# INTEGRATING PLYOMETRIC TRAINING FOR HIGH SCHOOL SOCCER ATHLETES—PART 2

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## CONSIDERING HIGH SCHOOL ATHLETES

We highlighted the principle and execution of plyometrics, as well as the main components of a needs analysis and application to the context of soccer, in part one of this two-part series. In this article, we will discuss program design with an emphasis on integrating lower limb plyometric training into soccer training to enhance power actions in kicking, jumping, sprinting, and agility for high school soccer athletes. The program design also considers high school athletes' biological characteristics and long-term athletic development (LTAD).

Understanding the pubertal development of high school athletes enables coaches to create an age-appropriate plyometric training program. High school athletes are growing and transforming into young adults, so their fitness components (e.g., strength, speed, and endurance) and motor skills are different compared to adults (11). LTAD models have been theorized from research that has explored athletic performance with the intent to help provide a general map for key variables that lead to peak performance at different developmental stages and the maintenance of physical activity and fitness across a lifespan. For example, the theory of "windows of opportunity" outlined the specific periods for youth to train specific components of fitness (3).

LTAD suggests youth participate in sports and physical activities early and throughout the developmental period to enhance both health- and skill-related components of fitness (19). Also, a training program should be safe and fun to encourage the development of physical fitness and psychosocial wellbeing in the long term instead of performance outcome oriented (19). Therefore, coaches should develop a plyometric program containing a high degree of variation to promote long-term motor skill development and enhance fitness behaviors that can be adapted to an athlete's post-high school career (e.g., college sports) or retained later in life (18,19). The training adaptation from plyometrics may differ based on high school athletes' characteristics, such as maturation and trainability (2). Understanding these characteristics helps coaches to apply training principles in designing a plyometric program for high school athletes. A plyometric training program also needs to consider female athletes' physical changes and related injury risk.

### MATURATION

Children and adolescents are in a progress towards a mature state, but they may experience a growth spurt in different timing, tempo, and duration between different bodily systems (19,25). Maturation status affects physical fitness, sports performance, and talent selection for young athletes (13,26). Comparing to chronological age, peak height velocity (PHV), which refers to the maximum velocity of growth in stature, better predicts the maturation status and changes (i.e., height, weight, body composition, and physical performance) (8). The average age of PHV is around 14 years old for boys and around 12 years old for girls (19,25). Students usually begin high school at 14 years of age, so boys are typically in their mid-PHV or post-PHV and girls typically are in their post-PHV. Researchers have reported that the greatest increases in running speed occur before PHV, and maximal aerobic power reaches maximal growth alongside PHV (25). Plus, the greatest rate of increases in strength and power occurs after PHV, mainly due to the growth spurt in muscle mass and sport-specific training (25). However, high school athletes can continue to improve their physical performance with appropriate training in their late adolescence (19).

Plyometric training can improve power performance for sport participants over 13 years old, especially those between 16 – 18 years, old due to their maturation status (1). A study found that plyometric training improved jumping ability and power performance for older youths in post-PHV than younger youths in pre-PHV, possibly due to the training adaptations, such as increased neural drive to the agonist muscles, changes in the muscle-tendon mechanical-stiffness characteristics, improvements in intermuscular coordination, and changes in muscle size and/or architecture (2). Also, the increase in sprint performance in post-PHV could be due to the increase in stride length and improvement in stabilization of stride frequency and ground reaction times (2). It is noticeable that athletes who are training during the interval of maximal growth may encounter "synergistic adaptation," which refers to a concurrent increase in performance as a combined result of physical growth and training stimulus (19). Although both elicit similar adaptations, physical training can serve to complement the physiological adaptation due to growth and maturation (19). Therefore, coaches should consider each individual athlete's maturation status to design a plyometric training program to improve power performance.

### TRAINABILITY

Children and adolescents can significantly improve physical performance in motor skills, strength, power, speed, agility, and endurance after different modes of training at various stages of development (19). Some LTAD models define high school athletes as being in the sport specializing stage or the windows of optimal trainability (i.e., speed, strength, and aerobic) according to chronologic age or PHV (3,9). However, the youth physical development model suggests that fitness components (e.g., agility, speed, power, strength, and hypertrophy) and sport-specific skills should remain the training focus even after the adolescence growth spurt (18). Overall, children and adolescents are encouraged to engage in different long-term training programs to develop all components of fitness throughout the developmental period.

A well-constructed and long-term plyometric training program can develop certain fitness components (e.g., strength and power) and transfer the skills to sports performance. Besides growth and maturation, a youth athlete's previous training experience will influence the responsiveness to the plyometric training stimulus (17). It is common for high school students to participate in multiple high school sports, club sports, and recreational physical activities. As a result, they are exposed to sport training early, which provides advantages in developing muscular strength and motor skills (11). For high school athletes with advanced training level, coaches should create a plyometric training program accordingly to maximize the training adaptation.

### FEMALE ATHLETES

During adolescence, boys and girls encounter different physical changes (e.g., body composition and muscular strength) that have an impact on sports performance (11). Compared to males, females gain a higher amount of fat mass than lean muscle mass during puberty, which reduces relative muscle strength (16). The weight gain and growth of long bones (tibia and femur) in females puts stress on the joints during intense activities, such as plyometrics (8). If a female athlete does not have sufficient muscular strength and core stability, she tends to perform jumping and landing with poor biomechanics (i.e., knee valgus alignment) and increases the risk of knee injuries (8).

Plyometric training should consider common injuries and risk factors due to the physical changes for high school female athletes. For example, young female athletes have a high rate of knee injuries, such as knee sprain and anterior cruciate ligament (ACL) injury from non-contact sporting activities (e.g., landing and cutting) (8). ACL injuries often occur when an athlete is landing or cutting with the knee near extension (22). Common risk factors for knee injuries in female athletes are due to hormonal changes, pelvic structure, and lower extremity alignment (16). Plyometric exercises often include jumping, landing, and cutting movements, which put great stress on the knee joints. Female athletes with poor biomechanics tend to perform knock-knee landing, which causes excessive knee rotation that increases the risk of knee injuries (8). Also, female athletes often have increased valgus angles with poor cutting techniques and double knee valgus loads with cutting maneuvers in unanticipated sport situations (22). Soccer is a sport requiring multi-directional movements and sudden cutting lower extremity musculoskeletal injuries, such as ankle sprains, are common in both male and female soccer athletes. Therefore, coaches should be thoughtful in the implementation of plyometric exercises that include jumping, landing, and cutting movements, which put great stress on the knee joints.

Despite the intense nature of plyometrics, a study found that plyometric jump training helped increase muscle strength, reduce impact force, decrease knee flexion momentum, and decrease adduction and abduction momentums (16). In addition, plyometric training emphasis on dynamic movements was showed to reduce ACL loading by producing low-abduction knee joint torque; it also improved reaction times by providing more time to voluntarily precontract the lower limb muscles (22). Before starting a plyometric program, coaches need to educate female athletes with proper movement skills and biomechanics (i.e., decrease varus and valgus torques) in order to receive the benefits of plyometric training and reduce risk of knee injury.

## PROGRAM DESIGN

After completing the needs analysis and assessment for high school soccer athletes, coaches can start designing a safe and effective plyometric training program to meet the physical demands of high school soccer and the biological development of high school athletes. Again, pubertal development has an impact on physical abilities, such as strength, mobility, and balance (11). The rapid increase in both body stature and body mass increase risk of injuries in lower limbs, especially the knee injury for females (19). Youth athletes who are undergoing rapid growth should develop strength and power to counter the excessive loading of the muscular system during dynamic and reactive actions such as plyometrics (19). At the beginning of a plyometric training program, coaches should ensure athletes have developed fundamental movement skills to reduce the occurrence of injuries (8).

The squat exercise is a basic and important movement skill to develop hip hinge, postural control, and the primary muscles in jumping and landing (8). Figures 1 – 4 demonstrate squat variations using a fitness ball. These exercises progress to develop fundamental movement skills and strength that help to the athlete to perform plyometric jumping.

1. Wall squat: The lower back gently presses against the fitness ball and bodyweight is loading through heels. The feet are directly underneath the body and straight ahead, aligning with the knee throughout the movement. Keep the fitness ball rolling on the back, but avoid leaning on it. Then push upwards with the hips, knees, and heels during ascending. This exercise helps to develop leg strength and move the hips backward (Figures 1A and 1B).

2. Seated squat: During descending, gradually sit on the fitness ball while trying to force the thighs parallel to the ground. Shoulders are right over the ankles. This exercise helps athletes to reach appropriate squat depth and avoid excessive upper body forward lean (Figures 2A and 2B).

3. Overhead squat: Hold the fitness ball overhead during the exercise with the head and chest facing forward. This exercise helps athletes to improve shoulder mobility and core stability (Figures 3A and 3B).

4. Squat jump: Start in a squatting position with the fitness ball against the chest. Extend the hips, knees, and ankles explosively to jump up. Press the fitness ball overhead at the same time. Perform a soft landing into squatting position and bring the fitness ball down against the chest (Figures 4A, 4B, and 4C).

FIGURE 1A. WALL SQUAT - START POSITION

FIGURE 1B. WALL SQUAT - END POSITION

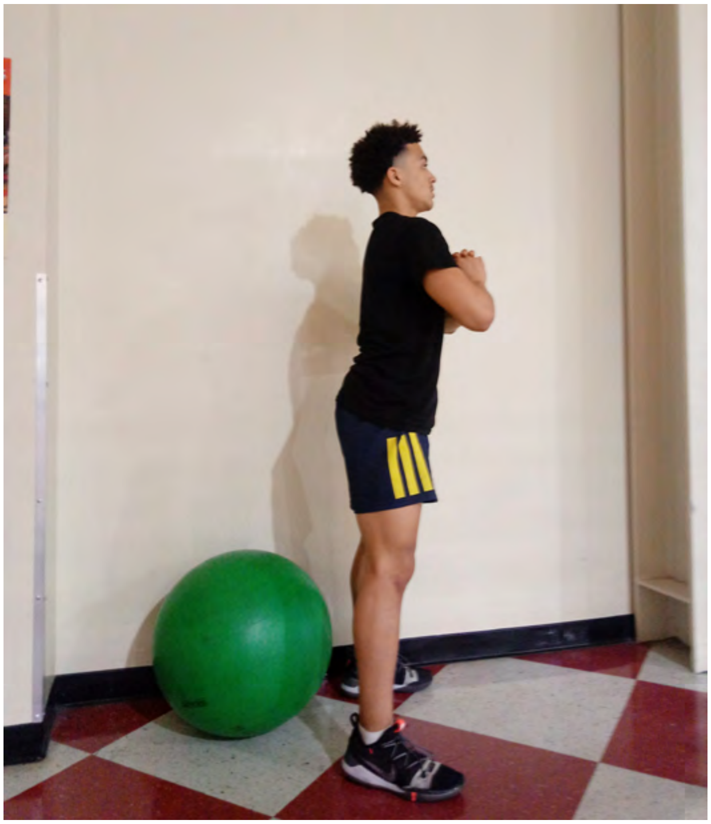

FIGURE 2A. SEATED SQUAT - START POSITION

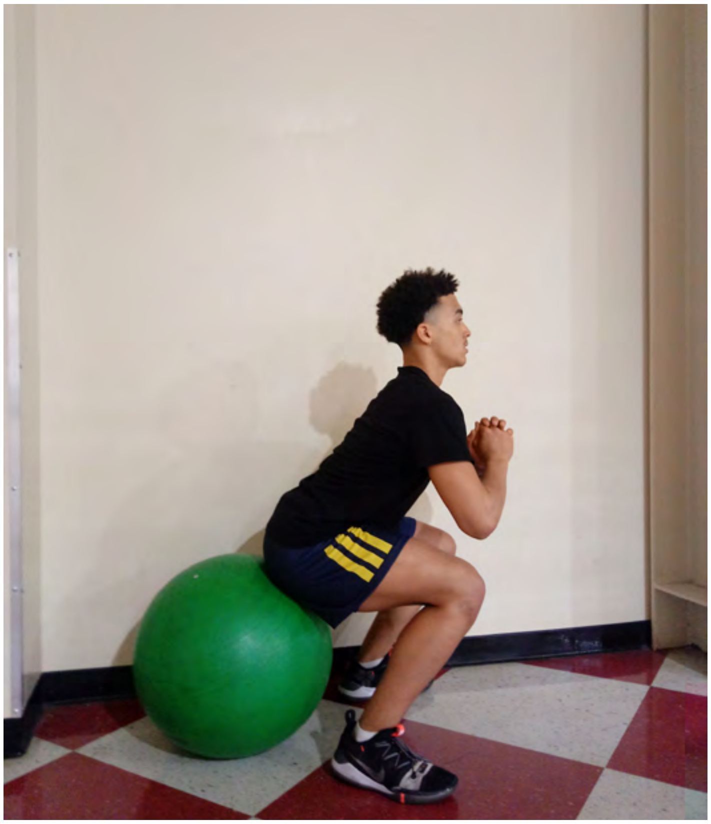

FIGURE 2B. SEATED SQUAT - END POSITION

FIGURE 3A. OVERHEAD SQUAT - START POSITION

FIGURE 3B. OVERHEAD SQUAT - END POSITION

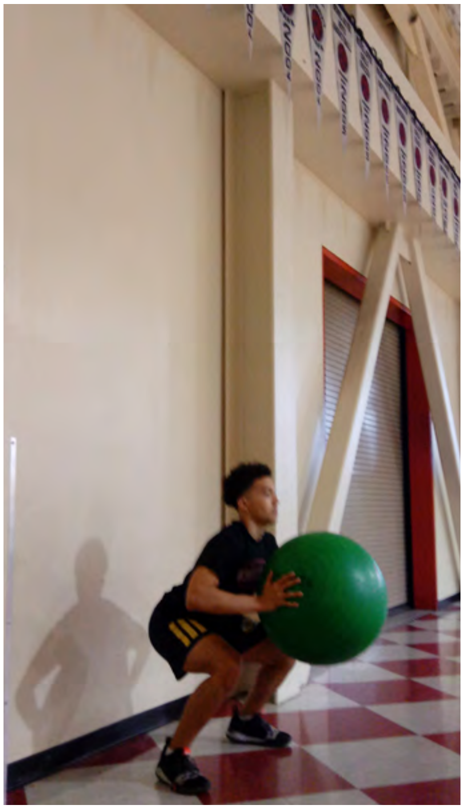

FIGURE 4A. SQUAT JUMP - START POSITION

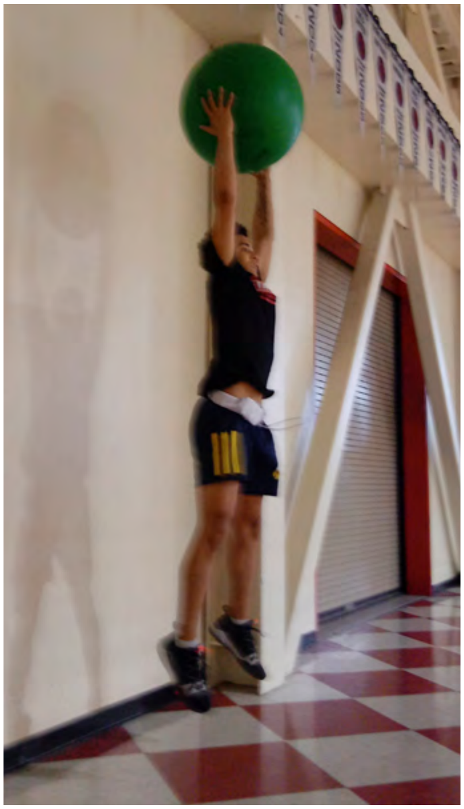

FIGURE 4B. SQUAT JUMP - JUMPING ACTION

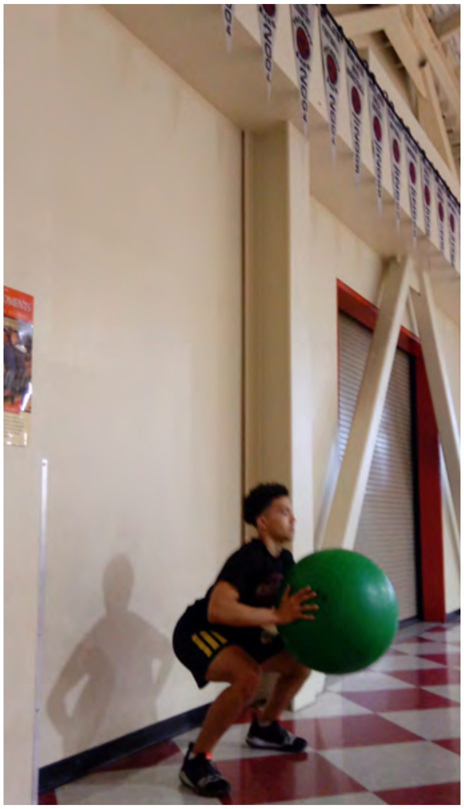

FIGURE 4C. SQUAT JUMP - LANDING

For a well-structured plyometric training program, coaches need to apply the general training principles (e.g, specificity, overload, and progression) to exercise prescription in terms of exercise selection, duration, intensity, and volume (10,11). Table 1 demonstrates an example design of an eight-week plyometric training program to develop power actions for high school soccer athletes. It applies the training principles to consider exercise selection, duration, intensity, volume, and recovery based on several recommended training guidelines for young athletes (5,8,11).

### EXERCISE SELECTION

The selection of plyometric exercises follows the training specificity and improves athletes' work capacity in terms of muscle strength, explosive power, and anaerobic endurance (8). Also, coaches select specific plyometric exercises to meet the training needs for different power actions (e.g., kicking, jumping, sprinting, and agility) for soccer athletes, as discussed in part one of the series. Table 1 lists several plyometric exercises that aim to develop power actions for soccer athletes. Plus, the selected exercises follow training progression principles in terms of intensity and volume to continue training adaptation and reach training effects.

Integrating plyometrics with general training methods (e.g., resistance, speed, and agility training) is an effective way to improve soccer-specific power movements in kicking, jumping, sprinting, and agility (11,27,29). First, combined strength and plyometric training can stimulate both neural and structural adaptations for some high school athletes who are after the pubertal growth spurt (19). Combining plyometrics (e.g., depth jump and standing triple jumps) with resistance exercise (e.g., squats) adds the speed component in muscle performance and stimulates neuromuscular adaptation (8). Second, a combined sprint training and plyometric training program enhances fast muscle action and improves metabolic systems for sprinting activities (24,28). Certain types of plyometric exercises involving slow short-stretching cycle (SSC) or fast SSC targets different parameters of sprint ability (27). A combined training program should include plyometric exercises focusing on different parameters, such as acceleration, maximal speed, and explosive muscle action. For example, coaches can add plyometrics with slow SSC (e.g., squat jump) for acceleration and fast SSC (e.g., drop jump) for maximal velocity accordingly to speed training. Third, adding plyometric training can reinforce various components of agility activities (14,15). Also, plyometric movements with directional cues enhance unanticipated cutting maneuvers and better prepare an athlete for multidirectional sports activities (22). Thus, a combined training program should select plyometric exercises targeting explosive power and movement biomechanics (e.g., unanticipated cutting maneuvers) for agility tasks, such as box drops with quick change of direction following verbal cues or hand signals (Table 1).

**TABLE 1. SAMPLE 8-WEEK PLYOMETRIC TRAINING PROGRAM FOR HIGH SCHOOL SOCCER ATHLETES**

| | WEEK 1 | | WEEK 2 | | | WEEK 3 | | WEEK 4 | |
|---|---|---|---|---|---|---|---|---|---|
| | S1 | S2 | S1 | S2 | | S1 | S2 | S1 | S2 |
| **Tuck Jumps** | 3 x 8 | 3 x 8 | 3 x 8 | 3 x 8 | **Jump to Box** | 3 x 8 | 3 x 8 | 3 x 8 | 3 x 8 |
| **Box Drop** | 2 x 8 | 2 x 8 | 2 x 8 | 2 x 8 | **Box Drop** | 3 x 8 | 3 x 8 | 3 x 8 | 3 x 8 |
| **Lateral Jumps** | 3 x 4 e | 3 x 4 e | 3 x 4 e | 3 x 4 e | **Lateral Jumps Over Flat Cone** | 3 x 4 e | 3 x 4 e | 3 x 4 e | 3 x 4 e |
| **Skip** | 3 x 10 | 3 x 10 | 3 x 10 | 3 x 10 | **Skip** | 3 x 12 | 3 x 12 | 3 x 12 | 3 x 12 |
| **Total Volume** | 94 | 94 | 94 | 94 | **Total Volume** | 108 | 108 | 108 | 108 |

| | WEEK 5 | | WEEK 6 | | | WEEK 7 | | WEEK 8 | |
|---|---|---|---|---|---|---|---|---|---|
| | S1 | S2 | S1 | S2 | | S1 | S2 | S1 | S2 |
| **Jump to Box** | 3 x 10 | 3 x 10 | 3 x 10 | 3 x 10 | **Jump to Box2** | 3 x 10 | 3 x 10 | 3 x 10 | 3 x 10 |
| **Box Drop3** | 3 x 8 | 3 x 8 | 3 x 8 | 3 x 8 | **Box Drop + COD4** | 3 x 8 | 3 x 8 | 3 x 8 | 3 x 8 |
| **Single-Leg Lateral Jumps Over Flat Cone** | 3 x 5 e | 3 x 5 e | 3 x 5 e | 3 x 5 e | **Single-Leg Zigzag Jumps Over Flat Cone** | 3 x 5 e | 3 x 5 e | 3 x 5 e | 3 x 5 e |
| **Power Skip** | 3 x 12 | 3 x 12 | 3 x 12 | 3 x 12 | **Power Skip** | 3 x 12 | 3 x 12 | 3 x 12 | 3 x 12 |
| **Total Volume** | 120 | 120 | 120 | 120 | **Total Volume** | 120 | 120 | 120 | 120 |

***Key:*** *e = each foot or each lateral direction*

*Box2 and Box3 = increase box height, may need different heights for different athletes*

*COD4 = add verbal cues or hand signals to lateral change of direction after box drop*

Exercise selection needs to consider maturity-associated risk factors such as joint flexibility, muscle imbalances, and linear bone fracture (19). Also, the sex-related risk factors put female athletes in high risk of knee injury. Therefore, high school athletes can start with exercises involving both legs to focus on sound athletic positioning and dynamic control over the center of gravity (22).

Progressively, unilateral movements are introduced emphasizing correct technique in single-leg landing, such as progression from double-leg lateral jumps to single-leg lateral jumps (22) (Table 1). Also, jumping in multiple planes with explosive double- and single-leg movements can be added in later training sessions (22). For example, drop jumps could progress to add lateral movements with cueing (Table 1). For high school athletes with low trainability, they can begin plyometric training with low complexity. For plyometric jumping exercises, the scale of complexity from low to high is as follows: jumps in place, standing jumps, multiple jumps, box jumps, and depth jumps (8). For example, athletes can begin with tuck jumps (e.g., jumps in place) then progress to box jumps (Table 1). Also, the use of equipment (e.g., hurdles and cones) can increase intensity and complexity of a plyometric exercise (Table 1).

**DURATION**

A master schedule, including days per week and total weeks of plyometric training, needs to be determined before the season starts. Young athletes will see the plyometric training results in various durations from 6 – 16 weeks according to the training purposes: jumping, kicking, sprinting, and agility (20). Several studies reported that youth who incorporated a twice a week plyometric training program over an eight-week period showed significant improvement in running, jumping, and agility, although they used different training protocols (5,17,21,24,26). This training duration may fit high school soccer athletes. The regular high school soccer season usually lasts about 3 – 4 months including pre-season and in-season. During the season, there is more time to spend on games and soccer-specific practice. A plyometric training program that starts early in pre-season may result in better fitness improvement (4). The plyometric training effect of the pre-season eight-week program would still maintain throughout the season after detraining (5). Table 1 is an example of an eight-week plyometric training program that starts early in pre-season because there is more time allotted for soccer specific training later during the season. The program was periodized in two progressive mesocycles of four weeks each, allowing training adaptation to occur (11). The first four-week training block is progressed by gradually increasing total volume (volume x intensity) while the second four-week training block is progressed mainly by increasing intensity, which will be discussed in the following section.

Again, high school athletes often participate in multiple high school sports and/or club soccer; for instance, they enter the high school soccer season right after volleyball season or club soccer season. Therefore, these athletes may have just finished some sort of sports-specific training and other resistance or plyometric training. Coaches need to closely monitor these athletes' fitness status and adjust the workload in terms of volume and intensity.

**INTENSITY**

Appropriate overload and progression in terms of intensity are necessary to reach optimal training results (11). Gradually increasing workload allows for training stimulus and adaptation, such as box height (Table 1) (11). Adding external resistance is a way to increase workload. However, increased height gain, training loads, and matches put youth soccer athletes at high risk of injury (6). Instead of adding external resistance, coaches should instruct athletes to perform with their bodyweight to master the jumping mechanics and avoid injury. Adding different forms of external resistance may be better adapted in athletes with higher trainability, such as athletes with developed physical status in their late adolescence (18,19). Progression of plyometrics is determined by exercise technique and the length of the amortization phase (21). If an athlete is able to perform plyometric exercise with quality technique without alternating form or prolonged ground contact time, they can progress to an exercise with higher complexity (21). For instance, a jumping exercise from bilateral to unilateral, or increasing box height (Table 1).

A plyometric progression model suggested that high school athletes are in the stage to perform medium- to high-intensity plyometrics (19). However, the quick increased length of arms and legs relative to the truck may cause physical impairments and low performance in adolescents (6). Younger athletes who are around their PHV may have decreased flexibility and bone density (6). Therefore, training loads and difficulty need to be modified to prevent injury for these athletes. For example, female athletes with high risk of lower-limb injury should start plyometric training with appropriate loaded progressions, such as box height and from bilateral to unilateral movement. For example, the box height for drop jumps and box jumps may need to be modified for athletes with low trainability (Table 1).

**VOLUME**

Coaches need to determine the proper training volume to ensure training effect and reduce the risk of overuse injury. The volume of plyometric exercises should follow the overload and progression principles to focus on training improvement. Lower-limb plyometric exercises often use foot contacts to determine the volume of an exercise. Per training session, it has been suggested that the beginner phase is 80 – 100 foot contacts, the intermediate phase is 100 – 120 foot contacts, and the advanced phase is 120 – 140 foot contacts (5,17). The progression should not exceed a maximum of 90 – 190 foot contacts per session at the end of the program for young athletes (5). For bounding plyometric exercises, athletes can begin with 30 m and progress to 100 m (8). Each session should include 3 – 4 plyometric exercises for 2 – 4 sets of 6 – 15 repetitions (5). High-intensity plyometric exercise should be introduced with low volume to allow proper execution and maintain movement speed (19). For example, box drops should begin with a low height and low volume (Table 1).

As the high school soccer season starts, the volume of soccer technical and tactical practice increases. Therefore, the total volume of plyometric training should be adjusted. When in-season is approaching, the training program will focus on high-intensity plyometric exercises performed with maximal effort instead of relative high volume (Table 1). High-intensity low-volume plyometric training also provides adequate training stimulus and induces training changes in sprinting, jumping, and agility (26). This training method will use time efficiently and allow athletes to focus on soccer practice and games during the soccer season. In contrast, high training volume was related to fatigue and increased risk of injury for high school athletes (19). If plyometrics were integrated into other training methods (e.g,, resistance), plyometric training can be implemented on a separate day to avoid overtraining. Again, a high school soccer team consists of athletes with various training status and training level, so an individual training plan may be better for each player to reach the desired training result.

### SAFETY AND RECOVERY

Safety guidelines are important for youth athletes to gain training effects, reduce muscle fatigue, and prevent overuse injury (8). Coaches need to ensure athletes follow safety guidelines in each training session. A plyometric training session usually lasts about 10 – 30 min in duration, including sufficient warm-ups (e.g., dynamic stretching and light jogging) and cool-downs (e.g., passive stretching and slow walking) (17). It is preferred that plyometric exercises are performed on a firm rubber surface or turf, which allow for better landing force absorption. Soccer athletes can perform plyometrics on a grass field as well. It simulates the real game situation and improves dynamic balance better than training on a stable surface, such as a wood floor (23). The plyometric exercises listed in Table 1 are designed to be performed on a turf or grass field with equipment (plyometric box, hurdles, or cones) set up on the field. It aims to reduce the landing impact from plyometrics.

Resting time is needed to ensure proper execution and recovery. A plyometric exercise usually lasts about a few seconds to 90 seconds (8). The work-to-rest ratio of plyometrics is based on the intensity and level of the activity. For plyometric exercises (e.g., jumps in place, standing jumps, and depth jumps) that last less than 30 s, the adenosine triphosphate (ATP) or creatine phosphate system is the primary energy system. The work-to-rest ratio should be 1:5 – 1:10 between repetitions and 2 – 3 min rest between sets (11). Because plyometrics can be considered as power exercises, longer inter-set resting time is needed for maximum recovery and results in greater gains in power performance (e.g., jumping and kicking) (8,26). For plyometric exercises (e.g., multiple jumps and bounding) that last between 30 – 90 s, the inter-set rest ratio could be 1:3 to target the lactic acid threshold (8,11). Coaches should closely monitor training activities and allow athletes sufficient time for recovery. Also, youth athletes need adequate rest for growth processes to occur and to avoid accumulated fatigue (19). For example, young females may encounter muscle imbalance (quadriceps versus hamstrings) when fatigued, which increase the risk of ACL injury (19). Hence, plyometric training should start with 1 – 2 times a week and 48 – 72 hr of recovery for the same muscle group (17). For example, if the first training session starts on Monday, then the second session should start on Thursday in a two sessions per week plyometric training program (Table 1).

## SUMMARY

In conclusion, plyometric training can be a valuable addition to enhance power actions, such as kicking, jumping, sprinting, and agility, for high school soccer athletes. Integrating plyometrics to general training methods is beneficial to improve physical performance. A plyometric training program needs to consider high school students' maturation status and trainability, as well as the physical changes for females during the high school period. Plyometric techniques and program design are essential to ensure the safety and effectiveness of a plyometric training program. A plyometric training program should be designed to improve overall physical fitness and promote LTAD for high school athletes. It should be noted that plyometrics target agonist muscles, such as triple extensors in plyometric jumping exercises. Muscle imbalance (e.g., hamstring versus quadriceps) may occur, so functional strength training may be necessary to increase antagonist muscle (e.g., hamstring) strength to prevent related injury (16). Also, balance training can help to reduce the stress of rapid eccentric to concentric transition in SSC from plyometric training (7). Therefore, athletes can start training early and may incorporate functional training that focuses on strengthening leg muscles and core stability to increase muscular strength and proprioceptive stability (8).

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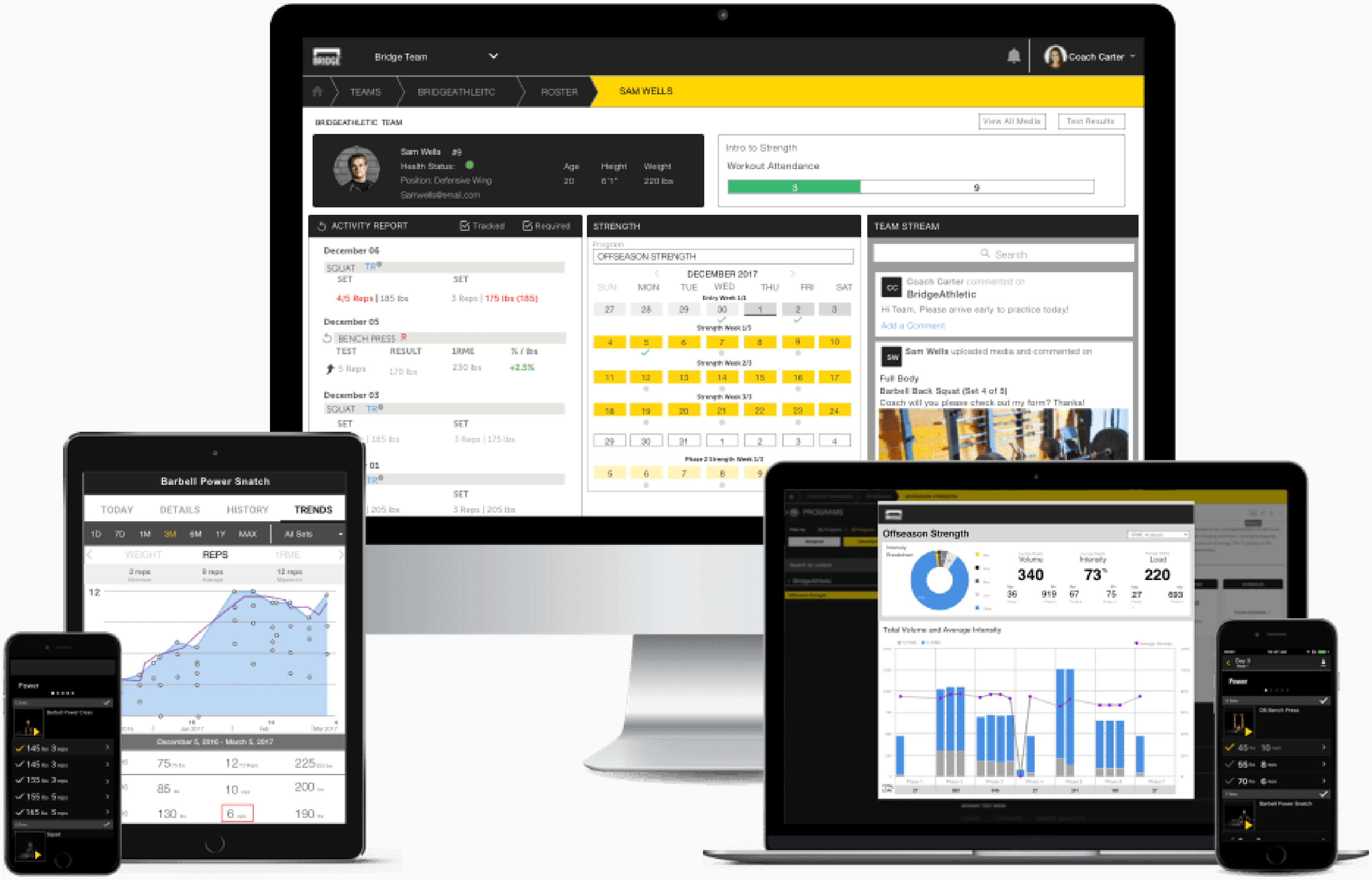


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