INTEGRATING PLYOMETRIC TRAINING FOR HIGH SCHOOL SOCCER ATHLETES—PART 1

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INTRODUCTION

Plyometrics have been widely accepted in sports training by athletes of various ages and competitive levels. Athletes use plyometrics to enhance performance in several categories: strength, explosive power, muscle conditioning, balance, and anaerobic endurance (7). Plyometric training is also adopted in high school soccer to increase explosive actions, such as kicking, jumping, sprinting, and agility (18,20). In addition to general training methods (i.e., resistance, speed, and agility training), plyometric training is beneficial for high school soccer athletes to meet the sport's demands in these movements.

Plyometric training is convenient for high school athletes in terms of time, space, and equipment. High school athletes usually spend more time in soccer training during the season, so they do not have much time for physical training in the weight room. When time and space are challenges, athletes can choose plyometric training that can be performed on the soccer field. Plyometric training often consists of 3 – 4 plyometric exercises that can be performed before soccer practice on the field. Moreover, plyometric exercises are usually performed with bodyweight or simple equipment (e.g., box, cone, or hurdle). This makes it convenient for high school athletes with limited training equipment or no access to the weight room. Therefore, the training benefits make plyometric training a valuable addition to a high school soccer program.

Plyometric training is safe and effective for high school athletes under proper instruction by qualified coaches (15). Strength and conditioning coaches and soccer coaches should possess knowledge in youth sports, as well as plyometrics to provide a quality plyometric training program specifically for high school athletes. It is important to understand the principle and execution of plyometrics to create and implement a successful training program. In order to accomplish this, it is important to first conduct a needs analysis in order to select and design the most appropriate plyometric exercises and programs. This article, which is part one of a two-part series, will briefly highlight the main components of a needs analysis and apply it to the context of soccer. Part two of the series will present plyometric exercise selection and design in respect to the needs analysis, and introduce plyometric training fundamentals with an emphasis on integrating lower limb plyometric training into general training methods to enhance power actions in kicking, jumping, sprinting, and agility for high school soccer athletes.

NEEDS ANALYSIS

Before designing a plyometric training program, coaches should conduct a two-stage needs analysis to evaluate the game activity profile and the athlete's needs. The first stage is to determine the physiological demands, biomechanical movements, and common injuries in soccer. The second stage will assess the athlete's training status, physical abilities, and primary training goal. This article will focus on the analysis of the skeletomuscular system of the lower extremity. Table 1 provides an example of the application of the needs analysis for a high school soccer athlete.

EVALUATION OF SOCCER

Soccer is an intermittent sport that requires players to make frequent changes in different types of movements (e.g., running, sprinting, and jumping) (14). These game activities vary in intensity, volume, and frequency throughout the whole competition. On average, soccer players cover 9 – 12 km,

TABLE 1. EXAMPLE OF A NEEDS ANALYSIS

SCENARIO: HIGH SCHOOL SOCCER ATHLETE				
Sex: Male	**Age:** 16 years old	**Position:** Forward	**Season:** Pre-season	
SPORTS EVALUATION		**ATHLETE'S PROFILE**		
Movement Analysis	**Physiological Analysis**	**Training Background**	**Plyometric Training Status**	**Training Goals**
Major Movements: Sprinting, kicking, dribbling, jumping, and running **Muscular Involvement:** All major muscle groups, especially the lower extremity	Aerobic endurance Anaerobic power Muscular endurance Muscle strength/power	• Just finished fall club soccer season • Practiced 5 days per week, and played 2 games per week for the last 10 weeks, including 2 speed training sessions per week • Had resistance training regularly (3 times per week) for the last 2 years	• Had plyometric training 2 times per week in last pre-season • Possesses excellent skills in jumping, landing, and cutting • Classification of training status: intermediate	• Speed endurance • Speed technique • Kicking strength • Jumping ability

with about 40% of high-intensity running and 1 – 11% of time sprinting during a match (3,14). It is important to note that the physical demands and technical performance (e.g., kicking and jumping) are slightly different according to the player's position. For instance, forwards and fullbacks spend 20 – 40% more time sprinting, midfielders cover 5 – 15% more distance, and goalkeepers perform more jumps (3). Soccer players perform both linear sprints and repeated sprints with change of direction (COD) at various distances during a match. Most of the sprinting activities are shorter than 20 m and each sprint lasts between 2 – 4 s on average (14). These intermittent repeated sprints are close to the intensity of anaerobic threshold and depend on aerobic metabolism (VO_2max) for recovery (3). Thus, soccer training should be modified to target aerobic capacity, anaerobic capacity, and neuromuscular components (e.g., power, strength, balance, and proprioception) according to player position and game tactics (28).

Youth players spend about 9% of the total match time in high-intensity activities, such as short sprinting with COD, jumping, and kicking (5). Kicking is one of the fundamental technical skills and scoring methods in soccer. The high velocity of the foot and high angular velocity of the knee joint at ball impact, and fast approach to the ball, contribute to a fast kick (16). In addition, muscle strength of the knee extensor and hip flexor is associated with the speed of the ball (16). After resistance training, ball speed may increase due to the altered activation patterns of several muscles within the kicking leg in the following order: hip flexor, rectus femoris, and vastus lateralis (16).

Soccer players perform vertical, horizontal, and lateral jumps throughout the match. These jumping movements involve the major muscles around the hips and knees, especially the quadriceps and ankles (7). Compared to other athletes, soccer athletes spend a smaller amount of time in jumping movements (3). However, jumping activities such as a jump header and a goalkeeper jump-save are crucial movements that require explosive power and muscle strength. Therefore, coaches should develop neuromuscular qualities (e.g., power, strength, and endurance) and efficient jumping techniques to prepare soccer athletes for those high-intensity jumping movements.

Sprints need high force production and power to generate high velocity during the acceleration phase (19). Because most soccer sprints are short distances with COD, soccer athletes have to decelerate before reaching the maximal velocity, which occurs at about the 20-m mark (9). Thus, sprint techniques involved in acceleration and deceleration are crucial in these short soccer sprints. The primary muscles involved in sprinting are the hip extensors (hamstrings, adductor magnus, and gluteus maximus), hip flexors (psoas major and rectus femoris), and knee flexors (hamstrings) muscle groups (9). Speed training usually focuses on neuromuscular adaptions (e.g., maximal force production, rate of force production, and reaction time) and sprint technique (9).

The most common lower extremity musculoskeletal injuries in soccer are ankle, knee, hamstring, and groin strains (8). Studies report up to 34% of soccer injuries are overuse injuries (11,21). Soccer athletes frequently perform high-intensity activities such as jumping and sprinting with sudden COD, which cause great stress on the joints and muscles of the lower limbs and increase risk of injuries. It is noticeable that quadriceps and adductor injuries were more common in the dominant leg, because it involves a greater volume of shooting and passing actions during pre-season (11). Coaches should be aware of some common risk factors (e.g., previous injury, strength, flexibility, and fatigue) for non-contact musculoskeletal injuries (11). Plus, youth players with less experience may have a higher chance of injury due to the weakness in techniques, tactics, muscle strength, endurance, and coordination (21). Therefore, coaches should improve youth athletes' movement skills and physical abilities to prevent related injuries.

ASSESSMENT OF HIGH SCHOOL SOCCER ATHLETES

High school soccer athletes are a unique group of athletes who may also play club soccer, multiple high school sports, and other recreational sporting activities. Before implementing a plyometric training program for high school soccer athletes, coaches should assess their training status (9). First, coaches need to receive a medical evaluation of any current or previous injuries that may affect plyometric training for athletes (9). Some athletes may have just finished a club soccer season or another high school sport season, so coaches should closely monitor their fitness status and inquire about any injuries. Second, coaches should examine athlete's training background in plyometric training and other trainings (e.g., resistance training), such as the length of previous training and the level of training.

Next, physical testing can be conducted to evaluate youth athlete's motor skill and plyometric technique. Repeated tuck jumps can be used to identify neuromuscular deficits and movement technique flaws during a plyometric exercise (25). During the testing, an athlete performs tuck jumps in place for 10 s. From the assessment, coaches can identify neuromuscular deficits in the knee and thigh motion (e.g., lower extremity valgus), foot position during landing (e.g., excessive contact noise), and plyometric technique (e.g., pause between jumps) (7). The neuromuscular deficits may also indicate an increased injury risk, such as knee injury (25). Therefore, testing provides valuable information for coaches to make an individual training plan for each athlete.

Based on the testing, movement analysis, and training priority of sports season, coaches can better set a primary training goal and design a plyometric training program or integrate plyometrics into other training methods. For these high-intensity power movements (e.g., kicking, jumping, sprinting, and agility), coaches should design a specialized program that focuses on one outcome at a time and prescribes and progresses plyometric exercises accordingly. Before implementing any program, it is also important

for coaches to understand the basic mechanics and techniques of plyometrics.

PLYOMETRICS MECHANICS AND TECHNIQUES

Understanding fundamental mechanics and techniques are essential to executing plyometric exercises properly. Plyometric exercises begin with a countermovement and finish with forceful muscle contractions. During a plyometric movement, the muscles are lengthened and stretched, followed by rapid shortening. This fast and powerful muscle movement involves the stretch-shortening cycle (SSC), which is a key process in plyometric exercises. Researchers have classified the SSC based on duration into two types: slow SSC (>0.25 s) and fast SSC (<0.25 s) (19). The SSC is divided into three phases: the eccentric phase, amortization phase, and concentric phase (7).

ECCENTRIC PHASE

The eccentric phase is initiated with a countermovement and finishes with eccentric muscle loading. There are three essential mechanisms in the eccentric phase: muscle potentiation, muscle elasticity, and stretch reflex. First, the lengthening of the agonist muscle increases muscle cross bridge formation and muscle potentiation (7). As a result, it produces greater force for subsequent muscle contraction during the concentric phase (7). Second, the muscle tendon's rapid stretch develops tension and restores elastic energy that allows for greater contraction force in the concentric phase (7). Third, the stretch of muscle spindles in the agonist muscle causes a fast reflex response, which also contributes to the concentric phase (9). Therefore, a full countermovement with a high stretch rate will increase muscle recruitment (9). All three mechanisms of the eccentric phase are critical to prepare for explosive muscle action.

AMORTIZATION PHASE

The amortization phase should be a smooth and quick transition between eccentric muscle action and concentric muscle action. The fast reflex causes alpha neurons to transmit signals to the agonist muscle during the amortization phase (9). A delay of the amortization phase will affect the activation of the stretch reflex reaction (9). Also, a discontinuous coupling will cause decreases in stored elastic energy (7). Therefore, a smooth transition without a visible pause ensures the proper function of the plyometric exercise.

CONCENTRIC PHASE

During the concentric phase, muscle contraction occurs right after the rapid muscle coupling. The explosive muscle action and greater muscle contraction force result from the three mechanisms in the eccentric phase. Coaches should focus on maximal effort of muscle contraction when instructing athletes. For instance, coaches instruct an athlete to forcefully extend hips, knees, and ankles to push off the ground during concentric phase in plyometric jumps.

In addition, plyometric jumping exercises usually engage the arm action to increase momentum. The arms cock back during the countermovement, then forcefully swing forward when the jumping action starts. Other fundamental movement techniques, such as landing and cutting, are essential in performing lower limb plyometric exercises (Table 2).

TABLE 2. GLOSSARY OF MOVEMENT TECHNIQUES

Jumping	**Loading** • Arms swing back • Hips hinge, knee flex, and ankles plantarflex • Weight shifts to the ball of feet **Ascending** • Fully extend hips, knees, and ankles • Open shoulders and swing arms upward
Landing	• Soft landing with hip hinged, knees flexed, and ankles plantarflexed • Shoulders in line with the knees in the sagittal plane • Knees in line with feet • Toe to heel rocking
Cutting	• Backward squat with hip and knee flexion • Keep the knee bent during cutting maneuver • Plant foot on the ground briefly • Keep arms and legs close to the body • Fully extend the leg to takeoff in the new direction • Head leads the body through the turn

PLYOMETRICS FOR SOCCER

Again, soccer players frequently perform short sprinting with COD, jumping, and kicking during a match. These power activities share common characteristics with the lower-body plyometric exercises: maximal power production, high rate of power development, and short ground contact against gravity (7,27). Studies have shown that plyometric training can enhance kicking, jumping, sprinting, and agility in youth soccer athletes (22).

KICKING

Plyometric exercises are beneficial to improve kick distance and velocity (23,24). Increased strength and power of leg extensor muscles results in an improvement of kick performance (4). Moreover, a study showed that plyometric jumping exercises could increase maximal kicking velocity due to an increase in the force development and the linear and angular velocities of the ankle in the kicking leg (4). Increased maximal kicking velocity contributes to increased speed of the ball, which is essential in shooting performance.

Certain kicking actions involve SSC muscle movements. For instance, an in-step kick starts with eccentric muscle action (rear leg swing) followed by concentric muscle action (forward leg swing). Researchers found that plyometric training can enhance SSC muscle movement during the kicking action (17). In addition, combined plyometric and speed training may result in higher ball speed due to the increased transfer of energy from proximal to distal segments (4). Hence, plyometric exercises are an optimal addition to improve the explosiveness of the kicking movement. Exaggerated skipping (Figures 1A and 1B) is an example of a plyometric exercise that targets the primary muscles involved in kicking: hip flexors and leg extensors. Plyometric exercises, such as skips and hops, also work on the hip flexors and leg extensors, as well as potentially enhance kick performance. These exercises should focus on a quick and smooth transition from rear leg swing to forward movement with maximal effort.

JUMPING

The explosive action of plyometric jumping results in neuromuscular adaptations that can benefit soccer athletes (23). Studies show that plyometric jumping exercises involving the slow SSC could induce training adaptation in increasing jumping height and distance (23). Examples of slow SSC plyometrics include countermovement jumps in the vertical plane and multiple jumps in the horizontal plane (23). Compared to the slow SSC, plyometric jumping exercises using the fast SSC may better develop reactive strength, which reduces ground contact time and improves agility performance (23). Hence, plyometric jumping exercises with fast SSC (e.g., drop jumps) are beneficial for soccer athletes, especially goalkeepers, who require quick reaction and sudden COD to perform jumping activities (e.g., lateral diving save).

Another essential adaptation is an increase in knee extensor strength and explosiveness (23). Figures 2A and 2B demonstrate the hexagonal bar squat jump exercise that aims to increase leg strength and power. When performing the jump, athletes extend both arms straight down with hands holding the hexagonal bar. For athletes with a lack of strength and movement techniques, coaches should guide them to jump with their bodyweight or lighter resistance (e.g., dumbbell).

SPRINTING

Studies show that plyometric training could enhance sprint performance between 10 – 40 m distances for soccer athletes (2,22). Plyometric training could increase quick reaction, ground reaction forces, and fast movement velocities in those repeated sprints with COD (6,24). Plyometric exercises in horizontal displacement are ideal exercises to increase horizontal force production and horizontal acceleration for the short sprinting tasks (19,27). Alternate-leg bounding (Figures 3A and 3B) is an example of a plyometric exercise with quick leg transition and short ground contact. Slow SSC plyometrics (e.g., squat jumps) transfer more to the start and acceleration, while fast SSC plyometrics (e.g., drop jumps) transfer more to the maximum running velocity (26). Hence, coaches should select plyometric exercises accordingly to target different sprinting components. A practical application could be that coaches integrate slow SSC plyometrics into speed training focusing on sprinting technique on Monday and integrate fast SCC plyometrics into speed training focusing on maximal speed on Thursday.

AGILITY

Agility is an essential performance in many sports (including soccer) that involve a rapid, whole-body movement with COD reacting to a stimulus (13). Soccer players have to make quick reactions and change direction according to the different game situations with or without a soccer ball. To improve agility performance, a training program must work on the perceptual, technical, and physical factors of an agility task (13).

Plyometrics can work on the physical ability, technical movement, and perceptual factor of an agility task (13,18). First, plyometric training increases muscular strength and coordination in COD activities (18). Plyometric exercises improve both eccentric and concentric lower limb muscle strength (1). Studies have shown that increases in concentric muscle force contributes to the increase of COD velocity (12).

Second, certain plyometric exercises in the frontal plane require the same technical movements as in COD activities. For instance, plyometric jumps with cutting movements involve short ground contact times and a quick transition between deceleration and re-acceleration. Movement techniques in acceleration and deceleration are practical in the short sprints with COD in soccer. Plyometric exercises can improve muscle firing frequency and patterns that enhance an athlete's ability to switch between deceleration and acceleration (11). Again, the increase in eccentric strength positively impacts COD performance during deceleration (19). Therefore, plyometrics are effective in enhancing the technical movement of COD activities. The single-leg lateral jump

FIGURE 1A. EXAGGERATED SKIP - START POSITION

FIGURE 1B. EXAGGERATED SKIP - END POSITION

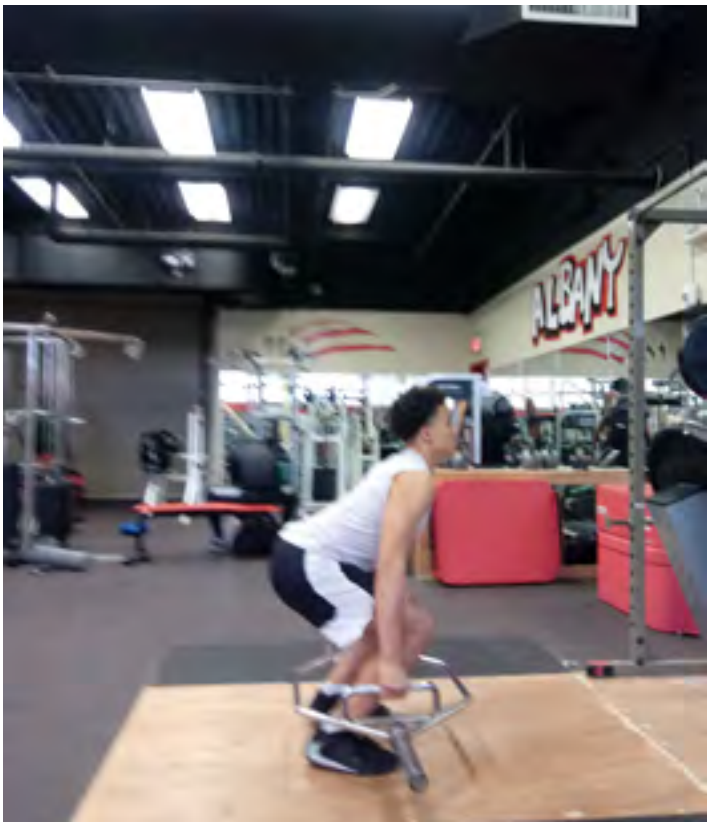

FIGURE 2A. HEXAGONAL BAR SQUAT JUMP - START POSITION

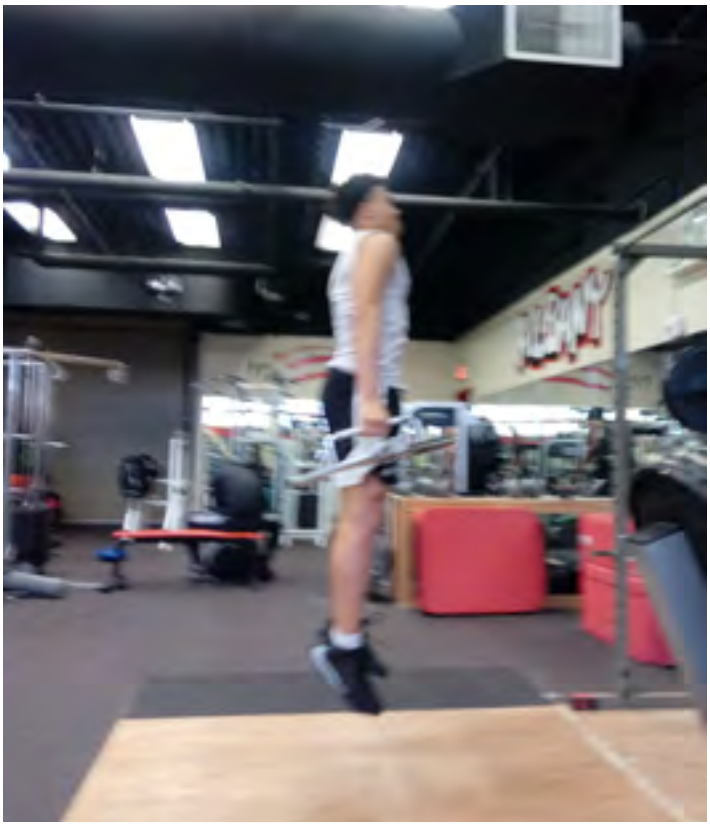

FIGURE 2B. HEXAGONAL BAR SQUAT - JUMPING

FIGURE 3A. ALTERNATE-LEG BOUNDING - START OF BOUND

FIGURE 3B. ALTERNATE-LEG BOUNDING - BOUNDING ACTION

FIGURE 4A. SINGLE-LEG LATERAL JUMP - START POSITION

FIGURE 4B. SINGLE-LEG LATERAL JUMP - END POSITION

(Figures 4A and 4B) is an example of a plyometric exercise with powerful lateral movements that work on both concentric and eccentric strength of the lower limbs. Athletes should focus on brief loading and ground contact, followed by an explosive takeoff between each jump.

Third, adding cues when performing lateral plyometric exercises can work on the athlete's perceptual ability (13). Using a box drop with cueing to prompt the athlete into a single-leg lateral jump can practice the reactiveness of COD tasks. For example, coaches use hand signals or verbal cues to instruct an athlete to change lateral jumping direction right after the box drop.

SUMMARY

In conclusion, plyometric training can be a valuable addition to enhance power actions such as kicking, jumping, sprinting, and agility. Understanding a soccer needs analysis and plyometric techniques allows coaches to design a safe and effective plyometric training program for high school soccer athletes. The second article of this two-part series will expand upon the soccer needs analysis and show how to apply it to design a plyometric training program. Part two will emphasize integrating lower limb plyometric training into general training methods to enhance power actions for high school soccer athletes. It will also consider youth strength and conditioning guidelines on adolescent physical development and long-term athletic development when designing the plyometric training program for high school soccer athletes.

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