Lacrosse: Biomechanics, Injuries, Prevention and Rehabilitation

A Case Report

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Doctor of Physical Therapy

By

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The final copy of this case report has been examined by the signatories, and we find that both the content and the form meet acceptable presentation standards of scholarly work in the above mentioned discipline.
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Abstract

Lacrosse is a sport deeply embedded in traditions and respect for the game. The biomechanics necessary to be successful in the sport demand athletes to possess the speed and power of football and hockey athletes as well as the endurance, agility, and strategy of basketball and soccer athletes. With these physical and mental skills athletes are expected to perform shooting, passing, and checking with precision. The sports combination of speed, sticks, balls, and contact make for a unique set of injury types, biomechanics, and preventative interventions. Injuries range from minor strains and sprains to season ending anterior cruciate ligament tears, broken bones, and severe concussions. Rehabilitation specialists and strength and conditioning coaches must have a good understanding of each injury sustained in order to ensure each athlete is returned to play based on an appropriate timeline for tissue healing and re-injury is not likely to occur.
INTRODUCTION

Lacrosse is the most rapidly growing sport in North America. Since 2003, overall growth of the sport has increased by 41%.¹ Youth participation alone has grown over 77% since 2006 to nearly 400,000 participants in 2012. Thirty new collegiate varsity teams began play in 2012, with a projected 48 more to begin by the end of 2013.² The sport has many different arenas starting from youth and high school levels, branching to collegiate teams and club levels, and finally climaxing with national and international teams.

The modern sport first came into popularity on the Northeastern Coast of the United States and Southeastern Canada; it has since spread west through North America and to 45 other nations. However, the sport of lacrosse has been played for centuries in North America and has its roots in Native American tradition, making it the oldest team sport known on the continent. In Native American tradition, lacrosse was played to resolve conflict, heal the sick, and develop strong men. Today the game is still referred to as “The Creator’s Game” by the founding population. The sport gained its modern name in 1637 when French missionaries observed Native Americans playing a ball game with sticks that resembled a bishop’s crosier, hence “lacrosse”. The first collegiate game was played at New York University in 1877, followed by the first high school games starting in 1882. Women’s lacrosse had a delayed start with the first game occurring at St. Leonard’s School in Scotland in 1890; however the first official women’s team was not established until 1926 at the Bryn Mawr School in Baltimore, Maryland.²

Like the traditional version of the sport, modern lacrosse is a mild contact sport that requires speed, agility, and power. The 60-minute game is played at a continuous, fast pace and resembles a mixture of soccer, basketball, and ice hockey. Thus the speed
and power of football and hockey athletes as well as the endurance, agility, and strategy of soccer and basketball athletes must all be mastered. The sports combination of speed, sticks, balls, and contact also make for a unique set of injury types, biomechanics, and preventative interventions.

EQUIPMENT

Lacrosse is played with a stick, also known as the crosse (See Figure 1). The crosse is the primary piece of equipment used during the game and must be mastered to throw, catch, and scoop the ball. The crosse is commonly made of plastic, metal, or wood. Wood was the only material used for the crosse up until the 1970s. Synthetic sticks, generally made of aluminum and titanium, were introduced in the 1980s and are lighter and more durable than their wood predecessors. Today sticks may be made of wood, laminated, or synthetic material. Men’s lacrosse is played with either a short crosse (40 to 42 inches in length) or a long crosse (52 to 72 inches in length) depending on the player’s position title. Attackmen and midfielders are assigned to a short crosse while defensemen are assigned to a long crosse. The goalkeeper’s crosse may vary from 40 to 72 inches in length. The crosse handle must be straight and have a circumference of no more than 3 ½ inches. The head of the crosse must measure between 6 ½ to 10 inches in width, while the head of the crosse designated for the goalkeeper must measure 10 to 12 inches in width. The head length on the crosse must be a minimum of 10 inches, while the goalkeepers head length can be a maximum of 16 ½ inches in length.3 The net of the crosse shall consist of gut, rawhide, linen, or synthetic material woven into a roughly triangular shape. The net creates a pocket for the ball to rest during play. A net that creates excessive sagging so that the top of the ball does not cross the plane of the bottom edge of the side wall when in the pocket is prohibited due to unfair advantage. A sagging
net allows the ball to rest deeper in the pocket causing an opponent’s efforts to dislodge it from the pocket to increase in difficulty.

Women’s crosses must be 35 ½ inches to 43 ¼ inches in length. A goalkeeper’s crosse may be 35 ½ inches to 48 inches in length. Women’s crosses do not have a deep mesh pocket, which allows the ball to become dislodged easier during play. Instead the pocket of a woman’s crosse is strung tightly in the traditional style with 7 to 9 strings. Thus the top of the ball must remain above the top of the side wall when dropped into the pocket of a horizontally held crosse.⁴

The lacrosse ball is a hard ball slightly smaller than a baseball. Dimensions should be between 7 ¾ and 8 inches in circumference, between 5 and 5 ¼ ounces in weight, and it shall bounce 43 to 51 inches when dropped from a height of 72 inches onto a concrete floor in an atmosphere of 65° to 70° Fahrenheit. The lacrosse ball may be white, yellow, orange, or lime green and made of smooth or textured solid rubber.³

**Figure 1.** An offensive short crosse (bottom), a defensive long crosse (top), and a rubber lacrosse ball

Men’s lacrosse is played on a field roughly the size of a football field (110 yards long and 60 yards wide) with the goals placed 80 yards apart (See Figure 3). The lacrosse goal should form an opening that is 6 feet wide and 6 feet high, with a net backing that
does not allow the ball to re-enter the field of play once a goal is scored.⁹ There are 10 players on the field per team. These 10 players consist of 1 goal keeper, 3 midfielders, 3 attackmen, and 3 defensemen. At all times during the game, 4 players must stay on the defensive side of the field, and 3 players must stay on the offensive side of the field. Men are required to wear helmets with full face mask, rib pads, non-cantilever shoulder pads, elbow pads, padded gloves, genital protective cups, and mouth guards (See Figure 2). Helmets must consist of a chin pad and chin strap, while face masks must have a center bar from top to bottom. Mouth guards must cover the entire upper jaw and be yellow or any other highly visible color. Goalkeepers are not required to wear shoulder pads or arm pads but must wear additional equipment which includes a chest protector, a throat protector, and shin guards. Shoe cleats may not be longer than ½ inch.³

Figure 2. Protective Equipment. Helmets with full face mask and chin guards, padded gloves, shoulder pads, elbow pads, and cleats
Figure 3. Men’s Lacrosse Field of Play

Women’s lacrosse is played on a longer (110 to 140 yards) and wider (60 to 70 yards) field than men’s lacrosse, with goals 100 yards apart (See Figure 4). The lacrosse goal should form an opening that is 6 feet wide and 6 feet high, with a net backing that does not allow the ball to re-enter the field of play once a goal is scored. There are 12 players on the field per team. These 12 players consist of 1 goal keeper, 5 attack players, and 6 defensive players. At all times during the game, 5 players must stay on the defensive side of the field, and 4 players must stay on the offensive side of the field. Women are required to wear far less equipment than men due to rules which prohibit body contact. However, women must wear protective eyewear and a mouth guard, with gloves being optional. Full protective equipment as required in men’s lacrosse is only required for the goalkeeper. Full goalkeeper equipment includes a helmet with face mask, a throat protector, padded gloves, a mouthpiece, and a chest protector. Goalkeepers may
wear arm, leg, and shoulder pads that do not excessively increase the size of such body parts. Women are allowed to wear optional neoprene gloves, nose guards, and soft protective head gear. Women, unlike men, may not wear spiked cleats, however plastic, leather, or rubber cleat-studs may be worn.\(^4\)

![Figure 4. Women’s Lacrosse Field of Play\(^6\)](image)

Rules which differ between men’s and women’s lacrosse due to difference in equipment requirements include mandatory penalties in women’s lacrosse for slashing, dangerous play, and dangerous follow through. Offensive shots taken in an uncontrolled way or without regard of the opposing field player require a penalty. A penalty must also be called when a defensive player guards the goal with any part of the body which denies the attacker the opportunity to shoot safely in the free space, further increasing the risk of
injury. The “bubble rule” described as breaching the 7-inch sphere around the head of any opponent with the lacrosse stick is also cause for a penalty call. To enforce such rules and help to minimize risk of injury it is strongly recommended to use at least two US Lacrosse trained umpires during games. When penalties do occur, affected players must report to the special-substitution area immediately in front of the scorer’s table.

BIOMECHANICS

Lacrosse requires coordination of the upper extremities, trunk, and lower extremities, all while navigating uneven terrain with a swivel-like head. In addition, most collisions occur with the lacrosse stick in an overhead position which necessitates dynamic stabilization. In terms of the upper extremities, the stick is generally held overhead with the elbow at or below shoulder level (See Figure 5). This posture creates a longer lever arm due to the stick overhead, which is also a main mechanism for shoulder injuries.

Figure 5. Typical lacrosse stance with stick held overhead while the elbows are below shoulder level creating a longer level arm for force production.
Lacrosse Shot

The lacrosse shot is an essential skill for each offensive player. The purpose of this movement is to accelerate the ball as fast as possible while maintaining accuracy to place the ball into the goal. The lacrosse shot may be broken down into the following phases: approach, crank-back, stick acceleration, stick deceleration, follow through, and recovery (See Table 1). Each of the mentioned phases has a beginning of the phase and an ending of the phase. The lacrosse shot may be performed overhand, underhand, or side arm, thus all shots may not fit into or encompass all of the phases listed. Events in which players are shooting with a long stick as opposed to the typical short stick an offensive player carries will also alter the typical movement pattern.⁸

Approach. --- The approach phase of the lacrosse shot initiates with the player taking several steps towards the goal with the intent to shot (See Figure 6A). These steps are typically of high velocity and include stepping styles such as stepping forward, sideways, backwards, cross-over, or hopping. The approach phase concludes when the player decreases lower extremity velocity and the “drive leg” is planted into the ground. The drive leg is the lower extremity that performs forceful hip extension, knee extension, and ankle plantarflexion during the lacrosse shot to exert force upward through a rigid level and push the player forward. The “lead leg” to be referenced later, is the other lower extremity which is the leg planted in front of the player during the lacrosse shot. When performing a right handed lacrosse shot the drive leg is the right leg and the lead leg is the left leg; vice versa for a left handed lacrosse shot.⁸
**Crank back.---** The crank back phase, also called the wind-up or cocking phase, consists of preparatory movements for the angular motion seen in the stick acceleration phase. The crank back phase begins with the drive leg planting into the ground (See Figure 6B). The crank back phase ends when the top arm, arm in between the bottom arm and the head of the stick, attains maximum elbow flexion. During a right handed shot the right arm is the top arm, while a left handed shot establishes the left arm as being the top arm. The crank phase is subdivided into phase A and phase B.\(^8\)

Phase A deal with placement of the lower extremities, known as a drive step, in preparation for stick acceleration. This phase of the crank back begins when the drive leg contacts and is planted into the ground. Phase A ends when the foot of the lead leg contacts the ground.\(^8\)

Phase B deals with placement of the upper extremities into a wind up position in preparation for stick acceleration. The phase begins when the foot of the lead leg contacts the ground. The phase ends when maximum flexion is demonstrated at the elbow of the top arm. Placement of the stick is of upmost importance during this phase. Proper placement is necessary for increased shot velocity and accuracy. Peak elbow flexion velocity has also been hypothesized to elicit a stretch-shortening reflex and increase elbow extension velocity during the stick acceleration phase.\(^8\)

**Stick Acceleration.---** Stick acceleration phase is an extremely short and dynamic phase. The phase begins when the elbow of the top arm reaches maximum flexion (See Figure 6C). From this point of maximal flexion, rapid extension of the elbow and forward propulsion of the stick occur. The trunk swiftly transitions from a backward rotation and extension position to a forward rotation and flexion position based on the stick handling side. The rapid change of position propels the head of the stick in the
direction of the goal and releases the ball from the pocket of the crosse. The stick acceleration phase concludes with the release of the ball.  

**Stick deceleration. ---** The stick deceleration phase of the lacrosse shot begins once the ball is released from the pocket of the crosse (See Figure 6D). This phase will vary based on the shot technique performed, player skill level, stick type, and the general acceleration arc of the head of the stick. During this phase shoulder musculature for stability and elbow flexor eccentric strength for deceleration of the extending elbow are tested. The phase ends when the elbow of the top arm reaches maximum extension.  

**Follow-through. ---** The follow-through motion represents an essential phase of movement to dissipate forces produced from the previous phases of the lacrosse shot and to prevent injuries. The phase begins when the top arm reaches maximal elbow extension (See Figure 6E). As the body continues to attempt to decelerate the upper extremity, the trunk begins to rotate. This phase is comparable to the follow-through phase seen in a baseball swing. The phase is ends with the completion of trunk rotation.  

**Recovery. ---** Recovery phase is considered a transitional phase. The phase begins with the termination of trunk rotation. Movements during this phase vary based on the next task the player needs to perform. There is no specific movement which concludes this phase. Players will often perform a lacrosse pass or checking maneuver while running down field rather than immediately beginning another lacrosse shot.
Table 1. Biomechanics of the Phases for a Right-Handed Lacrosse Shot

<table>
<thead>
<tr>
<th>Body Part</th>
<th>Approach</th>
<th>Crank Back Phase A</th>
<th>Crank Back Phase B</th>
<th>Stick Acceleration</th>
<th>Stick Deceleration</th>
<th>Follow Through</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top Elbow</td>
<td>30° flexion moving into further flexion, biceps concentric</td>
<td>125° flexion moving into further flexion, biceps concentric</td>
<td>160° flexion remaining in flexion, biceps concentric</td>
<td>A rapid 160° flexion to 75° flexion moving into extension, triceps concentric</td>
<td>Maximal extension moving into flexion, triceps concentric &amp; biceps eccentric</td>
<td>60° flexion moving into further flexion, biceps concentric &amp; triceps eccentric</td>
</tr>
<tr>
<td>Bottom Elbow</td>
<td>70° flexion moving into further flexion, biceps concentric</td>
<td>90° flexion moving into further flexion, biceps concentric</td>
<td>100° flexion remaining in flexion, biceps concentric</td>
<td>A rapid 100° flexion to 15° flexion moving into extension, triceps concentric</td>
<td>Remaining in 15° flexion moving into further flexion, triceps &amp; biceps concentric for stability</td>
<td>120° flexion &amp; remaining in flexion, biceps concentric &amp; triceps eccentric</td>
</tr>
<tr>
<td>Body Part</td>
<td>Approach</td>
<td>Crank Back Phase A</td>
<td>Crank Back Phase B</td>
<td>Stick Acceleration</td>
<td>Stick Deceleration</td>
<td>Follow Through</td>
</tr>
<tr>
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<td>----------------------------------------------------------------------------------</td>
<td>-----------------------------------------------------------------------------------</td>
<td>-----------------------------------------------------------------------------------</td>
<td>--------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Top Shoulder</td>
<td>Abducted 100° &amp; externally rotated moving into horizontal adduction &amp; extension, Pectoralis major concentric &amp; rotator cuff/scapular musculature eccentric</td>
<td>Abducted 50° &amp; externally rotated moving into adduction, Pectoralis major &amp; latissimus dorsi concentric &amp; rotator cuff/scapular musculature eccentric</td>
<td>Maximal external rotation, 40° abduction &amp; 10° horizontal adduction moving into horizontal adduction, Pectoralis major concentric &amp; rotator cuff/scapular musculature eccentric</td>
<td>External rotation &amp; horizontal adduction moving into horizontal adduction &amp; extension, pectoralis major concentric, rotator cuff/scapular musculature eccentric</td>
<td>70° flexion, 35° horizontal adduction, &amp; relative external rotation moving into extension &amp; internal rotation, pectoralis major &amp; latissimus dorsi concentric &amp; deltoid &amp; rotator cuff/scapular musculature eccentric</td>
<td>Slight horizontal adduction, internal rotation &amp; 35° flexion moving into extension, pectoralis major, teres major, subscapularis, &amp; latissimus dorsi concentric &amp; deltoid &amp; rotator cuff/scapular musculature eccentric</td>
</tr>
<tr>
<td>Body Part</td>
<td>Approach</td>
<td>Crank Back Phase A</td>
<td>Crank Back Phase B</td>
<td>Stick Acceleration</td>
<td>Stick Deceleration</td>
<td>Follow Through</td>
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</tr>
<tr>
<td>Bottom Shoulder</td>
<td>Horizontal adduction &amp; Internal rotation moving into flexion, pectoralis major, subscapularis, &amp; anterior deltoid concentric</td>
<td>Horizontal adduction &amp; Internal rotation moving into flexion, pectoralis major, subscapularis, &amp; anterior deltoid concentric</td>
<td>Maximal horizontal adduction, 110° flexion, &amp; 70° internal rotation remaining in position, pectoralis major, subscapularis, &amp; anterior deltoid concentric</td>
<td>Horizontal adduction, 45° flexion, &amp; 30° internal rotation moving into extension &amp; external rotation, latissimus dorsi &amp; posterior deltoid concentric</td>
<td>Slight horizontal adduction, 30° flexion &amp; neutral rotation moving into extension &amp; external rotation, teres minor, &amp; latissimus dorsi concentric</td>
<td>Slight external rotation &amp; extension, infraspinatus, teres minor, &amp; latissimus dorsi concentric &amp; pectoralis major eccentric</td>
</tr>
<tr>
<td>Trunk</td>
<td>Backward rotation &amp; extended over right hip moving into a neutral rotation</td>
<td>Backward rotation over right hip &amp; extension moving into a neutral rotation</td>
<td>Slight backward rotation &amp; flexion moving into flexion &amp; forward left rotation</td>
<td>Neutral rotation &amp; flexion moving into neutral rotation &amp; flexion</td>
<td>Slight forward left rotation &amp; forward flexion moving into further rotation</td>
<td>Forward flexion &amp; complete forward rotation over left hip</td>
</tr>
<tr>
<td>Drive Hip</td>
<td>Slight flexion &amp; external rotation moving into extension &amp; internal rotation</td>
<td>Slight extension &amp; internal rotation moving into further extension &amp; internal rotation, gluteus maximus &amp; adductor complex concentric</td>
<td>Slight extension &amp; internal rotation moving into further extension &amp; internal rotation, gluteus maximus &amp; adductor complex concentric</td>
<td>Extension in neutral moving into further extension &amp; internal rotation, gluteus maximus &amp; adductor complex concentric</td>
<td>Slight extension &amp; internal rotation moving into further extension &amp; internal rotation, gluteus maximus &amp; adductor complex concentric</td>
<td>Extended &amp; internally rotated, gluteus maximus &amp; adductor complex concentric</td>
</tr>
<tr>
<td>Body Part</td>
<td>Approach</td>
<td>Crank Back Phase A</td>
<td>Crank Back Phase B</td>
<td>Stick Acceleration</td>
<td>Stick Deceleration</td>
<td>Follow Through</td>
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<tr>
<td>Lead Hip</td>
<td>Internal rotation moving to neutral, gluteus medius concentric for stabilization</td>
<td>Slight flexion &amp; internal rotation moving into further flexion &amp; remaining neutral, quadriceps, adductors, &amp; external rotator complex concentric</td>
<td>70° flexion moving into further flexion &amp; remaining neutral, quadriceps, adductors, &amp; external rotator complex concentric</td>
<td>75° flexion moving into further flexion &amp; remaining neutral, quadriceps, adductors, &amp; external rotator complex concentric</td>
<td>80° flexion moving into extension &amp; internal rotation, quadriceps &amp; adductor complex concentric</td>
<td>60° flexion &amp; slight internal rotation moving into extension &amp; further internal rotation gluteus maximus, adductor complex &amp; hamstrings concentric &amp; quadriceps eccentric</td>
</tr>
<tr>
<td>Drive Knee</td>
<td>Approx 90° flexion moving into extension, quadriceps concentric &amp; hamstrings eccentric</td>
<td>Approx 30° flexion moving into further flexion, quadriceps eccentric &amp; hamstrings concentric</td>
<td>Approx 75° flexion moving into further flexion, quadriceps eccentric &amp; hamstrings concentric</td>
<td>Flexion increases to approx 85° then returns to 75° moving into extension, quadriceps &amp; hamstrings both concentric &amp; eccentric</td>
<td>Approx 65° flexion moving into extension, quadriceps concentric &amp; hamstrings eccentric</td>
<td>Near complete extension, quadriceps concentric &amp; hamstrings eccentric</td>
</tr>
<tr>
<td>Body Part</td>
<td>Approach</td>
<td>Crank Back Phase A</td>
<td>Crank Back Phase B</td>
<td>Stick Acceleration</td>
<td>Stick Deceleration</td>
<td>Follow Through</td>
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<td>-------------------------------------------------------</td>
</tr>
<tr>
<td>Lead Knee</td>
<td>Extended moving into flexion, quadriceps &amp; hamstrings for stabilization</td>
<td>Approx 30° flexion moving into further flexion, quadriceps eccentric &amp; hamstrings concentric</td>
<td>Approx 60° flexion moving into further flexion, quadriceps eccentric &amp; hamstrings concentric</td>
<td>Approx 70° flexion moving into extension, quadriceps concentric &amp; hamstrings eccentric</td>
<td>Approx 45° flexion moving into extension, quadriceps concentric &amp; hamstrings eccentric</td>
<td>Approx 35° flexion moving into extension, quadriceps concentric &amp; hamstrings eccentric</td>
</tr>
<tr>
<td>Drive Ankle</td>
<td>Neutral moving into plantarflexion, gastrocsoleus complex concentrically contracting</td>
<td>Relative plantarflexion, gastrocsoleus complex concentric</td>
<td>Relative plantarflexion, gastrocsoleus complex concentric</td>
<td>Relative plantarflexion, gastrocsoleus complex concentric</td>
<td>Relative plantarflexion, gastrocsoleus complex concentric</td>
<td>Plantarflexion completing pushoff, gastrocsoleus complex concentric</td>
</tr>
<tr>
<td>Lead Ankle</td>
<td>Plantarflexion moving into dorsiflexion, anticipating ground contact</td>
<td>Neutral, tibialis anterior &amp; gastrocsoleus complex in combination for stability</td>
<td>Neutral, tibialis anterior &amp; gastrocsoleus complex in combination for stability</td>
<td>Neutral, tibialis anterior &amp; gastrocsoleus complex in combination for stability</td>
<td>Neutral, tibialis anterior &amp; gastrocsoleus complex in combination for stability</td>
<td>Relative plantarflexion initiating next pushoff, gastrocsoleus concentric</td>
</tr>
</tbody>
</table>
Lacrosse Swing/Pass

A fundamental movement of the sport is the lacrosse swing or pass. Teams must have the ability to quickly and effectively transition the ball from defense to offense. Offense relies heavily on this movement to pass the ball and create shot opportunities. Although there are several variations of the swing, an overhand swing is used most often during play. The swing consists of two phases: the draw phase and the release phase (See Figure 7). During the draw phase the stick is overhead and the shoulder is down and behind the head. The upper arm is in a flexed and externally rotated position. During this phase the stick acts as a long lever that allows the player to apply leverage and increase the velocity of the ball to act as a catapult during the release phase. During the release phase the head of the stick is moved in a forward and downward direction. The upper arm moves into a position of extension and internal rotation. The other lacrosse swings include underhand, backhand, and side-arm swings. Each swing consists of the two mentioned phases while movement of the upper arm depends on the swing utilized. The lacrosse pass should be directed at the shoulder of the intended player opposite of the defender, which allows the offensive player to provide a shield. Passes performed while running should be directed in front of the receiving player to allow maintenance of running speed. The pass should be strong and quick to allow a high velocity pass and avoid interception by a defender due to a soft, slow, floating pass.

During lacrosse movements, the trunk acts as a solid base from which all movements originate. In terms of the lower extremities, movements mimic those observed in soccer and basketball. High velocity cuts, pivots, and twists as well as sudden body blocks compose the sport’s footwork. The lower extremities may be affected by the
upper extremities during passing and shooting. This is due to the increased lever arm as mentioned previously, as well as the fact that these actions are performed with both hands holding the lacrosse stick. By placing both hands on the stick, an increased valgus load is placed on the knee when landing and cutting.¹

Different biomechanical abilities are needed for each of the four field positions associated with the sport of lacrosse (See Table 2). For an offensive position or attacker, the player needs to possess speed, agility, and elite stick skills in order to outmaneuver an opponent and score. For a defensive position, agility is still necessary, however, the ability to produce large power outputs is also mandatory in order to body check opponents and guard the goal. For a midfielder, speed and stamina are required as a means of playing both offensive and defensive positions. For a goaltender, agility is still needed but hand-eye coordination as well as proprioceptive footwork is essential for providing full goal coverage.¹⁰

<table>
<thead>
<tr>
<th><strong>Table 2. Skills by Field Position</strong></th>
<th><strong>Midfielders</strong></th>
<th><strong>Defensemen</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Attackmen</strong></td>
<td><strong>Midfielders</strong></td>
<td><strong>Defensemen</strong></td>
</tr>
<tr>
<td>• Experienced player</td>
<td>• Versatility</td>
<td>• Reliable stick checking &amp; shot blocking ability</td>
</tr>
<tr>
<td>• Exceptional shooting skills</td>
<td>• Consistent ball skills</td>
<td>• Strong body checking positioning</td>
</tr>
<tr>
<td>• Precision passing skills</td>
<td>• Capable of shooting from the outside</td>
<td>• One-on-one marking ability</td>
</tr>
<tr>
<td>• Strong ball skills</td>
<td>• Accurate passer</td>
<td>• Ability to anticipate and intercept a loose ball</td>
</tr>
<tr>
<td>• Able to transition from offense to defense</td>
<td>• Endurance to cover entire field</td>
<td>• Speed to recover</td>
</tr>
<tr>
<td>• Agility and speed to get open and receive passes</td>
<td>• Speed for fast breaks</td>
<td>• Good strategic decision making</td>
</tr>
<tr>
<td>• Good field vision and space awareness</td>
<td>• Good field vision and space awareness</td>
<td>• Strong communicator</td>
</tr>
<tr>
<td>• Ability to dissolve a body hit</td>
<td>• Ability to anticipate a transition from offense to defense</td>
<td>• Strong communicator</td>
</tr>
</tbody>
</table>
The previously mentioned biomechanics performed during the sport cause athletes to possess a physiological fitness profile similar to that of basketball, soccer, and track players. However, lacrosse players differ in that they possess only average flexibility and a body fat percentage 5.9% higher than that of collegiate soccer players.\textsuperscript{11} These findings suggest there is room for improvement in lacrosse players’ physiological fitness profiles which may in turn produce biomechanical improvements in movement.

<table>
<thead>
<tr>
<th>Attackmen</th>
<th>Midfielders</th>
<th>Defensemen</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Confidence with one-on-one matchups</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Strong communicator</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Checking

Checking primarily consists of action performed at the elbow with accessory movements from the glenohumeral joint. The traditional checking method in the sagittal plane consists of an up to down motion in which the glenohumeral joint remains stationary in neutral or in slight flexion while the elbow repetitively moves from full flexion to extension while holding the stick (See Figure 8C). Checking may also be done in the transverse plane with a side motion in which the elbow is held in a relatively flexed 90° position while the glenohumeral joint slightly abducts and repetitively moves from an
internally rotated position to an externally rotated position (See Figure 8A-B). During 
both checking techniques the primary movement is through the dominant arm; however 
both hands are on the stick for increased stability and power (See Table 3). Checking may 
be performed with one hand holding the stick; however this method provides the player 
with less control of the stick and decreases the amount of force that is able to be exerted 
through the stick. Checking is a forceful activity and requires adequate stabilization 
ability from glenohumeral and elbow musculature and normal ligament integrity. A male 
player’s gloved hands and padded arms are considered part of the stick and may legally 
be checked.12 Female rules allow stick checking, however checking must be directed 
toward the pocketed end of the stick. Sticks must also be kept away from the 7-inch 
protective sphere around the female player’s head. A foul is called if a stick breaches the 
7-inch protective sphere around a player’s head. This rule is especially important in 
women’s lacrosse considering hard helmets are not allowed.7
Figure 8. Checking Maneuvers. A, Across the body checking away from the dominant arm. B, Side check in the direction of the dominant arm. C, Forward check against an offensive shot

<table>
<thead>
<tr>
<th>Table 3. Step by Step Checking Techniques</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Forward Check</strong></td>
</tr>
<tr>
<td>1. Hold stick with both hands</td>
</tr>
<tr>
<td>2. Approach opponent sideways angling your top shoulder to their bottom shoulder</td>
</tr>
<tr>
<td>3. Extend stick forward and attempt to make contact with opponent’s bottom arm</td>
</tr>
<tr>
<td>4. If missed, attempt to block opponent’s top arm or stick</td>
</tr>
<tr>
<td>5. Follow through with opponent creating resistance and possibly creating body contact</td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>
Table 3. continued

<table>
<thead>
<tr>
<th>Forward Check</th>
<th>Side Check</th>
<th>Across Body</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>swing their stick forward or sideways for a shot or pass</td>
<td>extend your stick across your body and your opponent’s body</td>
</tr>
<tr>
<td></td>
<td>5. Attempt to maintain contact with your opponent’s stick or arm throughout the check attempt</td>
<td>6. Aim to make contact with your opponent’s stick, keeping it as close to their body as possible</td>
</tr>
</tbody>
</table>

INJURY PREVENTION

Warm-Up

A warm-up period is important to include prior to each practice session or competition. The act of warming up prepares the athlete mentally and physically to perform. A well designed warm-up should promote physiological effects such as increased muscle temperature, core temperature, and blood flow, while disturbing unnecessary connective tissue bonds within muscle. A warm-up consists of two phases: a general warm-up period and a specific warm-up period. The general warm up period should last 5 to 10 minutes and consist of low-intensity, low velocity activity. A general recommendation for warm-up intensity is to acquire a target heart rate of 50% the targeted heart rate for the succeeding stimulus activity, such as a strengthening or aerobic training session. Such activities to be used with lacrosse players are a slow jog around the field, stationary cycling, or skipping the length of the field. The objective of this period is to increase blood flow, heart rate, respiratory rate, deep muscle temperature, and perspiration, while decreasing synovial fluid viscosity of the joints.\textsuperscript{13}
A specific warm-up should begin with 8 to 12 minutes of dynamic stretching using sport specific movements similar to those seen during play. The movements are dynamic and should encompass the entire range of motion seen during play. Such movements may include leg swings, arm circles, and elbow to instep lunges. The period of dynamic stretching is followed by a period of line drills which resemble sports-specific movements. These drills may include carioca, gluteal kicks, A-skips, B-skips, and lateral shuffles. Drills for the trunk and upper extremity must also be incorporated due to whole body involvement during lacrosse play. The intensity of the warm-up should be progressive, however the warm-up should not cause fatigue or reduce energy stores prior to the upcoming practice or competition.\(^{13}\)

**Stretching**

The flexibility of an athlete must be preserved in order to maintain each joints range of motion and not inhibit performance due to stiffness. Stretching should be performed to maintain flexibility of the shoulders, trunk, hips, knees, and ankles. Athletes should be mindful to perform a stretch to only minor discomfort and avoid sensation loss or radiating pain which may cause nerve damage or joint instability from excessive stretching.\(^{13}\)

Dynamic stretching may be performed as an active stretch which occurs through active joint movement. The technique targets movement patterns rather than individual muscles and is used in dynamic warm-ups between the general warm-up and the sports specific line drills. Individuals with poor flexibility, especially of the hamstrings or triceps may benefit from partner stretching through a hold-relax technique. This
technique includes a 10-second passive stretch, a 6-second isometric contraction held against partner resistance, and a 30-second passive stretch held in the newly acquired range. A stretching regimen should be performed a minimum of two days a week to preserve flexibility, however stretching after each practice, competition, or as part of an active recovery session is ideal. Static stretching should be performed after activity. When performing a static stretch, each stretch should be held for 30 seconds and each stretch should be performed for several repetitions.

**Strength and Conditioning Program**

The sport of lacrosse requires coordination and agility rather than sheer strength and power. Quickness and speed are highly prized in competition, thus strength and conditioning program must adhere to standards which optimize these characteristics. The strength and conditioning program should start in off-season and continue into in-season. The program should allow competitive play throughout preseason and insenasion, while allowing a peak of performance during tournament games. A successful strength and conditioning program should include plyometrics, neuromuscular training, basic strength training, and sport specific strength and agility training (See Table 4). The strength and conditioning program should be established by a qualified professional to ensure proper progression and avoid overtraining or overuse injuries due to improper prescription of rest periods. Lacrosse players generally should have one to two days of recovery time per week. At the end of each season players should be allowed at least one to two months a year for postseason or active rest recovery period.
Table 4. One Week Example Programs

### Off-Season: Strength/Power Phase

**Week 1: 4x/week**

**Lower Body: 2x/week (Monday/Thursday)**

*Heavy Day: Monday*

- **Power Clean**: 4 x 3 90% 3RM
- **Clean Pull- Below Knee**: 3 x 3 90% 3RM
- **Deadlifts**: 4 x 3 90% 3RM
- **Split Squats**: 4 x 5 each 90% 4RM
- **Band resisted Seated Hamstring Curls**: 3 x 8 80% 1RM
- **Seated Calf Raise**: 3 x 8 80% 1RM

*Light Day: Thursday*

85% of Monday's load for power/core exercises

**Upper Body: 2x/week (Tuesday/Friday)**

*Heavy Day: Tuesday*

- **Push Jerk**: 4 x 3 90% 3RM
- **Push Press**: 4 x 3 90% 3RM
- **Dumbbell Bench Press**: 4 x 4 90% 4RM
- **Seated Row**: 3 x 8 80% 1RM
- **Band Overhead Triceps Extension**: 3 x 8 each 80% 1RM
- **Seated Hammer Curl**: 2 x 8 each 80% 1RM
- **Abdominal Crunch**: 3 x 20

*Light Day: Friday*

85% of Tuesday's load for power/core exercises

### In-Season

**Week 1: 2x/week**

**Weekly Workout #1**

- **Push Press**: 1 x 6 75% 1RM
- **Incline Bench Press**: 1 x 6 85% 1RM
- **Dumbbell Hammer Curl**: 2 x 8 each 80% 1RM
- **Triceps Extension**: 2 x 8 80% 1RM
- **Lateral Shoulder Raise**: 2 x 10 75% 1RM
- **Abdominal Crunch**: Max in 60 seconds

**Weekly Workout #2**

- **High Pull**: 1 x 4 80% 1RM
- **Back Squat**: 1 x 6 85% 1RM
- **Dumbbell Single Leg Deadlifts**: 2 x 6 each 85% 1 RM
- **Hip Sled**: 2 x 10 75% 1RM
- **Seated Row**: 2 x 12 67% 1RM
- **Supine Leg Raise**: Max in 60 seconds
ETIOLOGY OF INJURIES

Intrinsic Factors

Muscle strength imbalances, muscle fatigue, decreased neuromuscular activation patterns, proprioception deficits, joint laxity, and bony alignment are all intrinsic risk factors that predispose an athlete to injury (See Table 5). Muscle weakness is a key intrinsic factor for injury among all levels of lacrosse play. Muscular weakness or imbalances may be caused by training errors resulting in unconditioned muscles which are injured early in preseason practice and scrimmages. The incidence of injury increases with increased muscular fatigue. This increase in injury rate among fatigued muscles may be due to improper execution of techniques. Decreased neuromuscular activation patterns may also lead to improper execution of technique and cause overuse injuries due to muscular compensation.

Proprioception deficits have been identified as a primary cause of ankle and knee injuries. The implementation of proprioceptive training as well as core training has been shown to decrease the risk of ankle and knee ligament injuries in lacrosse players. Joint laxity and limb alignment are two factors which were thought to influence injury rates; however limited research supports these theories with need for further studies to be conducted on the topic.

As a result of increased incidence of the anterior cruciate ligament (ACL) injuries in female athletes, it has been speculated that intercondylar notch size as compared to the
size of male counterparts is the suspected cause. A decrease in notch width may be the reason for increased ACL failure in both newly injured and reconstructed knees. Thus athletes with smaller notch widths are at an increased risk of ACL injuries compared to athletes with notch widths in the normal range. Intrinsic factors for injury in adolescents engaging in lacrosse may be linked to skeletal immaturity. These injuries are commonly identified through fractures of the epiphyseal plate.

Extrinsic Factors

Extrinsic factors which influence injury during lacrosse play are due to the environment in which play is performed. These factors may include body movements, playing surface, contact or rule violations, and level of skill and conditions (See Table 6). Specific body movements in lacrosse, such as planting, cutting, and decelerating may play a role in incidence of knee injury. Technique for the plant and cut maneuvers may be modified to increase knee flexion and position the feet under the hips which provides increased stability at the knee and may lower injury rates. As lacrosse is played outside, defects in the turf contribute to possible injury. Weather and erosion can cause irregularities in the playing surface, therefore, maintenance to repair holes and maintain a level playing surface must be a priority.

Although contact is illegal in women’s lacrosse, contact is a primary factor for injury. Contact in terms of player to player, player to ball/stick, or player to ground are all common causes of injury among lacrosse players. High contact or illegal contact from

<table>
<thead>
<tr>
<th>Table 6. Extrinsic Factors for Injury</th>
</tr>
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<tbody>
<tr>
<td>• Improper techniques for specific body movements</td>
</tr>
<tr>
<td>• Deficits in playing surface</td>
</tr>
<tr>
<td>• Alternation of equipment</td>
</tr>
<tr>
<td>• Illegal contact</td>
</tr>
<tr>
<td>• Rule violations</td>
</tr>
<tr>
<td>• Level of skills</td>
</tr>
</tbody>
</table>
non-rule abiding players increases the incidence of injuries. The altering of equipment, such as helmets or mouth guards, may also be an extrinsic factor for injury. The level of competition has been linked with an increase in incidence of injury.\textsuperscript{12} This may be a result of increased intensity, duration, and frequency of play with each rise in level.

**COMMON INJURIES AND THEIR REHABILITATION**

Although tagged “the little brother of war” lacrosse has comparatively low injury rates when compared to other contact sports. However, due to the mild contact nature of the sport, injuries to players are probable rating lacrosse as a moderate risk sport. Injuries occur by player to player contact, player to object contact, and/or non-contact. For the 2004 season of intercollegiate men’s lacrosse, injury rate per 1000 athlete exposure was 4.7.\textsuperscript{1} Of these injuries, 40\% were produced by non-contact mechanisms. A difference in cause of injury is seen between the genders with men sustaining more injuries due to player to player contact while women sustain more injuries due to non-contact.\textsuperscript{16} Injuries are seen at significantly higher rates in games than in practice situations. These ratios consist of a 4:1 ratio for men’s collegiate games and a 2:1 ratio for women’s collegiate games. Injury rates also increase with each rise in level of competition for both genders.\textsuperscript{12} Differences in body region injured exist between practice and game settings with 75\% of all injuries in practice and 53\% of all injuries in competition being in the lower extremity while 8\% of all injuries in practice and 22\% of all injuries in competition were to the head (See Figures 9-10).\textsuperscript{17}
Figure 9. Women's Lacrosse Injuries by Body Area (%) Practice 2006-07 and 3 Year Average\textsuperscript{17}

Figure 10. Women's Lacrosse Injuries by Body Area (%) Competition 2006-07 and 3 Year Average\textsuperscript{17}
At all levels of competition, injuries are highest in preseason as compared to postseason. These injuries often involve muscle strain and may be linked to a poorly planned offseason and preseason conditioning program. Injury patterns seen across the sport are based on age, gender, and level of play. The majority of injuries sustained from lacrosse are strains, sprains, bruises, and abrasions. However, significant injuries can occur.12

Head/Neck Injuries

Concussions are the most commonly sustained injury to the head and neck during lacrosse games. Concussion rates are 9 times higher in men’s games than practice situations and 4 times higher in women’s games than practice situations.12 US Lacrosse rates head injuries in the top three injuries for both men’s and women’s college and youth level lacrosse.18 The rate of concussions in high school boys lacrosse players per 1000 athlete exposures is .28 to .34. While the rate of concussion in high school girls lacrosse players per 1000 athlete exposures is .1 to .21. These rates place boys high school lacrosse in third ranking while the girls high school lacrosse place in seventh ranking for occurrence among high school sports; the rating is out of 11 sports with football and girls’ soccer being the sports with highest incidence of concussion.19 This trend is also common in the collegiate population with twice as many concussions occurring in collegiate men’s lacrosse (85%) as collegiate woman’s lacrosse (41%).20 Cerebral concussions sustained during men’s lacrosse are typically caused by collision of the head to body during player to player contact. Whereas cerebral concussions sustained during women’s lacrosse are typically caused by contact from the stick, ball, or the ground.1 However female collegiate lacrosse players are more prone to significantly higher injury
rates (0.54 per 1000 athletic exposure) to the nose and eyes than the injury rates (0.38 per 1000 athletic exposure) of their male counterparts. The difference in injury location and prevalence may be suggested due to the differences in the protective gear commonly worn by males versus females. Mouth guards have been shown to decrease dental injury and concussion from an impact from under the jaw.

It is apparent at the highest level of women’s competition that players are becoming increasingly physical with more incidental and purposeful contact. An increase in concussive events in men’s games is also indicative of an increase in the force used during player to player contact. Such increases in contact and concussive events lend concern to follow and enforce contact rules as well as promote safe coaching techniques and equipment usage.

**Shoulder Injuries**

In lacrosse the shoulder is a commonly injured body region. This may be due to the increased torque on the shoulder produced by the stick when the player falls or receives a blow on an outstretched arm. The majority of the injuries above the waist occur due to direct trauma which may lead to instability or fracture of the associated structures. Anterior instability of the shoulder may cause subluxation or dislocation due to a direct blow from a body check or a stick check. Posterior instability of the shoulder is common when the direct blow is delivered with the arm in a forward flexed position. Typically when an unanticipated direct blow is delivered to an individual whose arms are in front of the body subluxation of the glenohumeral joint occurs. However, in contact athletes such as lacrosse players, before receiving a direct hit the shoulder musculature is
tensed causing compression of the humerus into the glenoid fossa. It has been hypothesized that the combination of the compressive force and the posteriorly directed force at impact causes a shearing force to the posterior labrum and articular surface leading to a posterior labral tear. A superior labral tear may be produced during compression of the humerus into the glenoid fossa when the arm is in an abducted position. Clavicle fractures as well as acromioclavicular separations are fairly common with collision injuries (See Figure 11). Neurological injuries such as burners or nerve traction injuries may present due to direct contact. Overuse injuries of the upper extremity are rarely seen in lacrosse players. Male lacrosse players have a higher incidence of shoulder injuries, such as acromioclavicular separations, clavicle fractures, and contusions than female lacrosse players.

Figure 11. Acromioclavicular separations.

Hand Injuries

Based on data gathered by the NCAA Injury Surveillance System from 1986 to 2002 for hand injuries in stick handling sports, 692 injuries were documented among the sports of men’s ice hockey, men’s lacrosse, and women’s lacrosse. Of the 692 injuries, 276 injuries were from participating in men’s lacrosse. Of these injuries, there were 135
fractures, 60 contusions, 47 ligamentous injuries, 14 dislocations, 10 lacerations, and 10 injuries of other classification. Injuries of the thumb in particular were significantly higher in men’s lacrosse (0.16/1000) than men’s ice hockey (0.05/1000) or women’s lacrosse (0.09/1000). Specific injuries of the thumb that occurred at higher rates in men’s lacrosse include fractures and contusions. Men’s lacrosse players are particularly susceptible to thumb fractures from direct contact with an opponent’s stick. The increase in incidence of thumb fractures may be due to the thumb wrapping around the opposite side of the shaft of the crosse, leaving the volar side and tip of the thumb poorly protected. Implementation of a glove with circumferential padding of the thumb as see in ice hockey may serve for better protection than the currently used gloves which provide only dorsal padding for the thumb. Data on women’s lacrosse as compared to other women’s sticks sports were not analyzed due to the NCAA Injury Surveillance System initiating such collection in 2001.22

**Knee Injuries**

Injuries acquired below the waist account for 48% of all injury incidences during lacrosse play. Of these injuries, the majority are caused by non-contact mechanisms such as pivoting, twisting, and cutting. Knee injuries account for 14% and 21% of injuries in collegiate and high school female lacrosse player, whereas male collegiate and high school lacrosse players experience 9% and 16% of total injury from knee injuries.12 The most common below the waist injury in lacrosse players is damage to the medial collateral ligament of the knee. This injury, however, is not a season-ending injury as seen with an anterior cruciate ligament tear, which is more prominent in female lacrosse players. Anterior cruciate ligament (ACL) tears are typically caused by a sudden
deceleration accompanied by an abrupt change in direction on a planted foot. The key to the mechanism of injury is an eccentric contraction of the quadriceps during knee flexion which provides the significant anterior displacement of the tibia during the heel strike causing the ACL to rupture. ACL ruptures may also be caused during direct contact with another player with a valgus force striking the lateral side of the knee during play. Ligamentous injury to the knee is the most common cause of lost participation time of ten days or more.

Groin muscle strains to the hamstrings or quadriceps muscle groups, as well as shin splints and tibial stress fractures are common injuries due to the excessive running associated with the sport. Athletes are vulnerable to compartment syndrome of the lower leg as a result of a direct blow to the lower leg by an opponent or ball. Overuse injuries of the lower extremity such as patellar tendonitis or iliotibial tendonitis are also common complaints of lacrosse players.

Ankle/ Foot Injuries

Ankle injuries are the most common lower extremity injury for both female collegiate and high school levels with 23% and 25% injury rates respectively. These rates are much higher than men’s collegiate and high school injury rate with 11% and 16% respectively. Of these ankle injuries an ankle sprain is the most common. Ankle injuries are classified as either a high ankle injury or a low ankle injury. A high ankle injury is associated with an inversion mechanism of injury as seen with more non-contact injuries. A low ankle injury is associated with an eversion mechanism of injury as seen when contact is made to the player when the foot is planted on the ground. Shin splint
and foot blisters, although less severe, are common among lacrosse players and related to continuous running and changing of directions or field surfaces.

**Fractures**

Fractures in women’s lacrosse are generally caused by an impact injury from lacrosse sticks. The Consumer Product Safety Commission estimates that 73.6% of fractures that occur annually in female lacrosse players are located in the head, face, hand, or fingers. It has been speculated that these bony injuries may be prevented with the implementation of protective equipment such as a face mask, a helmet, or padded gloves. US Lacrosse reported a decrease in nasal and orbital fractures in women’s lacrosse games when given eyewear. Statistics on incidence of eye injuries drastically decreased from 0.10 to 0.016 per 1000 athlete exposure in women’s high school lacrosse when the eyewear mandate was placed in effect in 2005. Decreases of other injuries to the head and face were also seen with the implementation of the eyewear mandate, however concussion rate was unchanged.

**Commotio Cordis**

Commotio cordis, or sudden cardiac arrhythmias related to high speed localized chest trauma, is a condition relevant although not unique to the sport. The condition can be caused by inadvertent ball contact to the chest from a high speed shot. The majority of cases have been reported in adolescent males, primarily due to the relatively high ball speeds in the men’s games in combination with the biomechanics of an immature male chest wall. Treatment upon onset of commotion cordis requires early recognition, early initiation of CPR, and appropriate use of an Automated External Defibrillators. Chest
protectors are worn during lacrosse games for protection from contusions and rib fractures, however, studies have not shown that chest protectors decrease the risk of commotion cordis. Coaching techniques and rules to discourage body shots and decrease the amount of players around the goal area may prove to be beneficial in decreasing the incidence of such events.¹²

**INTERVENTIONS**

Although injuries sustained during lacrosse are common, surgical intervention is rarely necessary. Thus physical therapists dealing with contact sports related injuries need to have adequate knowledge in order to treat this patient population with the best possible care.

**Concussion Intervention**

Concussion injury treatment involves the patient having a thorough evaluation, to include a neurologic evaluation and a musculoskeletal evaluation of the head and neck, with a physician.²⁴ Once the patient is cleared by the physician, the physical therapist can initiate a gradual, step-wise program designed to return the patient to activity while allowing adequate healing time.¹ A patient should not be allowed to return to play or to exercise until all concussive related symptoms have ceased; this may take days, weeks, or months.²⁴ The physical therapist alongside the coach may also instruct the player in proper body checking technique with the head up to avoid future injury. Skills improvement among athletes may also prevent future head injury due to the majority of concussions sustained by female lacrosse players being by means of stick-to-body contact or during ball catching or passing.²⁰ There is a higher occurrence of concussion due to
equipment contact rather than player-to-player contact in women’s lacrosse than men’s lacrosse due to women not being able to wear hard helmets, aside from the goalkeeper, while hard helmets are a requirement in men’s games.4

A concern in regards to the increase in incidental and physical contact in women’s lacrosse has raised initiatives to mandate helmets in women’s lacrosse to decrease head injuries. However the effect of helmets/ headgear used specifically for concussion risk is inconclusive. Individuals who oppose a helmet mandate in women’s lacrosse fear a helmet mandate will encourage increased physical contact as seen in men’s lacrosse. However, when a helmet mandate was activated in the sport of ice hockey, reports identify no increased risk of other types of injuries due to more aggressive play. Although helmets are a debatable risk intervention and inconclusive on reducing the risk of concussion, implementation of hard helmets and facemasks have been successful in reducing subdural hematomas, and significantly decreasing the rate of contusions, head and face lacerations, and ocular, oral, and nasal injuries. Helmet supporters also suggest that the “bubble rule”, although self-regulated by players, does not apply to the path of the ball either directly or deflected, thus posing an ungovernable potential cause of injury. Consequently, further discussion is warranted in the topic of hard helmets with women’s lacrosse.7

**Shoulder Intervention**

For instability associated with shoulder injuries, surgical intervention may be necessary if conservative treatment to strengthen shoulder girdle musculature fails to provide increased stability. Tears of the glenoid labrum can be managed conservatively
or with surgical intervention. Conservative treatment of a labral tear includes intensive strengthening of the shoulder girdle musculature, gaining range of motion within a pain-free range, and retraining of muscle firing patterns of the shoulder girdle with dynamic movement. If conservative intervention fails, surgical arthroscopy for glenoid rim abradement and labral tear repair may be implicated.\textsuperscript{21}

**Lower Extremity Intervention**

Rehabilitation of anterior cruciate ligament (ACL) tears differs between females and males. Females need to focus on improving controlled knee position for stability in closed-chain exercises and increasing the strength of the quadriceps (See Table 7). Athletes with an ACL tear will often perform physical therapy prior to operative repair to restore strength, range of motion, and gait which will allow therapy post-surgery to progress quicker as long as complications do not arise. Return to sport ranges from 6 to 12 months depending on the progress of the athlete and physician clearance.\textsuperscript{15} Overuse injuries of the hip and lower leg, such as patellar or iliotibial tendonitis, are treated with rest, ice, and strengthening.\textsuperscript{1} Other interventions for shoulder, hip, or knee pathology follow the usual plan of care based on the severity of the injury. Emphasis is placed on performing rehabilitative exercises that have sports-specific carryover during the final phase of therapy.

In terms of injury prevention, new evidence supports the use of neuromuscular training as a means of reducing anterior cruciate ligament rupture in female lacrosse players (See Table 8).\textsuperscript{1} The implementation of proprioceptive training as well as core training has also been shown to decrease the risk of ankle and knee ligament injuries in
lacrosse players. More research is needed to evaluate the benefits and risks of implementing proprioceptive, plyometric, and balance training among male and female lacrosse players’ conditioning programs.

**Table 7.** Relation of intervention strategies to specific risk factors for injury of the ACL

<table>
<thead>
<tr>
<th>Position</th>
<th>Intervention strategy</th>
<th>Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extended knee at initial contact</td>
<td>Knee flexion</td>
<td>Concentric hamstring control and soft landing</td>
</tr>
<tr>
<td>Extended hip at initial contact</td>
<td>Hip flexion</td>
<td>Iliopsoas and rectus femoris control and soft landing</td>
</tr>
<tr>
<td>Knee valgus with tibial femoris loading</td>
<td>Address dynamic control; decrease dynamic valgus</td>
<td>Lateral hip control on landing</td>
</tr>
<tr>
<td>Balance deficits</td>
<td>Proprioception drills</td>
<td>Dynamic balance training</td>
</tr>
<tr>
<td>Skill deficiency</td>
<td>Improve agility</td>
<td>Agility drills to address deceleration techniques and core stability</td>
</tr>
</tbody>
</table>
Players returning to play post-injury must first be cleared by a physician.

Rehabilitation specialists must have a clear understanding of the demands of the sport on the athlete. These demands include the biomechanics of passing, checking, and shooting, the rules of the game, the demands of each field position, and the incidence and mechanism of injury. Rehabilitation parameters must be based on demands and rehabilitation techniques, as well as the integration of sports specific rehabilitation techniques in the final phases of the program.
For players to return to play it is recommended to recover 90 percent of their strength and demonstrate good proprioception. Agility, speed, and basic strength drills should be foundations of the rehabilitation program. Athletes should be able to start, stop, cut, jump, run, and demonstrate adequate strength and stabilization of the upper extremities to be considered for return to play. Once cleared to practice, the athlete should be conditioned on passing and shooting drills as well as practice scrimmages once muscular endurance increases. A controlled sport specific progression back to competition must be followed to ensure successful recovery and prevent re-injury.

A return to sport strengthening program may be similar to the weekly strengthening examples previously presented in the strength and conditioning section. The same exercises as well as sequence of exercise may be administered. However, the rehabilitation specialist must ensure the intensity of exercise is dosed to be progressive in order to promote a gradual and injury free return to sport program. Athletes beginning a return to sport program will start at intensities much less than presented in the weekly strengthening examples.

<table>
<thead>
<tr>
<th>Table 9. Sample Weekly Practice Schedule</th>
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<tbody>
<tr>
<td>Monday</td>
</tr>
<tr>
<td>Strictly Individual Skills</td>
</tr>
<tr>
<td>Tuesday</td>
</tr>
<tr>
<td>Skills by Position</td>
</tr>
<tr>
<td>Wednesday</td>
</tr>
<tr>
<td>Skills by Offense or Defense</td>
</tr>
<tr>
<td>&amp;</td>
</tr>
<tr>
<td>4 on 5 half field scrimmage</td>
</tr>
<tr>
<td>Thursday</td>
</tr>
<tr>
<td>Full field scrimmage</td>
</tr>
</tbody>
</table>
Table 10. Return to Sport Running Speed and Agility Program

Before beginning the progression athletes must regain full range of motion of the injured limb, demonstrate strength of at least 80% of the uninjured limb, have girth measurements within ½cm of uninjured limb, and possess symmetrical quadriceps and hamstrings flexibility. The athlete must also be able to hop forward on both legs at least 2 feet, hop to either side at least 1 foot, hop up and down on both feet 10 times, and jog without a limp for 100 yards.

The program should only be progressed when the previous activities can be performed without pain and with proper technique that does not elicit excessive muscle soreness or fatigue. When progressing the program, only add one new drill per workout.

**General Conditioning - progressed from least strenuous to most strenuous**
- Well- leg bicycling
- Two-leg bicycling
- Pool walking
- Pool running
- Stair walking (up/down, backward/forward)
- Stair stepper/ elliptical stepper
- Cross country skiing machine

**Phase 1**
- Straight-ahead jogging progressing to running
  - Run ½ speed 100 yards, 10 repetitions
  - Run ¾ speed 100 yards, 10 repetitions
  - Run ½ speed 100 yards, 3 reps; ¾ speed 100 yards, 3 reps; full-speed 50 yards, 4 reps
  - Continue ½ and ¾ speed 100 yard runs, 3 reps each. Add one 50 yard run each workout until 10 repetitions of 50 yard full speed runs can be completed.

**Phase 2**
- Basic Change of Direction Running
- Continue last drill from above progression
- Progress drills from walking to ½ speed to ¾ speed to full speed
  - Zig-Zag run, round corners, 50 yards, 5 repetitions
  - Backward run 25 yards to gradual stop, then forward run 25 yards to gradual stop, 5 repetitions
  - Large circles (20 feet or greater in diameter), walking or slow jogging, 3 repetitions to left and 3 repetitions to right
  - Figure- of -eight pattern run 20 feet for greater in length, 5 repetitions
  - Carioca 50 yards, 5 repetitions left, 5 repetition right
  - Small circles (15 feet or smaller in diameter), running, 3 repetitions to left and 3 repetitions to right

**Phase 3**
- Advanced Speed and Agility Running
  - Continue current workout from Phase 2 & progress as follows
  - Progress drills from walking to ½ speed to ¾ speed to full speed
Table 10. continued

- Run forward to plant and cut off of the uninjured limb, \( \frac{1}{2} \) speed, 5 repetitions
- Run forward to plant and cut off of the injured limb, \( \frac{1}{2} \) speed, 5 repetitions
- Zig-Zag drill with alternate limb plant and cut, 6 repetitions
- Box drill 20 yard square, 6 repetitions, alternate sides (See Figure 12)
- Shuttle run 50 yards with direction change every 30 yards, 5 repetitions
- Agility run, 5 repetitions, alternating starting sides (See Figure 13)

Return to Sport Phase

- Suggested combination to determine return to sport eligibility
  - 100 yard run \( \frac{1}{2} \) speed, \( \frac{3}{4} \) speed, and full speed each distance 2 repetitions each
  - Zig-Zag run, 6 repetitions
  - Forward/backward run, 6 repetitions
  - Small circle run, 6 repetitions
  - Figure- of –eight run, 6 repetitions
  - Carioca, 6 repetitions
  - Shuttle run 50 yards with direction change every 10 yards, 6 repetitions
  - Box drill 20 yard square, 6 repetitions alternate starting side
  - Agility run, 6 repetitions, alternating starting side

![Figure 12. Box Drill Setup](image-url)
Supplemental Ladder Drill Agility Progression
Single Ladder
- One foot in each box, forward and backward
- Two feet in each box, forward and backward
- Icky shuffle normal, forward and backward
- Icky shuffle foot placement on outside edge, forward and backward
- Two feet in/ two feet out linear, forward and backward
- Two feet in/ two feet out lateral, forward and backward

See Appendix 1 for sport specific drills and progression.

**SUMMARY**

Lacrosse is a sport deeply embedded in traditions and respect for the game. However, the modern version of the game has evolved to include a faster pace, longer fields, and harder hits, as some critics may argue. The evolution of the sport has called for the implementation of more protective equipment and better enforcement of rules. As more individuals enter the sport of lacrosse at a rapidly growing rate, the importance of coaching technique and installation of good sportsmanship in each player is crucial to permit the current game’s environment to continue for generations to come. Strength and
conditioning coaches must also cater the lacrosse athlete’s conditioning program to meet the unique performance demands of the sport and eliminate intrinsic factors which may predispose the athlete to injury.

The sports combination of speed, sticks, balls, and contact make for a unique set of injury types, mechanisms, and preventative interventions. Rehabilitation specialists and strength and conditioning coaches must have a good understanding of each injury sustained in order to ensure each athlete is returned to play based on an appropriate timeline for tissue healing and re-injury is not likely to occur.

CASE STUDY

Purpose

The objective of this case study on a lacrosse player is to determine the effects of conservative physical therapy treatment on bilateral shoulder pain and impaired functional capabilities secondary to a posteroinferior labral tear and global weakness of the rotator cuff musculature.

CASE DESCRIPTION

Patient Description

Patient is a 21-year old male collegiate lacrosse player who experienced a front on hit to the right shoulder during a lacrosse game on August 14, 2012. Immediate symptoms of the hit included referred pain and numbness to the anterior chest wall at a level of 5/10 on the visual analog scale (VAS). The patient also reported a development of left shoulder pain beginning in August of 2012 which had progressively become worse. Past medical history was significant for stingers and anterior chest pain from hits.
while playing high school football; however all pain had previously disappeared. Prior to onset, he had no functional limitations and worked as a grocery store stock personnel with no irritation. The patient discontinued lacrosse practice, administered cryotherapy for 20 minutes 3 times a day, and self-medicated with ibuprofen for 2 weeks before seeking out medical counsel.

The patient sought treatment with his physician on October 15, 2012 and was prescribed meloxicam for pain and swelling. A MRI was ordered on October 15, 2012 for bilateral shoulders which revealed a right posteroinferior labrum tear with rotator cuff tendinopathy and left rotator cuff tendinopathy with a small glenoid ganglion cyst. The patient was referred to physical therapy for two months of conservative treatment in an effort to avoid arthroscopic surgery.

Upon reporting to physical therapy the patient reported pain, decreased range of motion, and weakness during weight training exercises such as bench press or arm raises. The patient also reported interruptions of sleep due to throbbing pain which caused sleep duration to last less than six hours at a time. The patient was also unable to perform his job as a grocery store stock personnel due to a constant pain of 4/10 to 7/10 in his right shoulder and 0/10 to 8/10 in his left shoulder on the VAS.

Findings of the initial physical therapy evaluation included a forward head and rounded shoulders posture. Pain ranged from 4/10 to 7/10 in the right shoulder and 0/10 to 8/10 in the left shoulder which increased with activity. On the right shoulder, strength of the triceps and biceps was 5/5, while strength of the supraspinatus, infraspinatus, subscapularis, and deltoid were a 4/5 strength rating. Strength patterns on the left
shoulder were identical to the right shoulder. Range of motion of both extremities was limited in flexion and abduction. Additional measures may be seen in Table 11. Special tests revealed a positive Hawkins-Kennedy test on the left shoulder and positive bilateral Neer impingement tests.

<table>
<thead>
<tr>
<th>Table 11. Initial Range of Motion Measurements</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Date: 11/5/2012</strong></td>
</tr>
<tr>
<td>Internal Rotation</td>
</tr>
<tr>
<td>External Rotation</td>
</tr>
<tr>
<td>Flexion</td>
</tr>
<tr>
<td>Abduction</td>
</tr>
<tr>
<td>Extension</td>
</tr>
</tbody>
</table>

**Description of Treatment**

Physical therapy treatment commenced on November 5, 2012 with a plan of care to focus on decreasing pain, restoring correct postural alignment, increasing bilateral shoulder range of motion, increasing bilateral shoulder strength, and increasing functional status to allow return to previous level of activity. The plan of care was designed for the patient to be seen twice per week for four weeks with a corresponding home exercise program. At time of discharge the patient was seen for a 6 week period for a total of 10 treatments. Each treatment lasted a duration of 60 to 85 minutes, with treatments becoming progressively longer as the plan of care progressed.

The therapists performed passive range of motion of both shoulders and soft tissue mobilization of the anterior and posterior shoulder, as well as the pectoralis tissue and periscapular tissues with each treatment. An upper body ergometer or overhead pulley system was used to actively warm the tissue prior to each treatment, while also
reducing the need for an ultrasound modality. Treatment included moist hot packs and cryotherapy for pain control with each visit.

Early strengthening exercises to improve scapular and rotator cuff stability included scapular retractions with a theraband, bilateral shoulder extension with a theraband, internal rotation with a theraband, and external rotation with a theraband. Strengthening exercises were progressed to a prone position to include a row, shoulder extension, and horizontal abduction. Prone positioned strengthening exercises were further progressed with the addition of 2lbs, 3lbs and 4lbs hand weights. Proprioceptive neuromuscular facilitation extension patterns with a red theraband were added to the program to facilitate neuromuscular re-education of the scapular and rotator cuff musculature, followed by the addition of the supine proprioceptive neuromuscular facilitation flexion patterns with a red theraband. Shoulder and scapular stabilization exercises of body blade vibrations were added during the 5th visit, while stabilization exercises while in quadruped position were added during the 6th treatment session. Posterior joint mobilizations of the right shoulder at a grade of 3 or 4 were performed during the 8th and 9th treatment session to reduce movement restriction with internal rotation. During the 9th treatment session, plyometric ball tosses and a closed chain treadmill walking program were initiated to provide dynamic stabilization of the shoulder musculature, postural awareness of the upper extremity with full body movement, and to condition the athlete for return to sport. During the entirety of the plan of care, the patient performed supine internal rotation stretches and pectoral stretches while lying supine on a foam roller.
Upon beginning the treatment plan, the patient experienced minimal amounts of pain. However during treatment sessions eight and nine, the patient presented with tenderness along the right periscapular musculature with lateral tilting of the scapula, tightness of the right pectoralis major and minor muscles, as well as tightness during movement involving internal rotation. The patient continued to experience a clicking with front and side arm raise exercises during therapy.

The home exercise program prescribed to the patient included bilateral shoulder retractions resisted with a theraband, shoulder external rotation resisted with a theraband, overhead shoulder flexion resisted with a theraband, overhead shoulder flexion while performing small bounces with a ball, and a pectoralis major stretch while laying supine on a foam roll.

OUTCOMES

The patient was evaluated and scheduled for discharge from physical therapy on December 10, 2012. Findings demonstrated an improved shoulder posture and postural awareness. The patient had discontinued the use of meloxicam for pain and swelling and his pain rating had decreased to a 0/10 on the VAS for both shoulders. Strength of the rotator cuff musculature had increased attributing to a 5/5 rating for all previous muscles tested. Range of motion for both shoulders had improved, as seen in Table 12, to allow performance of functional ADLs, employment duties, and participate in lacrosse practice drills without hindrance or pain. The patient was transitioned to the home exercise program previously described and instructed to continue its execution as a preventative measure for shoulder injury.
Table 12. Discharge Range of Motion Measurements

<table>
<thead>
<tr>
<th>Date: 12/10/2012</th>
<th>Right Shoulder</th>
<th>Left Shoulder</th>
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<tbody>
<tr>
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<td>AROM T7</td>
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<tr>
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<td>AROM T3</td>
</tr>
<tr>
<td>Flexion</td>
<td>AROM 170°</td>
<td>AROM 170°</td>
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<tr>
<td>Abduction</td>
<td>AROM 165°</td>
<td>AROM 165°</td>
</tr>
<tr>
<td>Extension</td>
<td>AROM 70°</td>
<td>AROM 70°</td>
</tr>
</tbody>
</table>

The patient was evaluated on November 20, 2013 to assess the long term effects of the physical therapy treatment and the patient continued home exercise program. All strength measurements for both shoulders were at a 5/5 rating, except for the right subscapularis manual muscle test which presented at a 4+/5 rating. During manual muscle testing of the right subscapularis, an audible click was heard and the hold was broken when pressure was applied to the limb. The patient displayed no point tenderness during palpation of bilateral shoulder tissue. Range of motion of both shoulders presented as preserved and improved upon the increased range of motion acquired prior to discharge from physical therapy as seen in Table 13. Improvements in shoulder flexion and shoulder abduction were most significant for performance and function with overhead activities. The patient reported no pain or irritation, 0/10 on VAS, of either shoulder during ADLs, while working in the grocery store, or while playing lacrosse. The patient has returned to sport at the collegiate level with no further complaints or reoccurrences of pain or instability.

The patient continues to perform preventative exercises from the prescribed home exercise program in conjunction with his sports conditioning program. Exercises which continue to be performed include bilateral shoulder retractions resisted with a theraband, shoulder external rotation resisted with a theraband, overhead shoulder flexion resisted
with a theraband, overhead shoulder flexion while performing small bounces with a ball, and a pectoralis major stretch while laying supine on a foam roll.

<table>
<thead>
<tr>
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<th>Date: 11/20/2013</th>
<th>Right Shoulder</th>
<th>Left Shoulder</th>
</tr>
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<tr>
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<td>AROM T7</td>
<td>PROM 60°</td>
<td>AROM T7</td>
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<tr>
<td></td>
<td>PROM 65°</td>
<td></td>
<td>PROM 65°</td>
</tr>
<tr>
<td>External Rotation</td>
<td>AROM T5</td>
<td>PROM 95°</td>
<td>AROM T5</td>
</tr>
<tr>
<td></td>
<td>PROM 90°</td>
<td></td>
<td>PROM 90°</td>
</tr>
<tr>
<td>Flexion</td>
<td>AROM 170°</td>
<td>PROM 180°</td>
<td>AROM 175°</td>
</tr>
<tr>
<td></td>
<td>PROM 180°</td>
<td></td>
<td>PROM 180°</td>
</tr>
<tr>
<td>Abduction</td>
<td>AROM 178°</td>
<td>PROM 180°</td>
<td>AROM 175°</td>
</tr>
<tr>
<td></td>
<td>PROM 180°</td>
<td></td>
<td>PROM 180°</td>
</tr>
<tr>
<td>Extension</td>
<td>AROM 40°</td>
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<td>AROM 45°</td>
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</table>

**DISCUSSION**

This case study demonstrates the effectiveness of a conservative physical therapy management program for bilateral shoulder pain secondary to a posteroinferior labral tear, decreased shoulder range of motion, and unfavorable postural alignment. Conservative treatment includes intensive strengthening of the shoulder girdle musculature, regaining range of motion within a pain-free range, and retraining of muscle firing patterns of the shoulder girdle with dynamic movement. This case study suggests that resolution of shoulder pain is possible without the need for surgical repair of a posteroinferior labral tear when an aggressive strengthening and neuromuscular re-education program is applied to the proper candidates. If conservative intervention fails, surgical arthroscopy for glenoid rim abradement and labral tear repair may be implicated.

Long terms effects of a conservative management approach to posteroinferior labral tears may be assessed through this case study. When comparing range of motion of both shoulders upon discharge from physical therapy and eleven months post-discharge,
the patient’s bilateral range of motion continued to improve. These improvements were most notable in shoulder flexion and shoulder abduction. The movements of shoulder flexion and shoulder abduction are of significance for this patient due to the overhead nature of the sport of lacrosse as well as the overhead activities performed while working as a grocery stocker. However, a decrease in right subscapularis strength, 4+/5 rating, must be noted as to not have preserved the strength gains, 5/5 rating, observed at discharge from physical therapy.

Success of this patient may be attributed to age, prior level of activity, and a commitment to the rehabilitation program. As being 21 years old, the patient is subject to an increased healing rate and a decreased risk of prolonged swelling due to a healthy circulatory system when compared to an older individual. The patient’s prior level of activity was fairly high when compared to an older population. Outcomes studies usually attribute better outcomes measures to individuals who display a high prior level of activity when compared to individuals who demonstrate a sedentary lifestyle prior to injury. By trying to avoid surgery and return to play as quickly as possible, the patient demonstrated a commitment to the rehabilitation program. Aside from not missing treatment sessions, the patient performed the prescribed home exercise program thoroughly. The devotion to therapy is apparent when comparing measures from the initial evaluation against discharge measures. The patient was also mindful of physician and physical therapy orders to avoid practice, game, and strenuous weight lifting activities until cleared to participate. The avoidance of such activities enabled the reduction of swelling and pain, while allowing the smaller stabilization musculature to learn appropriate firing patterns leading to positive outcomes.
APPENDIX 1

Sport Specific Drills:

Cradle the Ball- essential skill for game play, players should work on keeping the ball in the cradle in a horizontal position when stationary and in a vertical position when facing off with a defender.

Scoop Drill- essential for controlling the ball when it is loose, the ball is rolled to the players and scooped into the cradle. This drill may be progressed to scooping a bouncing ball similar to grounding a baseball.

Box Area Drill- teaches the players to catch the ball next to the ear which provides protection from defenders and permits optimal hand-eye coordination. The drill should start with soft lobs to allow control and progress to confident passes with higher velocities.

Scoop on the Run Drill- players will continue to develop scooping skills while running a 20 yard length. Players will scoop and pass a ball at each 5 yard mark for 20 yards.

One on One Scoop Drill- players will prepare to battle for a loose ball. Two players with similar skill sets will be positioned 15 yards in opposite directions from a ball in the middle. When a whistle is blown, the players will utilize scooping technique, shielding techniques, and appropriate body contact techniques to acquire the loose ball and gain position.

Ball Control Drill- players will prepare to take the ball and defend the ball under pressure. Two players with similar skill sets are paired together, with one player carrying the ball and one player attempting to take the ball from the player carrying it. This drill will enable players to utilize a one handed stick grip while defending with the other hand, as well as defender checking methods.

Pass and Shoot or Quick Shot- passing players will pass ball from the corners to the shooter in the slot area (the area between the goal and about 10 yards out directly in front) between the circles. Depending on the intent of the drill, shooters may take preparation to shoot or immediately shoot for a quick shot. A goalie may be added for increased challenge once skill level increases.

Three Zone Shooting- Three cones are set up 10 to 15 yards from the net. Players are positioned at each cone where they scoop a ball and take a shot. This drill develops shooting skills outside of the slot area. A goalie may be used for an increased challenge and to increase skill level.
Rapid Fire - Same as above, but with the intent of improving the goalie’s skills. Players at each cone will fire in a predetermined order to challenge the goalie.

Foot Fire - Consists of rapid footsteps which move in a direction based on the coaches instruction. This skill is an essential basic sports specific agility drill.
References


http://search.proquest.com.ezproxy.fgcu.edu/healthcomplete/docview/213057078/full


