athlete has a 10 second recovery. Each phase is measured in audible beeps that get progressively faster as an athlete advances throughout the test. The Yo-Yo test is a good measure of aerobic fitness, sprinting and changing directions, despite its validity being questioned for female athletes[13].

Criteria to Progress to Phase 5:

In order to progress to phase 5, the athlete must demonstrate LSI greater than 95% on quadriceps, hamstrings and hip abduction strength measurements, LSI of greater than 90% on single leg hop testing, YBT and good motor control for 60s on single leg step down and lateral leap test[7,10–12,15,18,21]. The athlete must demonstrate excellent motor control and confidence for single limb landing activities, acceleration, deceleration, cutting and pivoting. It is recommended that the athlete complete a psychological return to readiness scale, such as the ACL-RSI scale, a 12 item questionnaire, evaluating confidence in performance, risk appraisal, and emotion, with good sensitivity 0.97 and specificity 0.63[7,9,26,27]. This should be completed on the next progress assessment prior to testing so that their score is not biased by the functional outcome measurements.

PHASE 5: RETURN TO PLAY

The athlete should continue to focus on improving individual impairments in strength, coordination and endurance under supervision, while combining agility, plyometrics and conditioning to imitate field hockey games. The clinician should progress previous exercises to include game-like scenarios as this has been proven to train neuromuscular control for return to sport. The clinician should begin to mimic the stop-and-

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go aspect of field hockey with cutting around defenders, passing and receiving while running, and turn-overs forcing change in direction of play. Cutting should be progressed towards a 45 degree knee flexion angle to simulate requirements of the game[15]. Previous exercises should be progressed to unanticipated cutting patterns, like having the athlete sprint dribbling the ball and having the PT call out change in direction, or calling out the specific stick skill maneuver to pass the defender, or the direction the athlete should pass the ball. This would simulate the unanticipated cutting a field hockey game would require.

Suggested Rehabilitation Program for Phase 5

Strength Exercises

The athlete can progress functional lower extremity strengthening exercises as needed by resistance, repetitions, and holds. One can progress to Olympic lifting to improve power such as dead-lifts, hang-cleans and push-jerk. Continued collaboration with the athlete's strength and conditioning coach, athletic trainer, coach, surgeon and athlete is important for clear understanding of patient's rehabilitation program and return to play plan. Collegiate and elite athletes can return to strengthening programs with their teams at this time.

Sport-Specific Activity

Practicing unanticipated scenarios to imitate a field hockey game is key for movement training. Therefore, cutting specific drills should be transitioned from conscious controlled tasks, like drills, to the chaotic and reactive nature of a game. Cutting around defenders should be practiced with stick and ball at various speeds. Turf sliding should also be practiced at this time for safety. Participating in full practice at this time is approved.

Criteria to Discharge to Return to Field Hockey

Athletes must maintain all of phase 4 criteria to progress along with excellent neuromuscular control with functional movement testing. Psychological readiness and confidence should be achieved by a score greater than 90 on the ACL-RSI questionnaire. No aberrant movements have been demonstrated with field hockey specific exercises such as running while passing the ball, shooting, dribbling, and cutting down the field around a defender and running with shooting.

SUMMARY

The evolution of field hockey as a fast paced sport has increased the number of non-contact ACL injuries over the last two decades[3]. Research is lacking in return of female athletes to the sport of field hockey post ACL reconstruction. Field hockey requires high cardiopulmonary demands, neuromuscular control, and lumbopelvic, hip and trunk strength to perform cutting and pivoting in a squat-like position with a ball and stick. Therefore, rehabilitation progression should follow a combination of physiological healing timelines with functional testing standards while also observing the quality of movement to ensure proper single limb strength and motor control. Collaborative communication with the athlete, parents, surgeon, athletic trainer, physical therapist and strength and conditioning team is essential for successful transition to the field. This guideline should assist the clinician in providing sport specific exercises and tools to assist the field hockey athlete's rehabilitation in preparation for a safe return to play.

Conflict of Interest Statement

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

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