BRIEF REVIEW

NEUROMUSCULAR TRAINING TECHNIQUES TO TARGET DEFICITS BEFORE RETURN TO SPORT AFTER ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION

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ABSTRACT

Surgical intervention and early-phase rehabilitation after anterior cruciate ligament (ACL) reconstruction have undergone a relatively rapid and global evolution over the past 25 years. Despite the advances that have significantly improved outcomes, decreases in healthcare coverage (limited visits allowed for physical therapy) have increased the role of the strength and conditioning specialist in the rehabilitation of athletes returning to sport after ACL reconstruction. In addition, there is an absence of standardized, objective criteria to accurately assess an athlete's ability to progress through the end stages of rehabilitation and safely return to sport. The purpose of this Scientific Commentary is to present an example of a progressive, end-stage return to sport protocol that is targeted to measured deficits of neuromuscular control, strength, power, and functional symmetry that are rehabilitative landmarks after ACL reconstruction. The proposed return to sport training protocol incorporates quantitative measurement tools that will provide the athlete with objective feedback and targeted goal setting. Objective feedback and targeted goal setting may aid the strength and conditioning specialist with exercise selection and progression. In addition, a rationale for exercise selection is outlined to provide the strength and conditioning specialist with a flexible decision-making approach that will aid in the modification of return to sport training to meet the individual athlete's abilities and to target objectively measured deficits. This algorithmic approach may improve the potential for athletes to return to sport after ACL reconstruction at the optimal performance level and with minimized risk of reinjury.

KEY WORDS ACL, knee, knee rehabilitation, lower extremity, sports reentry

INTRODUCTION

Traditional anterior cruciate ligament (ACL) rehabilitation protocols can be divided into phases such as acute, subacute, functional progression, and return to activity(90). These protocols usually focus on acute and subacute management with relatively stringent guidelines regarding progression of weight-bearing, advancement of range of motion (ROM), and progressive introduction of specific types of exercises early in rehabilitation. These guidelines and supervised therapy can significantly improve the early post-surgical outcomes (36). Conversely, the final phases of rehabilitation are typically more generalized, with more global categorizations of appropriate exercises and progressions, with the goal to transition the athlete after ACL reconstruction (ACL-R) from the ability to perform activities of daily living (ADL) to proficiency with higher level sport-related activities (44,83, 88,90). In addition to decreased late-stage rehabilitative guidelines available for rehabilitation specialists, decreased healthcare coverage (limited visits allowed for physical therapy) has increased the role of the strength and condition specialist in the rehabilitation of athletes retuning to sport after ACL-R.

The "release for full activity" is a potentially sensitive landmark for the athlete who has a strong desire to immediately return to high-level sports participation. This is in part due to the combination of decreased activity restrictions from the treating clinicians with the athlete's increased confidence in their ability from improved ADL

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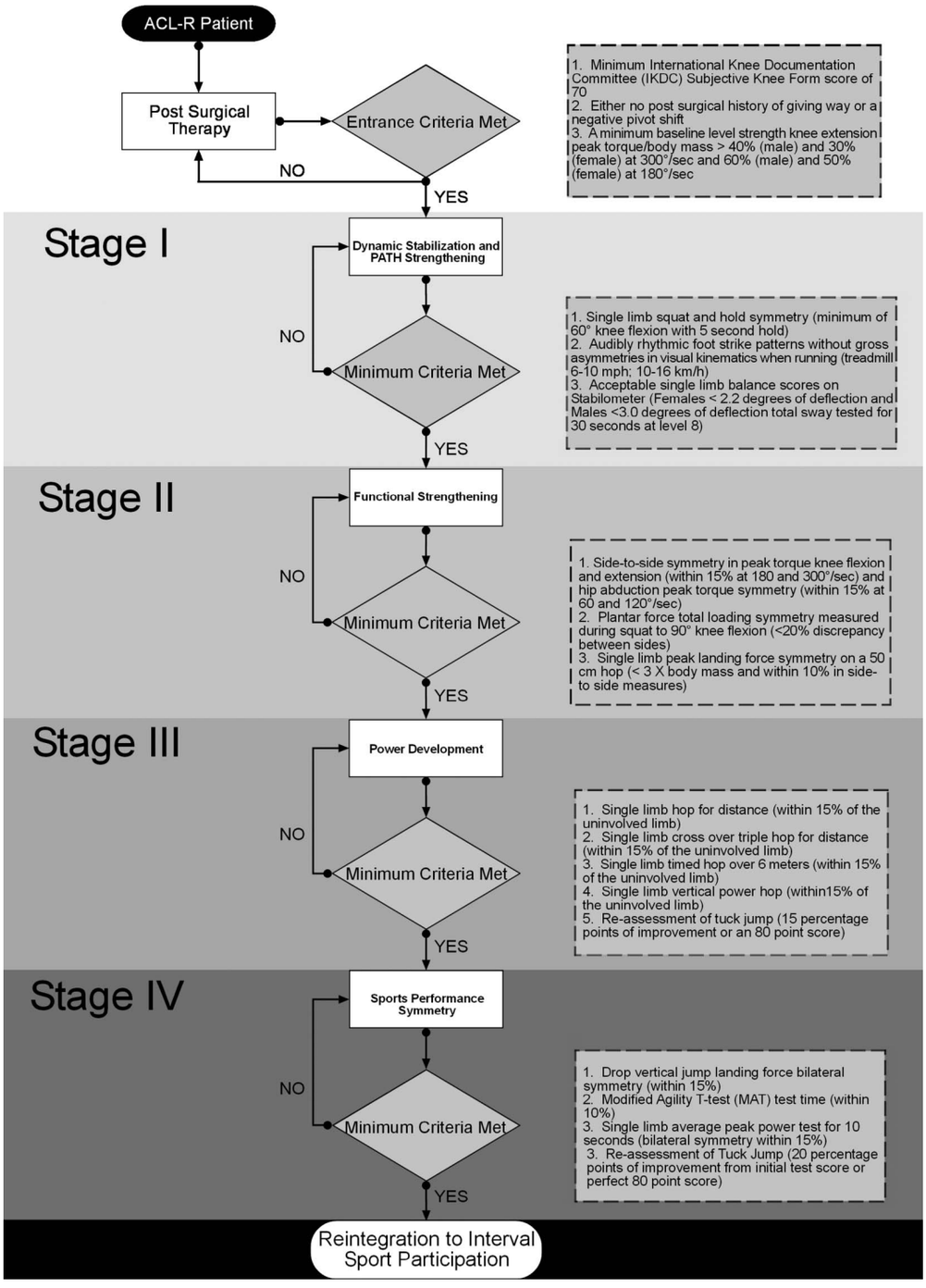

Figure 1. Return to sports algorithm post anterior cruciate ligament (ACL) reconstruction. Before progression to the next rehabilitative stage in the program, the athlete is required to meet the minimal progression criteria listed. Modified and reprinted from G.D. Myer, MV Paterno, et al. Rehabilitation after anterior cruciate ligament reconstruction: criteria based progression through the return to sport phase." *J Orthop Sports Phys Ther.* 36: 385–402, 2006 with permission of the *Journal of Orthopaedic and Sports Physical Therapy Sections of the American Physical Therapy Association.*

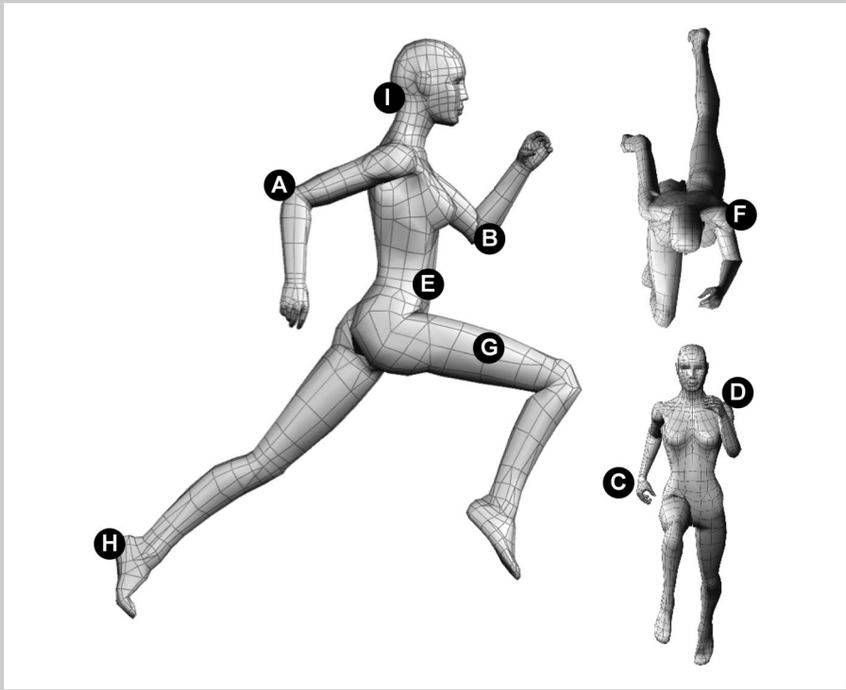

Figure 2. Running techniques instituted for athletes during their return to sport training. Running athletes on a treadmill during Stage I allows the strength and conditioning specialist to provide feedback on potential deficits and to control the intensity and volume of running bouts. A) Athletes are instructed to flex their elbows to 90° and maintain this position (although slightly increased elbow extension is acceptable at the endpoint range of motion) during the back swing. B) Athletes are instructed to maintain 90° position of elbow (although slightly increased elbow flexion is acceptable at the endpoint range of motion) during the forward arm swing. C) Athletes are instructed to extend their shoulder to a point at which their wrist would swing past their hip. In addition, during the back swing, the athletes are encouraged to minimize shoulder horizontal abduction by keeping their ''elbows in'' and ''brush your hip pocket with your wrist.'' D) During the forward arm swing, the athletes are told to continue to keep their elbows close to their body but not to horizontally adduct or flex their shoulder to a point that their ''wrist should not cross the midline of your torso'' or ''take your wrist higher than your chin.'' E) Athletes are instructed to ''maintain upright position of your torso'' during sprint training. Both the inclined treadmill training and resistive ground based training can influence forward trunk flexion beyond optimal positions. This teaching cue for torso alignment was cued often for both sprint groups during training. F) Athletes are encouraged to ''keep your shoulders square to the direction of travel'' to limit torso rotation during training. G) Athletes are encouraged to ''drive your thigh through'' and attempt to get your thigh parallel to the ground" (90° hip flexion) during the forward leg swing. H) Athletes are instructed to initiate foot strike ''on the balls of your feet'' and ''push off with full ankle extension.'' I) Athletes are encouraged to be relaxed and to avoid trying to ''strain'' through their sprint training bouts. They are instructed to ''relax your upper torso'' and to ''avoid clinching or straining your jaw and neck'' during training bouts. Reprinted with permission from the editor from G.D. Myer et al. Predictors of sprint start speed: the effects of resistive ground based vs inclined treadmill training. *J Strength Cond Res.* 21: 491–496, 2007.

function and a concomitant decrease in pain during and after sports-related activities. These factors are heightened with pressures from coaches, parents, and teammates to accelerate the return to sport timeline. During this phase of rehabilitation, the strength and conditioning specialist must be especially cognizant of the potential gap between the athlete's perceived vs. actual sports readiness, as subjective scores often do not correlate to quantified function and strength scores in athletes with ACL injuries and reconstructions (67,70,79). Without objective measures that identify potential deficits, it may be difficult for the strength and conditioning specialist to justify sport restriction and the associated limitations or to address any lasting impairments related to the initial ACL injury or reconstruction. Specific progressive guidelines, based on objective measures, can provide a goal-oriented rehabilitation process that may be an appealing approach for athletes (10).

Lack of systematic guidelines in late phases of training before return to sport, particularly in cases in which athletes progress to unrestricted activity, is counterintuitive, as this is the time frame when athletes begin to expose the lower extremity to forces and motions that can highly load the knee and reconstructed graft (7,15,31,53,72). Although athletes may be prepared to begin more functional training to better prepare for sport competition, they may have deficits that limit their potential for safe integration into full competitive sports. Residual biomechanical and neuromuscular deficits can increase reinjury risk during early sports reintegration (14,31, 73,75). Late-phase rehabilitation and return to sport training that is organized to meet predetermined objective guidelines may help to systematically transition the athlete with a reconstructed ACL through return to sport training in a safe and efficacious manner (64). This approach may help an athlete to develop bilateral symmetry and a dynamically functional lower extremity that is prepared to safely respond to the extreme forces generated during sports. In addition, an objective late-phase rehabilitation program after ACL reconstruction may reduce the athlete's increased risk of reinjury and optimally prepare them to meet and potentially exceed pre-injury performance levels (10,28,77,81,89).

The purpose of the following Scientific Commentary is to present an example of a progressive return to sport protocol designed to help the athlete to progress through objective measures of neuromuscular control, strength, power, and lower extremity symmetry that are rehabilitative landmarks after ACL-R. The proposed return to sport training protocol

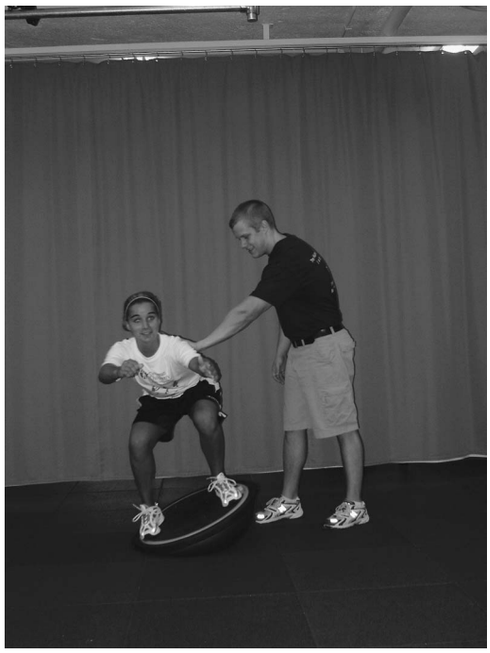

Figure 3. Partner perturbations are used to advance balance and postural control strategies. Reprinted with permission of the publisher from G.D. Myer et al. *J Musculoskel Med.* 23: 12–38, 2006.

incorporates quantitative measurement tools that will provide the athlete with objective feedback and targeted goal setting and will aid clinicians with exercise selection and progression. In addition, a rationale for exercise selection is outlined to provide the strength and conditioning specialist with a flexible decision-making approach to aid in the modification of return to sport training to meet the individual athlete's abilities and to objectively target measured deficits. This algorithmic approach may improve the potential for athletes to return to sport after ACL-R at an optimal performance level with minimized risk of reinjury.

Criteria for Progression into the Return to Sport Phase

The current ACL return to sport protocol is a four-stage, criteria-based program designed to guide the advanced stages of rehabilitation after ACL-R and facilitate successful and safe progression of the athlete back to sports. The four stages include (I) dynamic stabilization and pelvis/abdomen/trunk/hip (CORE) strengthening, (II) functional strengthening, (III) power development, and (IV) sports performance symmetry. Each stage design is targeted to treat common deficits of athletes after ACL-R and to address ACL injury risk factors that may have been demonstrated by an athlete before injury. If these goals are achieved, athletes after ACL-R may increase the potential for safe return to sport at maximized performance levels (14,31,57,61,62,75,90). Entrance into and progression through each stage of the program is dependent on meeting the minimal objective criteria measurements (Figure 1) specific to each stage (64). This algorithmic approach may help the athlete and clinician to monitor the progression toward a safe transition back to sport. If the athlete fails to meet the required criteria, it is recommended that they continue training with the protocol from the current stage. Appendix 1 provides a general protocol designed to target milestones used to transition athletes back to sport after ACL-R, address potential risk factors that may have been related to the initial injury, and potentially improve the individual's athletic performance (10,31,40,44,58,64). We recommend that the strength and conditioning specialist make modifications to address sports-specific or activity-specific needs of each individual athlete. Figure 1 presents an algorithmic flow chart used to track the athlete's progress through the return to sport training stages. Before initiation of return to sport training, our recommendation is that the athlete meets the following minimal baseline criteria in their previous rehabilitation (64):

1. Minimum International Knee Documentation Committee (IKDC) Subjective Knee Form score of 70.
2. Either a negative pivot shift or no post-surgical history of giving-way episode.
3. A baseline level of isokinetic knee extension peak torque/body mass of at least 40% (male) and 30% (female) at $300°\cdot s^{-1}$ and 60% (male) and 50% (female) at $180°\cdot s^{-1}$.

Return to Sport Stages

The rehabilitation progression should take the athlete through a combination of both low-risk and high-demand maneuvers in a controlled environment. The training should balance attempts to progressively increase load and develop the functional abilities of the athlete with minimal exposure to potential injury risk positions. The introduction to this type of training into the rehabilitation program may create acute muscle soreness. Consequently, the rehabilitation team should use discretion in all phases of return to sport training to avoid adverse reactions, such as excessive pain or joint swelling (11). Continual assessment of tissue tolerance and swelling will be necessary for the strength and conditioning specialist to determine the needed modifications to the outlined protocol to facilitate appropriate intensity and progression of exercises to their individual athletes (11). The presented criteria-driven guidelines may facilitate the decision-making approach toward intensity and exercise mode. The ultimate goal of the ACL return to sport algorithm of rehabilitation is to identify and address deficits that may inhibit the athlete from improving neuromuscular function and to raise them to a performance status that will minimize the risk of reinjury. In addition, we think this approach may provide the potential for athletes post ACL-R to improve their ability to manage dangerous forces and torques that may have incited the initial injury and hindered performance before injury.

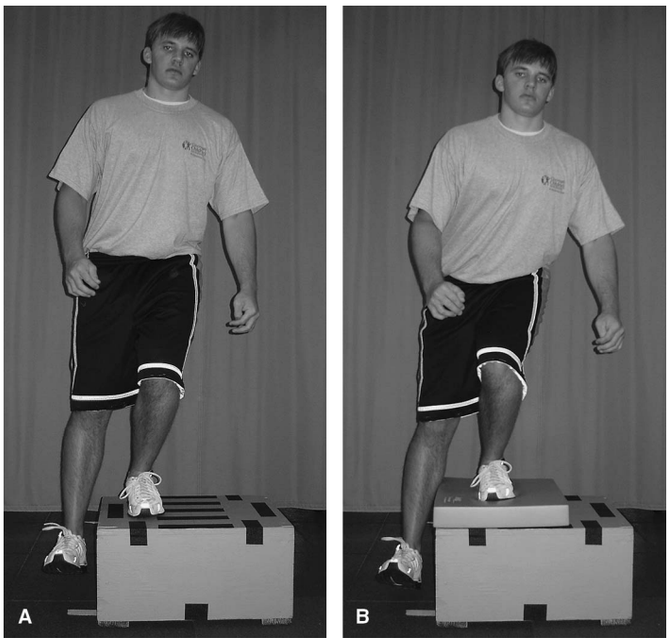

Figure 4. A) Box heel touches can be performed on a 12-in box. B) Difficulty can be increased by using an Airex pad to decrease stability. Reprinted with permission of the publisher from G.D. Myer et al. *J Musculoskel Med.* 23: 12–38, 2006.

1. Improvement of single-limb weight-bearing at increasingly greater knee flexion angles.
2. Improvement of side-to-side symmetry in lower extremity running mechanics.
3. Improvement of closed-chain single-limb postural balance.

Strength and conditioning specialists should modify guidelines to address deficiencies of each athlete, with a secondary focus on increasing the athlete's potential to meet the minimal criteria required to exit Stage I and progress to Stage II of return to sport training (64). A rationale for exercise selection is provided below to aid exercise prescription modifications necessary to meet the needs of individual athletes after ACL-R.

Stage I: Dynamic Stabilization and Pelvis/Abdomen/Trunk/Hip (CORE) Strengthening

The first stage of return to sport training should focus on the initiation of dynamic lower extremity stabilization techniques and the institution of a CORE strengthening regimen. More specifically, Stage I of the return to sport protocol focuses on the following goals (Appendix 1) (64):

The goal of the dynamic stabilization training and CORE strengthening is to develop a baseline level of CORE stability and coordination for the athlete that allows them to control the deceleration of the center of mass, maintain balance and posture, and subsequently accelerate their mass by rapidly generating force in the desired direction. Exercises to strengthen CORE stability specifically address the musculature about the torso and hip (60,62). Decreased CORE strength and muscle synergism may reduce

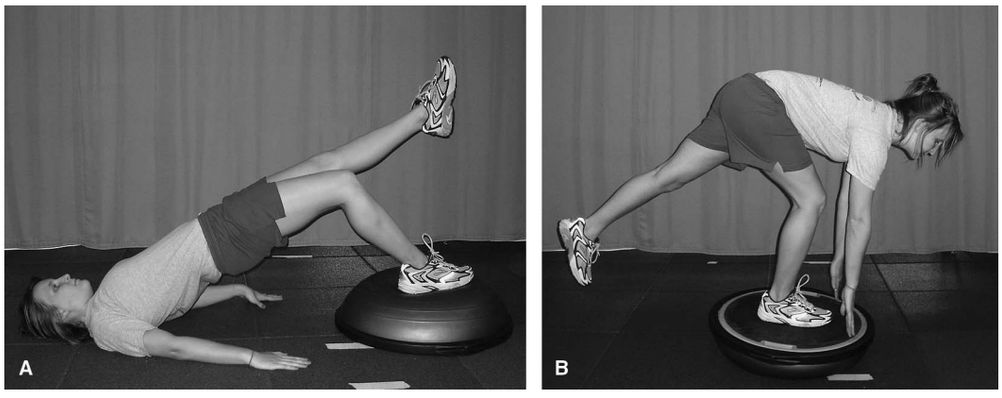

Figure 5. A) Single-leg pelvic bridge and the (B) single-leg straight leg dead lift can be performed on a BOSU training device with or without the addition of external weight. Reprinted with permission of the publisher from G.D. Myer et al. *J Musculoskel Med.* 23: 12–38, 2006.

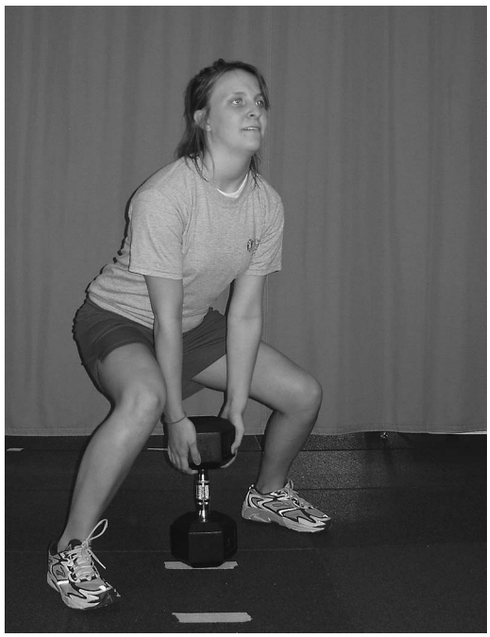

Figure 6. The sumo squat is performed with the feet wider than shoulder width apart. The athlete should focus on maintenance of an upright posture with minimized trunk flexion during the exercise.

performance in power activities and may increase the incidence of injury secondary to lack of control of the center of mass, especially in female athletes (37,93). Zazulak et al. reported that factors related to core stability predicted risk of knee, ligament, and ACL injuries with high sensitivity and moderate specificity in female athletes (94). A logistic regression model that incorporated measures of core stability and trunk proprioception predicted knee, ligament, and ACL injury risk in women with 84%, 89%, and 91% accuracy, respectively (94). Increased hip adduction with dynamic tasks and decreased hip muscle strength can contribute to lower extremity valgus.(74) Lower extremity valgus combined with limb asymmetries is related to increased risk of ACL injury in young female athletes (31).

Successful CORE strengthening requires a multifaceted approach to athlete preparation that includes total body strength and power training; fundamental movement and technique training; plyometrics; balance and stability; and speed and agility training (60,62,76). CORE strength and stability are related to the body's ability to actively control the body's center of mass in response to the forces generated from distal body parts during athletic competition. Neuromuscular training and rehabilitation geared toward increasing CORE strength and stability may both reduce the risk of injury through more effective control of the athlete's center of mass and prepare the athlete to achieve optimal performance levels (31,57,58,62). The program design incorporates dynamic stabilization and CORE strengthening into every facet of an athlete's return to sport training. However, the initiation of high level return to sport training requires the athlete to have an adequate level of balance and strength; thus, it is an early focus of return to sport training. In addition, balance board proprioceptive training should be utilized well past the early return to sport training stage, not only for restoration of function, but for the potential prophylactic effect on ligament reinjury (9,31,32,57,58, 61,89).

In the early stages of rehabilitation after ACL reconstruction, rehabilitation specialists focus on developing a proficient walking gait for the athlete. However, small gait deviations may still be present in the late phases of accelerated ACL rehabilitation protocols (16,43,90). These small gait deficits during walking may be exaggerated into pronounced gait

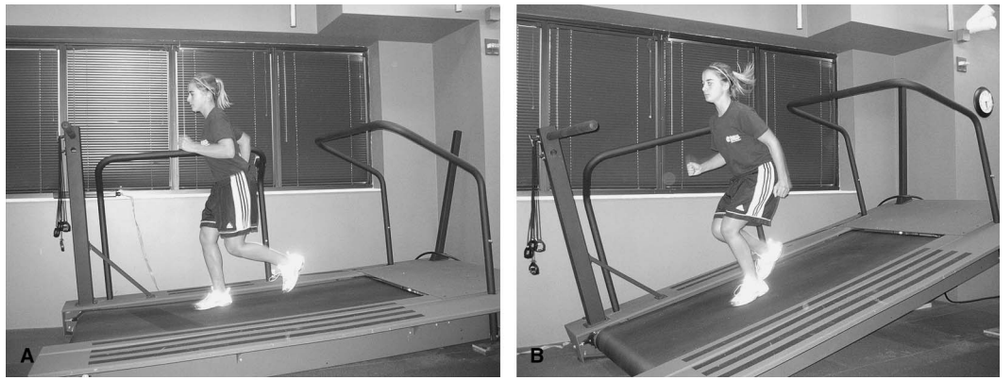

Figure 7. Retrograde training performed on (A) level and (B) inclined treadmill positions.

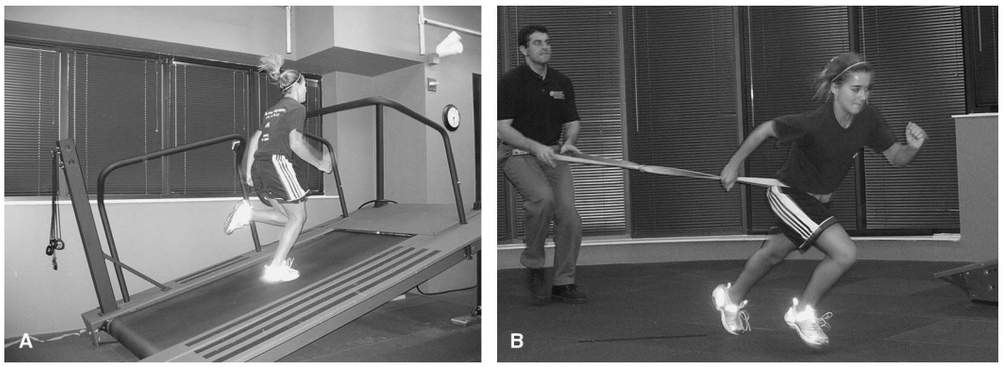

Figure 8. (A) Treadmill training and (B) resistive running are used to help athletes to regain functional speed and functional strength, respectively. The athlete is encouraged to improve symmetry in gait cycles when training.

deviations in athletes after ACL-R who attempt to run and sprint (17). Running gait training performed on a treadmill may allow the clinician to provide simultaneous and continuous verbal feedback cues to improve the athlete's running techniques (Figure 2) (56). An early goal in gait retraining is to normalize ROM in the involved and the noninvolved limbs (71,82). In addition, there should be a focused effort to improve symmetry of the lower extremity musculature, which may prevent abnormal side-to-side loading of the ligaments and soft tissue (33,82). The involved limb often demonstrates limited joint ROM during functional activities, especially at the hip, despite full anatomic ROM (16,48). Inclined treadmill running can force the athlete to increase hip flexion power and functionally utilize hip ROM during running (84). Care should be taken when initiating running gait training to monitor the athlete for signs of patellofemoral pain, which should be addressed accordingly with exercise modifications (27).

Increasing sprint speed (running velocity) on the treadmill will continue to require movement through larger joint ROM, especially at the hip and the ankle. Therefore, attention should be directed toward obtaining a normal rhythmic

Figure 9. Tuck jumps are an example of an exercise used to train the athlete to increase lower body power. The tuck jump can also be used as an assessment to grade improvement in technique. To perform the tuck jump, athletes starts in the athletic position with their feet shoulder-width apart. They initiate the jump with a slight crouch downward while they extend their arms behind them. They then swing their arms forward as they simultaneously jump straight up and pulls the knees up as high as possible. At the highest point of the jump, athletes are in the air with the thighs parallel to the ground. When landing, athletes should immediately begin the next tuck jump. Encourage the athletes to land softly, using a toe to mid-foot rocker landing. The athletes should not continue this jump if they cannot control the high landing force or if they demonstrate a knock-kneed landing. Reprinted from G.D. Myer, K.R. Ford, et al. Rationale and clinical techniques for anterior cruciate ligament injury prevention among female athletes. *J Athl Train* 39: 352–364, 2004 with permission from the editor.

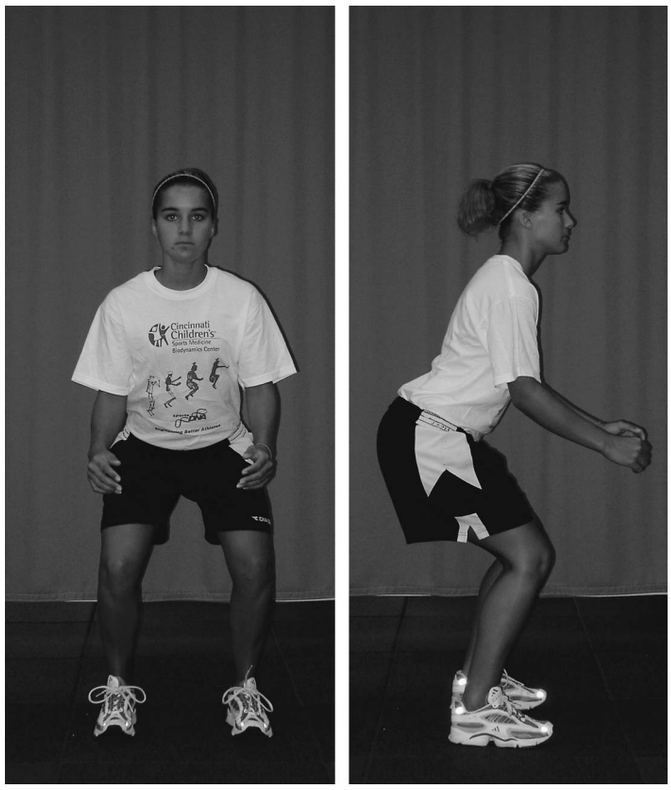

Figure 10. The athletic position is a functionally stable position with the knees comfortably flexed, shoulders back, eyes up, feet approximately shoulder-width apart, the body mass balanced over the balls of the feet. The knees should be over the balls of the feet and chest should be over the knees. This is the athlete-ready position and is the starting and finishing position for most of the training exercises. During some of the exercises, the finish position is exaggerated with deeper knee flexion (deep hold Figure 11) to emphasize the correction of targeted biomechanical deficiencies. Reprinted from G.D. Myer, K.R. Ford, et al. Rationale and clinical techniques for anterior cruciate ligament injury prevention among female athletes. *J Athl Train.* 39: 352–364, 2004 with permission from the editor.

stride. A non-rhythmic foot contact pattern during sprinting may be indicative of unbalanced limb contribution and is evident through the audible monitoring of foot contacts. If the athlete demonstrates unbalanced sprinting gait, the contributing factors are likely either pain or failure to utilize full ROM in the involved leg. If patellofemoral pain and decreased joint mobility are determined to be the limiting factors, then increased focus on backward running may limit patellofemoral loads and assist the athlete through this stage of progression (12,27). In addition, backward running may be used to increase work and decrease patellofemoral joint loads, which may effectively increase quadriceps strength (18,27,86).

Once the athlete has increased functional lower extremity joint ROM to normal levels and has attained lower extremity symmetry when jogging at lower intensity, treadmill speed can be increased to assess the athlete's sprinting form near functional speeds. Painfree symmetrical sprinting gait should be the ultimate goal of this treadmill training. The Stage I focus on CORE strengthening and running should be tailored to provide an appropriate balance between developing the proprioceptive abilities of the athlete and exposing the athlete to inadequate joint control.

The rehabilitation exercises should take the athlete through a combination of low- to high-demand maneuvers in a controlled situation (60). The intensity of the exercises can be modified by changing the arm position, opening and closing the eyes, changing support stance, increasing or decreasing surface stability with balance training devices, increasing or decreasing speed, adding unanticipated movements or perturbations, and adding sports-specific skills (Figure 3) (62). CORE strengthening and dynamic stabilization should provide the athlete with baseline levels of both torso and hip strength and coordination that are adequate to safely progress onto more dynamic sports-related training.

Simultaneous running gait retraining and a progressive CORE strengthening program will introduce athletes after ACL-R to strategies that will allow them to properly initiate, control, and decelerate ground reaction forces that they will encounter in competitive play when jumping, landing, and cutting. Before progression to Stage II of the ACL return to sport program, it is recommended that the athlete demonstrate minimal unilateral balance and functional strength measures described below (64). Athletes who have decreased neuromuscular control of the core measured during trunk repositioning and sudden load release tasks are at increased risk of ACL injury (94). Athletes should be evaluated for trunk and hip positioning and postural stability deficits before return to competition and perform targeted core neuromuscular training. The implementation of dynamic stabilization and CORE strengthening, including proprioceptive exercise, perturbation, and correction of body sway, has the potential to prevent the occurrence and to reduce the reoccurrence of ACL injury in athletes after ACL-R.

Figure 11. Line broad jump deep hold and broad jump deep hold exercise used to teach the athlete to achieve and maintain knee flexion when landing from a jump. The athlete prepares for this jump in the athletic position with the arms extended behind the body at the shoulder. Athletes begin by swinging their arms forward and jumping horizontally and vertically at approximately a 45° angle to achieve maximal horizontal distance. The athlete is encouraged to stick the landing with their knees flexed to approximately 90° in an exaggerated athletic position (Figure 10). The athlete may not be able to stick the landing during a maximal effort jump in the early phases. In this situation, have the athlete perform a submaximal broad or line jump in which he or she can stick the landing with their toes straight ahead and no inward motion of the knees. As their technique improves, encourage them to add distance to their jumps, but not at the expense of perfect technique. Reprinted with permission from the editor from G.D. Myer, K.R. Ford, et al. Rationale and clinical techniques for anterior cruciate ligament injury prevention among female athletes." *J Athl Train.* 39: 352–364, 2004.

Stage I: Criteria for Progression

We recommend that the athlete demonstrate proficiency in the following criteria before progression to Stage II (64):

1. Single-limb squat and hold symmetry (minimum of 60° knee flexion with 5-second hold).
2. Audibly rhythmic foot strike patterns without gross asymmetries in visual kinematics when running (treadmill 6–10 mph; 10–16 $km \cdot h^{-1}$).
3. Acceptable single-limb balance scores on stabilometer (women <2.2° of deflection and men <3.0° of deflection total sway tested for 30 seconds at level 8).

Stage II: Functional Strength

The second stage of return to sport training should focus on improvement of the athlete's functional strength. More specifically, Stage II of the return to sport focuses on the following (Appendix 1) (64):

1. Improvement of lower extremity non–weight-bearing strength.
2. Improvement of force contribution symmetry during activities involving bi-pedal stance.
3. Improvement of single-limb landing force attenuation strategies.

During this stage, we recommend that strength and conditioning specialists continue lower extremity weight-bearing strengthening activities, high-intensity balance, and perturbation training in the athlete's training regimen. In addition, the return to sport training program can now include non–weight-bearing lower extremity exercises such as knee extension exercises (55). Our strength coaches and trainers also progress the emphasis on improving the athlete's strength with squatting techniques, focusing on equal side-to-side limb contribution. Increased focus on appropriate force attenuation strategies with landing on a single limb may also be incorporated into the training regimen. Exercise prescription should be targeted to address other identified deficits specific to the individual athlete.

The prophylactic effects of increased strength or use of resistance training has not been shown in isolation to reduce ACL injury in normal populations or reinjury in athletes after ACL-R. Interestingly, assessment of quadriceps strength has traditionally been used as the gold standard to release athletes to return to sport (44). There is inferential evidence that resistance training improves functional strength and reduces injury based on the beneficial adaptations that occur in bones, ligaments, and tendons after training (25,41), and strength measures are related to increased functional outcome after an ACL injury (44,47,48). Lehnhard and colleagues reported significantly reduced injury rates with the addition of strength training in men's soccer (46). They monitored injuries for 2 years without training and 2 years with strength training. Although they did not report a reduction of ACL injuries, they reported a decrease in the percentage of ligament sprains in the study group, in which knee injuries accounted for up to 57% of the total injuries in a given year (46). In addition, Cahill and Griffith incorporated weight training into their preseason conditioning for football teams (8). They found a reduction both in reported knee injuries and in knee injuries that required surgery over four competitive seasons in the trained groups (8). Protocols that supplement plyometric and technique training with strength training may significantly reduce ACL injuries in female athletes (34). Thus, it seems that exercises designed to induce functional strength gains, especially those exercises that involve strength and balance (Figures 4 and 5), may be effective at reducing knee injuries when combined with other training components. However, the efficacy of a single-faceted resistance training protocol on ACL injury or reinjury risk reduction has yet to be demonstrated in the literature. Thus, once functional strength level progresses, more dynamic exercises that teach appropriate lower extremity control may be warranted (Tables 1–8).

The initial functional strength training can be performed with body weight only (Figures 4 and 5) with an initial high-volume, low-intensity protocol (41,42,65,92). When appropriate, external weight can be added to increase exercise intensity (Figure 6). Strength and conditioning specialists should take the time to prescribe the appropriate weight to be used before each session based on the workload achieved in the prior session to safely progress the athlete. The weight used or repetitions prescribed must be increased between

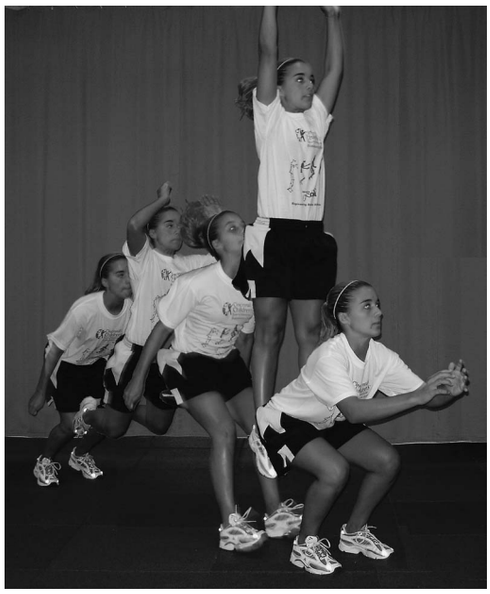

Figure 12. The athlete performs a broad jump, and the athlete immediately progresses into a maximal effort vertical jump. During the broad jumps, the athlete should attempt to attain maximal horizontal distance. Encourage the athlete to provide minimal braking during the transition form the broad jump to the maximal vertical jump. Coach the athlete to go directly vertical on the vertical jump and not move horizontally. Utilize full arm extension to achieve maximum vertical height. Reprinted with permission from the editor from G.D. Myer, K.R. Ford, et al. Rationale and clinical techniques for anterior cruciate ligament injury prevention among female athletes." *J Athl Train.* 39: 352–364, 2004.

sessions to ensure progression of exercise intensity and strength adaptation. However, intensity progression must not sacrifice proper technique or safety. If technique is not near perfect, then resistance should be decreased until proper technique is restored. The goals of the functional strength training component of the protocol are to strengthen major muscle groups through the complete ROM and to provide adequate muscular power to progress to more advanced plyometric components included in later stages of the protocol. In addition, the progressive CORE strength and dynamic stabilization techniques should be continued to ensure competence for progression to Stage III of the protocol. Again, appropriate care should be taken to limit patellofemoral pain during training, similar to the early stages of rehabilitation. For example, evidence suggests that the sumo squat (Figure 6) alters the mechanics and muscular activation (20,21) and therefore may sufficiently alter patellofemoral kinematics during closed-chain activities to reduce patellofemoral stress with increased (>45°) knee flexion. Modified squat exercises with increased hip abduction may allow athletes after ACL-R to increase knee flexion with potentially decreased anterior knee pain compared with shoulder width squatting exercises.

High-intensity retrograde incline running (Figure 7) can be used to facilitate functional knee ROM and to increase quadriceps functional strength with limited relative joint loading (12,27,86). The ability of inclined retrograde training to increase functional quadriceps activation and to limit patellofemoral stress was shown by Flynn and coauthors, who reported increased concentric quadriceps activation with decreased relative patellofemoral compressive forces in backward treadmill training (26,27). In addition to the ROM and strength benefits from retrograde training, it may help the athlete to regain cardio respiratory fitness without increased knee joint stress when compared with other training techniques that incorporate forward running (27,85). Lastly, retrograde treadmill training has been used in protocols to improve performance measures that may benefit athletes in sports that require speed, agility, and backward motion (58,85).

Sprint training can be accomplished through interval resistive band running or high-intensity treadmill training (Figure 8) (13,54,56,62). The important component with interval speed training is to emphasize short-duration and high-intensity running bouts. Performing excessive endurance training may interfere with explosive strength development needed for running and cutting sports (19,29). In addition to the strength, power, and anaerobic capacity gains achieved from sprint training, athletes after ACL-R can improve their muscular endurance and delay fatigue during high-intensity activities via mechanisms of improved efficiency of movements, improved aerobic energetics, and improved buffering capacity (19,91). To perform interval partner-resistive band running, two medium bands (Jump Stretch Inc, Youngstown, Oh.) can be tied together and anchored around the waists of two athletes (Figure 8) (56). The athlete in the forward position should be instructed to quickly transition from this starting stance to full running with proper biomechanics for the allotted time period. The trailing athlete provides a light, medium, or heavy resistance as instructed by the strength and conditioning specialist. During the initial session, the athletes should be instructed by the clinician how to vary the resistance. Strength and conditioning specialist should provide biomechanical feedback during each training bout (56). The final running of each session should include a non-resisted maximal effort run of varying distance.

Figure 13. Example of an exercise used to improve lower limb symmetry during an explosive plyometric task. The athlete begins this jump by bounding in place. Once they attain proper rhythm and form, encourage them to maintain the vertical component of the bound while adding some horizontal distance to each jump. The progression of jumps progresses the athlete across the training area. When coaching this jump, encourage the athlete to maintain maximal and symmetrical bounding height on both legs. Reprinted with permission from the editor from G.D. Myer, K.R. Ford, et al. Rationale and clinical techniques for anterior cruciate ligament injury prevention among female athletes." *J Athl Train.* 39: 352–364, 2004.

Figure 14. The single-leg hop and hold exercise can help to teach the athlete appropriate force attenuation and postural control strategies on a single leg. The starting position for this jump is a semi-crouched position on a single leg. The athlete should hold their arms fully extended behind them at the shoulder. They initiate the jump by swinging the arms forward while simultaneously extending at the hip and knee. The jump should carry the athlete up at an approximately 45° angle and attain maximal distance for a single-leg landing. Athletes are instructed to land on the jumping leg with deep knee flexion (to 90°). The landing should be held for a minimum of 3 seconds. Coach this jump with care to protect the athlete from injury. Start with a submaximal effort using line jumps and progress to a single-leg broad hop. Continue to increase the distance of the broad hop as the athlete improves their ability to stick and hold the final landing. Have the athlete keep his or her visual focus away from their feet to prevent too much forward trunk flexion at the waist. Reprinted with permission from the editor from G.D. Myer, K.R. Ford, et al. Rationale and clinical techniques for anterior cruciate ligament injury prevention among female athletes." *J Athl Train.* 39: 352–364, 2004.

If available, speed training can also be performed on high-performance treadmills that can accommodate high speeds and inclines to adjust protocol intensity (Figure 8) (54). Utilization of both inclined treadmill training and band resistive techniques in return to sport training may be best to achieve the goals of improved running mechanics (increased stride length and frequency, decreased vertical displacement), improved short distance speed, increased explosiveness, and increased muscular resistance to fatigue (19,56,91).

The global effects of strength training and rehabilitation training for athletes after ACL-R may be best achieved when combined with the progressed dynamic stabilization and CORE strengthening as well as the resistive and retrograde movement training (58). Before progression to the third stage, it is recommended that the athlete demonstrate the following minimal strength measurements (64).

Stage II: Criteria for Progression

We recommend that the athlete demonstrate proficiency in the following criteria before progression to Stage III (64):

1. Side-to-side symmetry in isokinetic knee flexion and extension peak torque (within 15% at 180 and 300°·s^{-1}) and hip abduction peak torque side-to-side symmetry (within 15% at 60 and 120°·s^{-1}).
2. Plantar force total loading symmetry measured during squat to 90° knee flexion (<20% discrepancy between sides).
3. Single-limb peak landing force symmetry on a 50-cm hop (<3 × body mass and within 10% in side-to-side measures).
4. Assessment of tuck jump technique (criteria not utilized to determine stage progression).

Stage III: Power Development

The third stage of return to sport training focuses on return of the athlete back to sport and improvement beyond their lower extremity pre-injury power levels. More specifically, Stage III of the return to sport focuses on the following (Appendix 1) (64):

1. Improvement of single-limb power production.
2. Improvement of lower extremity fatigue resistance.
3. Improvement of lower extremity biomechanics during plyometric activities.

During Stage III of the return to sport training, we recommend the incorporation of mid-level intensity double-limb plyometric jumps and the introduction of low-intensity single-limb repeated hops into the training regimen. We focus on proper and safe technical performance of the plyometric activities. The athlete's ability to properly perform the plyometric tasks can be used to guide the volume and intensity of the exercises selected (11).

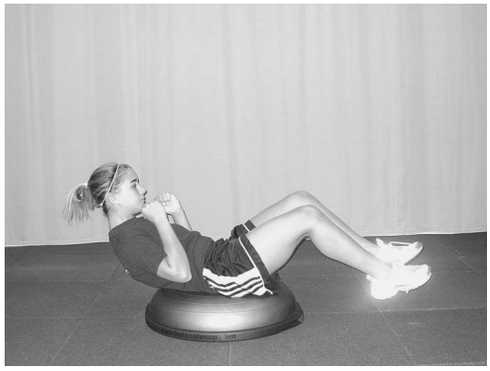

Figure 15. Athlete starts by sitting balanced on the center of the BOSU and then flexes their trunk simultaneous with hip flexion.

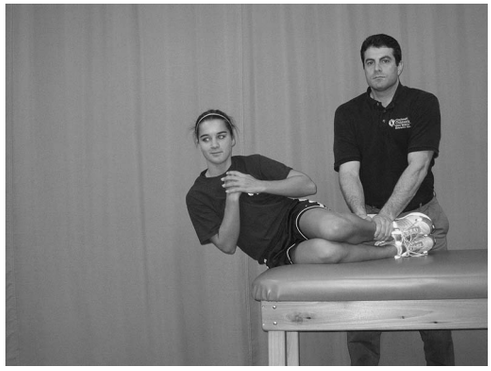

Figure 16. The athlete starts lying on the side with the hip located at the edge of the table. The athlete's feet and legs must be anchored during this exercise by the trainer or a stationary object. The athlete will proceed to flex and extend laterally at the waist for the prescribed repetitions.

The goal of the power development stage of the return to sport program is to progress increased strength into sports-related power. Plyometric training can be used to improve power measures and force dissipation strategies (35,38,58,62). The majority of the initial plyometric exercises should involve both legs to safely introduce the athlete to the training movements (Figure 9) (11). Early training emphasis should be on balanced athletic positioning (Figure 10) that can help to create dynamic control of the athlete's center of gravity (58,62,66). Soft, athletic landings that stress deep knee flexion with coronal plane knee control should be employed with verbal feedback from the strength and conditioning specialist to make the athlete aware of biomechanically undesirable positions (Figure 11) (60). Later training sessions utilize explosive double-leg movements focused on maximal performance in multiple planes of motion (Figure 12). The plyometrics and dynamic movement training components should progressively emphasize double, then reciprocal single-leg movements through training stages (Figure 13) (62). A greater number of single-leg movements can be introduced gradually while still maintaining the focus on correct technique. For example, the single-leg hop and hold exercise can be used as a teaching tool to help the athlete to develop proper force attenuation strategies on a single limb (Figure 14) (60). Volume of the initial plyometric bouts should be low because of extensive technique training required and decreased ability of the athlete to perform the exercise with proper technique for the given durations. Volume can be increased as technique improves to the midpoint of training, followed by a progressive decrease in volume during the final sessions to allow for concomitant increase in exercise intensity (11,58,62).

Continued progression of the functional strength and CORE training combined with plyometrics may provide additional benefits (Figures 15–17) (58). Subjects who underwent a combined plyometric and squat training program had significant increases in vertical jump compared with subjects who trained with squats or plyometrics alone (1). Additionally, Fatouros and colleagues found the combinatory effects of plyometrics and resistance training increased not only jump performance but also leg strength (23). Myer et al. (62) evaluated the effects of combined neuromuscular training including resistance, plyometric, CORE, and speed training among basketball, soccer, and volleyball players. After training, the athletes demonstrated improvements in performance measures (back squat, single-leg hop and hold distance, vertical jump, speed), as well as several biomechanical factors related to increased lower extremity injury risk (increased knee flexion-extension ROM, decreased abduction moments during the landing phase of a vertical jump, and increased single-leg postural stability) (31,62,76,87). Partner perturbation training was an important component of the training protocols used to improve measures of sports-related performance and reduce ACL injury risk factors and is suggested to be a critical training tool for returning athletes to full function after ACL injury (24,58,62). At this point in return to sport training, the partner perturbation training (Figure 3) may be progressed into single-leg activities. In addition, higher intensity resistance training exercises, especially those that target increased knee flexor strength and power (Figure 18), are critical in this stage of training. Hence, Stage III incorporates multiple training components that may be beneficial for the athletes after ACL-R to help facilitate return to sport with improved performance measures and lower injury risk.

Stage III: Criteria for Progression

To advance to the next stage, we recommend that the athlete meets the following criteria related to athletic power development (64):

Figure 17. Athlete positions the resistive band below the fifth cervical vertebrae and stands with both knees slightly flexed and feet on band. The movement is initiated with the trunk flexed to approximately 90°. A neutral spine should be maintained as the athlete extends the trunk from 90° to 0° (an erect posture).

1. Single-limb hop for distance (within 15% of the uninvolved side).
2. Single-limb cross-over triple hop for distance (within 15% of the uninvolved).
3. Single-limb timed hop over 6 m (within 15% of the uninvolved side).
4. Single-limb vertical power hop (within 15% of the uninvolved side).
5. Re-assessment of tuck jump (15 percentage points of improvement or an 80-point score) (Figure 9).

Stage IV: Sport Performance Symmetry

The final stage of return to sport training focuses on movement skills related to the athlete's sport and maximization of athletic development. More specifically, Stage IV of the return to sport protocol focuses on the following (Appendix 1) (64):

1. Equalization of ground reaction force attenuation strategies between limbs.
2. Improvement of confidence to maintain dynamic knee stability with high-intensity change of direction activities.
3. Improvement of power production symmetry between limbs.
4. Use of safe biomechanics (increased knee flexion and decreased knee abduction angles with symmetrical forces and motions between limbs) when performing high-intensity plyometric exercises.

In this stage, we recommend that the strength and conditioning specialist incorporate power, cutting, and change of direction tasks related to the athlete's sport (60,62). We suggest emphasis of the performance of power movements equally well in both directions, with sufficient hip and knee flexion angles with decreased knee abduction (60,62). Extensive verbal and visual feedback should be utilized to help the athletes post ACL-R to develop safe biomechanics during power movements.

The final progression of the plyometric and movement training in Stage IV of return to sport training should utilize unanticipated cutting movements during training. Single-faceted sagittal plane training and conditioning protocols that do not incorporate cutting maneuvers will not provide similar levels of external valgus/varus or rotational loads that are seen during sport-related cutting maneuvers (50). Training programs that incorporate safe levels of valgus/varus stress may induce more "muscle dominant" neuromuscular adaptations

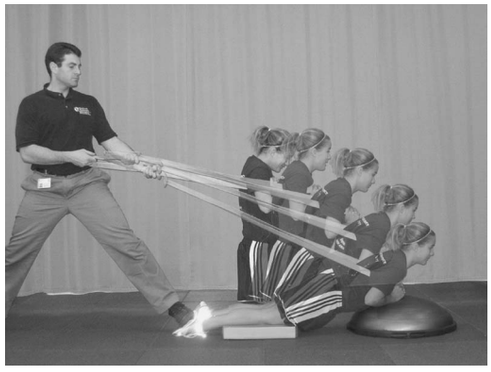

Figure 18. In this exercise, the strength and conditioning specialist anchors the athlete by standing on the arch of their feet and provides lift assistance with a strap that is wrapped around the chest. The athlete performs full eccentric and concentric movement with the assistance of the strength and conditioning specialist.

Figure 19. Examples of dynamic valgus positions that athletes post anterior cruciate ligament reconstruction (ACL-R) may demonstrate during agility and unanticipated cutting techniques. The strength and conditioning specialist should provide active feedback to the athlete to encourage them to perform reactive training with limited knee valgus positions.

(49). Such adaptations can better prepare an athlete for multidirectional sports activities that may improve performance and reduce risk of lower extremity injury (31,62). Female athletes perform cutting techniques with increased valgus angles (52). Valgus loads on the knee can double during unanticipated cutting maneuvers similar to those utilized in sport (4). By teaching the athlete to use movement techniques that produce low knee abduction moments during movements that can produce high loads on the joint, they can ultimately reduce the risk of injury (4–6,31). Training that incorporates techniques to focus on unanticipated cuts reduces knee joints loads (62). In addition, by improving reaction times to provide more time to voluntarily precontract muscles and make appropriate kinematic adjustments, ACL loads may be reduced (4,69). Figure 19 presents an athlete who demonstrates excessive dynamic knee valgus positions during agility and unanticipated cutting drills. Extensive verbal and potentially visual feedback (via video tape) is utilized to help the athletes post ACL-R to correct unsafe biomechanics during these movements.

Before teaching unanticipated cutting, athletes should first be able to attain proper athletic position (Figure 10). The athletic position is a functionally stable position with the knees comfortably flexed, shoulders back, eyes up, feet approximately shoulder-width apart, and the body mass balanced over the balls of the feet. The knees should be over the balls of the feet and chest should be over the knees (60,62). The athletic "ready position" should be the starting and finishing position for several of the training exercises. Further, this is the goal position before initiation of a directional cut. Addition of directional cues to the unanticipated training can be as simple as the strength and conditioning specialist pointing out a direction or as sports-specific as using partner mimic or ball

Figure 20. Example of athlete after anterior cruciate ligament reconstruction (ACL-R) demonstrating the tuck jump with staggered foot placement during landing. The strength and conditioning specialist should start the athlete in the desired foot position and encourage them to land in the same footprint.

Figure 21. Example of athlete post anterior cruciate ligament reconstruction (ACL-R) performing the tuck jump with staggered limb alignment during flight. The strength and conditioning specialist should encourage the athlete to achieve symmetrical thigh placement at the top of the jump to decrease this symmetry deficit.

retrieval drills. In addition to the development of safe biomechanics during unanticipated cutting, athletes should work to master techniques during high-intensity plyometrics. During the tuck jump (Figure 9), athletes post ACL-R often unload their involved side, as is visually evidenced by uneven foot placement (Figure 20) and asymmetrical limb alignment during flight of jumping (Figure 21). The strength and conditioning specialist should provide real-time feedback to encourage the athlete to equalize lower extremity biomechanics. Focused effort to improve jumping and landing symmetry may alleviate deficits demonstrated by athletes up to 2 years after ACL-R (75). Training the athlete to employ safe cutting and landing techniques in sports-related situations may help to instill technique adaptations that more readily transfer onto the field of play. The "ligament-dominant" and "leg dominant" athlete may become muscle-dominant and symmetrical if the desired training adaptations are achieved, thus ultimately reducing their risk factors of future ACL injury (31,60,62).

At this stage, it may become difficult to keep the athlete motivated to train for return to sport. The increased function attained may increase the athlete's desire to get back into game situations and cause him or her to sacrifice late-stage return to sport training sessions for competitive play. Offering more performance-oriented training may influence the athletes after ACL-R, especially the high-risk female athlete, to maintain the return to sport training.

Neuromuscular training programs for young women can improve performance measures of speed, strength, and power (41,42,62,92). Female athletes may especially benefit from neuromuscular training, as they often display decreased baseline levels of strength and power compared with their male counterparts (35,51). Dynamic neuromuscular training also reduces gender-related differences in force absorption, active joint stabilization, muscle imbalance, and functional biomechanics and increases strength of structural tissues (bones, ligaments, and tendons) (22,25,35,62,63,78). These ancillary effects of neuromuscular training, which likely reduce the risk of injury in female athletes, are positive results of training; however, without the performance-enhancement training effects, athletes may not be motivated to undertake neuromuscular training. Training that is oriented toward the reduction of lower extremity injuries, even in elite female athletes, may have compliance rates as low as 28% (66). However, training targeted toward the improvement of performance measures can have better compliance (80–90%) (3,29,41,42,92). In addition, "high-risk" athletes may be more responsive to neuromuscular training effects if the training protocols are targeted to address ACL injury risk factors (59). Therefore, if the protocol is designed to focus on safe performance-enhancement techniques during late-stage return to sport training and incorporates proven ACL injury prevention exercises, combined performance and reinjury preventative training may be instituted with high compliance in ACL-R athletes.

Stage IV: Criteria for Progression

Successful completion of Stage IV and ultimate clearance for integration back into sporting activities is dependent on the athlete's ability to achieve the following criteria related to sport-specific movements (Figure 1) (64):

1. Drop vertical jump landing force bilateral symmetry (within 15%).
2. Modified Agility T-test (MAT) test time (within 10%).
3. Single-limb average peak power test for 10 seconds (bilateral symmetry within 15%).
4. Re-assessment of tuck jump (20 percentage points of improvement from initial test score or perfect 80-point score).

Return to Sport

Once athletes meet the Stage IV criteria, they should be prepared to begin reintegration into their respective sport. However, we do not suggest that this is the time for unrestricted full participation in competitive events. Rather, it is suggested that athletes resume practice activities and begin to prepare themselves for competitive play. Return to sport after ACL-R can be a high-risk period for athletes because of both the risk of graft failure and the increased risk of injury to the contralateral limb, which may be higher than the involved side (30,81). Re-injury to either the contralateral or ipsilateral knee may reach as high as 20% in young athletes who return to competitive activities (80). However, athletes who attain sports performance symmetry in both limbs before sports reintegration after ACL reconstruction may significantly reduce their potential for future ACL injury (31,82). Successful execution of the suggested criteria of return to sport training may more objectively determine an athlete's readiness to return safely to sports participation. Systematic progression through these objective testing protocols may provide the athlete with both increased neuromuscular control and increased confidence, both of which will facilitate successful and safe return to sports after ACL injury (10,45).

Conclusion

Late-stage rehabilitation and return to sport training after ACL reconstruction without criteria-based guidelines may allow for deficits in lower extremity neuromuscular control, strength, and ground reaction force attenuation and production to persist beyond rehabilitation stages (2,14,16,32,39,68,75). These deficits may continue into competitive play and increase the risk of reinjury or limit the achievement of optimal performance levels. The developed protocol has the potential to target post-surgical deficits and address them through systematic progression during the stages of the return to sport training. Ultimately, this approach may translate into successful return to sports; however, long-term outcome studies are necessary to validate the described criteria-based progression and to confirm the relationship between achieving targeted goals to successful outcomes after the athlete returns to sport.

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Appendix

Phase I Dynamic Stabilization and CORE Strengthening

Stage I dynamic stabilization and CORE strengthening session 1	Time (s)	Reps	Sets
Jogging gait retraining (treadmill @ 7 mph 5% grade)	20		2
Deep hold position	5	5	1
Box butt touch squat		8	1
Line jump (forward)-deep hold	5	8	1
Line jump (lateral)-deep hold	5	4	R and L
Single-leg Airex balance (knee slightly flexed)	10	4	R and L
Single-leg squat-hold	5	6	R and L
BOSU (flat)-deep hold	5	8	1
Single-leg dumbbell bend over dead lift (focus on balance)		12	R and L
Walking lunges		16 steps	2
BOSU (round) bilateral knee balance	20		2
BOSU (round) crunches		25	2
BOSU (round) swivel crunch (feet planted)		40	1
BOSU (round) double leg pelvic bridges		12	1
BOSU (round) supermans		15	1
Running mechanics (treadmill @ 8 mph 10% grade)	15		3
Running mechanics (treadmill @ 9 mph 10% grade)	15		3

Phase I Dynamic Stabilization and CORE Strengthening

Stage I dynamic stabilization and CORE strengthening session 2	Time (s)	Reps	Sets
Jogging gait retraining (treadmill @ 7 mph 5% grade)	20		2
BOSU (flat) deep hold partner perturbations	20		3
BOSU (flat) drop off-deep hold	5	8	1
BOSU (flat)-rapid squat-deep hold	5	8	1
BOSU (flat)-athletic position-partner ball toss	20		3
BOSU (round) single-leg step-hold	5	6	R and L
Single-leg Airex step (front/back)-hold	5	4	R and L
Single-leg Airex step (side/side)-hold	5	4	R and L
BOSU (round) single knee-hold	20		R and L
BOSU (flat) single straight leg bend-over		10	R and L
Lateral stepping w/band resistance		20 steps	R and L
Wall aquats w/Swiss ball		12	2
BOSU (round)-reverse crunches		25	2
BOSU (round)-swivel ball touches (feet up)		40	1
BOSU (round)-trunk extensions		12	1
Running mechanics (treadmill @ 8 mph 10% grade)	15		3
Running mechanics (treadmill @ 9 mph 10% grade)	15		3

Phase II Functional Strength

Stage II functional strength session 1	Time (s)	Reps	Sets
Jogging gait retraining (treadmill @ 7 mph 0% grade)	20		2
Box drop off-deep hold	5	10	1
BOSU (round) jump up-deep hold	5	10	1
BOSU (flat) single-leg squat-hold	5	6	R and L
12-in box lateral step down (heel touch)		12	R and L
Split squats		10	2
BOSU (round) single-leg step-hold	5	6	R and L
Double leg bend over dead lift		10	2
Sumo squat dumbbell pick-up		10	2
Resisted lateral shuffling		6 passes	R and L
Table double crunch		15	2
Table double swivel crunch		8	R and L
Prone table manual resisted hip extension		12	2
BOSU (round) swimmers		10	R and L
BOSU (round) single-leg pelvic bridges		12	R and L
Resistive band running (heavy resistance)	15		4
Resistive band running (light resistance)	10		4

Phase II Functional Strength

Stage II functional strength session 2	Time (s)	Reps	Sets
Jogging gait retraining (treadmill @ 7 mph 0% grade)	20		2
BOSU (round) jump up-deep hold	5	10	1
Single-leg Airex hop (front/back)-hold	5	6	R and L
Single-leg Airex hop (side/side)-hold	5	6	R and L
Double BOSU (flat) rapid squats-deep hold	3	12	1
Single-leg X hop		3	R and L
12-in box Airex lateral step down (heel touch)		10	R and L
Split squats		10	2
Supine Swiss ball hamstring curl		10	2
Lateral lunges		15 steps	R and L
BOSU (flat) single-leg balance-hold	10	6	R and L
Table double crunch		15	2
Table double swivel crunch		8	R and L
BOSU (round) lateral crunch		10	R and L
BOSU (round) toe touch swimmers		10	R and L
Retrograde training (treadmill @ 3–4 mph 10% grade)	20		3
Retrograde training (treadmill @ 4–5 mph 5% grade)	12		3

Phase III Power Development

Stage III power development session 1	Time (s)	Reps	Sets
Jogging gait retraining (treadmill @ 8 mph 0% grade)	20		2
Wall jumps	15		2
Line jumps (side to side)-speed	10		1
Line jumps (front to back)-speed	10		1
Line jump-max vertical (four-way)		3	1
180° jumps (height)	10		2
BOSU (flat) drop off-single-leg-hold	5	5	R and L
BOSU (round) jump up-single-leg-hold	10	5	R and L
Single-leg X hop (reaction)		4	R and L
Barbell back squats		8	2
Assisted Russian hamstring curls		8	2
BOSU (round) butt balance (feet up) partner ball toss	25		2
BOSU (round) V-sit partner toe touch		10	2
Table lateral crunch		8	R and L
BOSU (round) toe touch swimmers partner perturbations		10	R and L
Bounding in place	15		2
Running mechanics (treadmill @ 8–10 mph 15% grade)	10		3

Phase III Power Development

Stage III power development session 2	Time (s)	Reps	Sets
Jogging gait retraining (treadmill @ 8 mph 0% grade)	20		2
BOSU (flat) drop off-75% max vertical		8	1
Tuck jumps	10		2
Broad jump, jump-deep hold	3	8	1
Broad jump, max vertical		6	1
Single-leg 90° hop-hold	3	8	R and L
Cross-over hop, hop, hop (distance)-athletic position	3	4	R and L
BOSU (round) single-leg (four-way) hop-hold	3	2	R and L
Dumbbell bent leg deadlift pick-up		8	2
Band good mornings		12	2
BOSU (flat) single-leg max depth squat (opposite leg extended forward)		8	R and L
BOSU (flat) single-leg hold (partner perturbations)	10	4	R and L
BOSU (round) double crunch		15	2
BOSU (round) opposite swivel crunch (feet up)		12	R and L
Swiss ball trunk extensions		12	1
Retrograde training (treadmill @ 4–6 mph 5% grade)	10		3
Retrograde training (treadmill @ 4–8 mph 0% grade)	12		3

Phase IV Sport-Performance Symmetry

Stage IV sport-performance symmetry session 1	Time (s)	Reps	Sets
Ground base warm-up (carioca, lateral shuffle, forward jog, backward jog)			4
Box drop off-athletic position		5	1
Wall jumps	15		2
Tuck jumps	10		2
Lunge jump	10		R and L
180° jump-broad jump	10		2
Power box steps		10	R and L
Bounding for distance		6	1
Box drop off-reaction		8	1
Broad jump max vertical-reaction step		6	1
Forward barrier jumps-reaction		6	1
Forward barrier jumps w/middle box-reaction		6	1
Box drop off-max vertical-reaction step		10	1
Assisted Russian hamstring curl		8	2
Partner-assisted single-leg box butt touch squats		8	R and L
Four corners drill		6	1
W-drill		6	1

Phase IV Sport-Performance Symmetry

Stage IV sport-performance symmetry session 2	Time (s)	Reps	Sets
Ground base warm-up (carioca, lateral shuffle, forward jog, backward jog)			4
Box drop off 180°-reaction		5	1
Wall jumps	10		2
Tuck jumps	8		2
Jump into bounding		6	1
Box drop off-max vertical		6	1
Box drop off-max broad jump-athletic position		6	1
Hop, hop, hop (distance)-hold	3	4	R and L
Cross-over hop, hop, hop (distance)-athletic position		5	R and L
Forward barrier hops w/staggered box-reaction		6	1
Lateral barrier hops w/staggered box-reaction		4	R and L
Box drop off-180°-box touch-max vertical-reaction		6	1
Lateral box drop off-max vertical		6	R and L
Assisted Russian hamstring curl		8	2
Dumbbell overhead squats		8	2
Wheel drill		6	1
V-drill		6	1

Glossary of Terms

- **12-In Box Airex Lateral Step Down (Heel Touch)**- (Figure 4) Athlete balances on one leg on a 12-in box with an Airex pad placed on top of the box. With the contralateral foot dorsiflexed, the involved knee is flexed until the contralateral heel makes contact with the surface of the floor, trying to keep the hips level, then the athlete ascends back up to starting position.
- **12-Inch Box Lateral Step Down (Heel Touch)**- (Figure 4) Athlete balances on one leg on a 12-in box. With the contralateral foot dorsiflexed, the involved knee is flexed until the contralateral heel makes contact with the surface of the floor, then the athlete ascends back up to starting position.
- **180° Jump-Broad Jump**- The jump is initiated by a direct vertical motion combined with a 180° rotation; once landed, a broad jump is immediately initiated to achieve maximal horizontal distance.
- **180° Jumps (Height)**- The jump is initiated by a direct vertical motion combined with a 180° rotation; once landed, the jump is initiated immediately to the opposite direction.
- **Airex**- 2-in foam balance pad. (Perform Better Inc, Cranston, R.I.)
- **Assisted Russian Hamstring Curls**- (Figure 18) The athlete begins in a kneeling position with a partner providing foot support and torso support (with band assistance). The athlete extends at the knee while maintaining a neutral spine. The strength and conditioning specialist should provide enough assistance so that the exercise can be performed without flexing at the hip.
- **Athletic Position**- (Figure 10) The athletic position is a functionally stable position with the knees comfortably flexed, shoulders back, eyes up, feet approximately shoulder-width apart, the body mass balanced over the balls of the feet. The chest should be aligned over the knees, which are over the balls of the feet. This is the athlete ready position and should be the starting and finishing position for most of the training exercises. During some of the exercises, the finishing position is over-exaggerated with deeper knee flexion to emphasize the correction of certain biomechanical deficiencies.
- **Band**- Resistive tubing, heavy Theraband or Jump Stretch band (Jump Stretch Inc, Youngstown, Oh.).
- **Band Good Mornings**- (Figure 17) Athlete positions the resistive band below the seventh cervical vertebrae and stands with both knees slightly flexed and feet on band. The movement is initiated with the trunk flexed to approximately 90°. A neutral spine should be maintained as the athlete extends the trunk from 90° to 0° (an erect posture).
- **BOSU**- Double-sided balance device (Team BOSU, Canton, Oh.).
- **BOSU (Flat)**- Flat side of domed balance apparatus is turned upward.
- **BOSU (Flat) Deep Hold Partner Perturbations**- (Figure 3) Athlete balances in deep hold position while standing on flat surface of a BOSU while the clinician perturbs the BOSU or the torso of the athlete.
- **BOSU (Flat) Drop Off-75% Max Vertical**- The athlete begins standing on the flat side of the BOSU in athletic position, then drops off the BOSU simultaneously with both feet and, on landing on the ground, performs a vertical jump with 75% of maximal effort.
- **BOSU (Flat) Drop Off-Deep Hold**- The athlete begins standing on the flat side of the BOSU in athletic position, then drops off the BOSU simultaneously with both feet and upon landing on the ground, the athlete immediately assumes the deep hold position.
- **BOSU (Flat) Drop Off-Single-Leg-Hold**- The athlete begins standing on one leg on the flat side of the BOSU, then drops off the BOSU and lands on the same leg with knee flexed.
- **BOSU (Flat) Single-Leg Balance-Hold**- The athlete assumes a single-leg stance on the flat side of the BOSU with knee and hip flexed and attempts to maintain this position for the duration of the exercise.
- **BOSU (Flat) Single-Leg Hold (Partner Perturbations)**- The athlete assumes a single-leg stance on the flat side of the BOSU with knee and hip flexed and attempts to maintain this position for the duration of the exercise while a partner or trainer perturbs the BOSU.
- **BOSU (Flat) Single-Leg Max Depth Squat (Opposite Leg Extended Forward)**- The athlete assumes a single-leg stance on the flat side of the BOSU with knee and hip flexed as much as possible within the limits of control and attempts to maintain this position for the duration of the exercise. Opposite leg is extended forward during the exercise.
- **BOSU (Flat) Single-Leg Squat-Hold**- The athlete assumes a single-leg stance on the flat side of the BOSU and attempts to squat to a position with the knee flexed to 90° and torso erect, then return to the original position.
- **BOSU (Flat) Single Straight Leg Bend- Over**- (Figure 5) Balancing on one leg on the flat side of the BOSU with knee slightly flexed and maintaining neutral spine, the athlete flexes the trunk to 90° reaching for the front of the BOSU.
- **BOSU (Flat)**- Athletic Position-Partner Ball Toss- The athlete begins standing with both feet on the flat side of the BOSU in athletic position, and a ball is tossed between the athlete and partner or trainer. When tossing the ball to the athlete, attempt to place it in positions that will perturb their center of mass.
- **BOSU (Flat)-Deep Hold**- The athlete assumes the deep hold position while standing on the flat side of the BOSU.
- **BOSU (Flat)**- Rapid Squat-Deep Hold- The athlete rapidly descends into a parallel squat position with feet shoulder width apart on the flat side of the BOSU.

● **BOSU (Round)**- Round side of domed balance apparatus is turned upward.

● **BOSU (Round) Bilateral Kneel**- The athlete begins this exercise by balancing in a kneeling position with knees shoulder width apart in the middle of the round side of the BOSU. The athlete will maintain this balanced position with the hips slightly flexed for the duration of the exercise.

● **BOSU (Round) Butt Balance (Feet Up) Partner Ball Toss**- Athlete begins sitting on the round side of the BOSU in a balanced position (Figure 15) with feet held in the air. A trainer or partner provides perturbations by tossing a ball back and forth with the athlete.

● **BOSU (Round) Crunches**- Athlete begins sitting on the round side of the BOSU in a balanced manner with the feet planted on the ground. The exercise is performed by extending the spine in such a way that the athlete allows their back to touch the ground, followed by flexing their spine to allow their elbows to touch their knees.

● **BOSU (Round) Double Crunch**- Athlete starts by sitting balanced on the round side of the BOSU, then flexes their trunk simultaneous with hip flexion.

● **BOSU (Round) Double Leg Pelvic Bridges**- The athlete lays supine with their hip and knees flexed and their feet planted on the round side of the BOSU. The athlete then extends their hips and elevates their trunk off the ground to execute a pelvic bridge. This position should be held for 3 seconds before the next repetition (see Figure 1 for single-leg pelvic bridge).

● **BOSU (Round) Jump up-Deep Hold**- The athlete starts on the ground and jumps onto the round side of the BOSU and lands in a deep hold position.

● **BOSU (Round) Jump up-Single-leg-Hold**- The athlete starts on single leg on the ground and jumps up onto round side of the BOSU and lands on that same leg with the knee flexed.

● **BOSU (Round) Lateral Crunch**- Athlete starts lying on side with hip located in the center of the round side of the BOSU. The athlete's feet and legs must be anchored during this exercise by the trainer or a stationary object. The athlete will proceed to bend laterally at the waist back and forth for the prescribed repetitions.

● **BOSU (Round) Opposite Swivel Crunch (Feet Up)**- Athlete begins sitting on the round side of the BOSU in a balanced position with the feet held in the air (similar to figure 15). Athlete begins exercise by twisting the trunk so that they can touch the ground with their hands. The movement is reversed and the athlete swivels their torso so that they can touch the ground on the other side of the body.

● **BOSU (Round) Single Knee-Hold**- The athlete begins this exercise by balancing in a kneeling position with one knee directly in the middle of the round side of the BOSU and the other knee extended out to the side. The athlete will maintain this balanced position with the hip slightly flexed for the duration of the exercise.

● **BOSU (Round) Single-leg (4-way) Hop-Hold**- The athlete starts in a single-leg athletic position immediately behind the BOSU. The athlete hops forward onto the round side of the BOSU and lands in a balanced position. After achieving a balanced single-leg stance on the BOSU, the athlete proceeds to hop off the BOSU laterally and assumes this same stance on the floor immediately next to the BOSU. The athlete will then continue to hop on and off the BOSU, achieving a balanced athletic position, in each of the four directions: forward, backward, lateral, and medial.

● **BOSU (Round) Single-leg Pelvic Bridges**- (Figure 5) The athlete lays supine with their hip and knees flexed and a single foot planted on the round side of the BOSU and the contralateral leg fully extended. The athlete then extends their hips and elevates their trunk off the ground to execute a pelvic bridge. This position should be held for 3 seconds before the next repetition.

● **BOSU (Round) Single-leg Step-Hold**- The athlete starts off of BOSU in athletic position. The movement begins with the athlete stepping onto the round side of the BOSU and continuing to balance with knee flexed to approximately 90°.

● **BOSU (Round) Supermans**- The athlete begins in prone position with their arms overhead and legs extended and abdomen centered on the round side of the BOSU. The movement is initiated by extending the hip and trunk while maintaining shoulders in flexed position. Hold the position for 3 seconds and repeat.

● **BOSU (Round) Swimmers**- The athlete begins in prone position with abdomen centered on the round side of the BOSU and with their arms overhead and legs extended. The movement is initiated by elevating the opposite arm and leg and held for 3 seconds.

● **BOSU (Round) Swivel Crunch (Feet Planted)**- Athlete starts out balancing supine on the round side of the BOSU with lower back/butt centered on the BOSU. The athlete rotates at the spine as they flex the trunk for the crunch.

● **BOSU (Round) Toe Touch Swimmers**- The athlete begins in a prone position with their abdomen centered on the round side of the BOSU and their arms overhead and legs extended. The athlete reaches back with one arm to touch opposite foot and returns to the outstretched superman position.

● **BOSU (Round) Toe Touch Swimmers Partner Perturbations**- The athlete begins in a prone position with their abdomen centered on the round side of the BOSU and their arms overhead and legs extended. The strength and conditioning specialist should perturb the BOSU while the athlete reaches back with arm to touch opposite foot while performing swimmer technique.

● **BOSU (Round) V-Sit Partner Toe Touch**- Athlete starts out on the round side of the BOSU with lower back/butt centered on the BOSU, leaning their shoulders

back on the floor and their arms reaching overhead. With their feet extended upward at a 45° angle, the partner holds their feet and gives support while the athlete crunches forward, reaching to touch their toes.

● **BOSU (Round)-Reverse Crunches**- Athlete starts out balancing supine on the BOSU with lower back/butt centered on the BOSU. The athlete flexes the hip while attempting to maintain a balanced position on the BOSU.

● **BOSU (Round)-Swivel Ball Touches (Feet up)**- Athlete starts by sitting balanced on the round side of the BOSU with feet up and with the athlete leaning slightly back. The athlete rotates at the spine as they flex the trunk for the crunch.

● **BOSU (Round)-Trunk Extensions**- The athlete begins in a prone position on the round side of the BOSU and performs the exercise by extending the upper torso.

● **Bounding**- (Figure 13) Athlete jumps horizontally off one foot, landing on the other. Once proper rhythm is attained, the vertical component of the bound should be maximized.

● **Box Butt Touch**- A box is placed behind the athlete and the athlete starts with feet shoulder width apart and performs a squat down to the height of the box, softly touches the box without resting, then ascends up to initial starting position.

● **Box Drop Off 180°-Reaction**- Athlete drops off the box performs a 180° jump and lands in an athletic position and follows with a lateral reaction to a cue, such as the strength and conditioning specialist pointing out a random cut direction, using defender reaction cut or ball retrieval drills.

● **Box Drop Off-180°-Box Touch-Max Vertical-Reaction**- Athlete drops off the box performs a 180° jump, then jumps back up on the box and immediately drops down forward off the box, performs a maximal vertical jump, lands in an athletic position, and follows with a reaction to a cue such as the rehabilitation specialist pointing out a random cut direction, using defender reaction cut, or ball retrieval drills.

● **Box Drop Off-Athletic Position**- Athlete drops down from a box landing with both feet simultaneously in the athletic position (Figure 10).

● **Box Drop Off-Deep Hold**- Athlete drops down from a box landing with both feet simultaneously in the deep hold position (ending position of Figure 11).

● **Box Drop Off-Max Broad Jump**- Athletic Position-Athlete drops down from a box landing with both feet simultaneously and immediately jumping horizontally to achieve maximal horizontal distance. The athlete should stick the landing in athletic position.

● **Box Drop Off-Max Vertical**- Athlete drops down from a box landing with both feet simultaneously in the athletic position and immediately performs a maximal vertical jump and lands in an athletic position.

● **Box Drop Off-Max Vertical-Reaction Step**- Athlete drops down from a box, landing with both feet simultaneously in the athletic position. Immediately after landing, the athlete performs a max vertical jump, lands in an athletic position, and reacts to the strength and conditioning specialist's directional cue with a submaximal effort cut. Focus is on the desired technical performance and not speed of movement.

● **Box Drop Off-Reaction**- Athlete drops off lands in an athletic position and follows with a reaction to a cue, such as the strength and conditioning specialist pointing out a random cut direction, using defender reaction cut, or ball retrieval drills.

● **Broad Jump Max Vertical-Reaction Step**- The jump is initiated horizontally to achieve maximal horizontal distance. Immediately after landing the athlete performs a maximal vertical jump (Figure 12), lands in an athletic position, and reacts to the strength and conditioning specialist's directional cue with a submaximal effort cut. Focus is on the desired technical performance, not speed of movement.

● **Broad Jump, Jump-Deep Hold**- (Figure 12) The athlete prepares for this jump in the athletic position with their arms fully extended behind their back at the shoulder. The athlete begins by swinging their arms forward and jumping horizontally to achieve maximum horizontal distance. The athlete must stick the landing with their knees flexed to approximately 90° in an over-exaggerated athletic position. The athlete may not be able to stick the landing during a maximal effort jump in the early phases. In this situation, have the athlete perform a submaximal broad jump in which they can stick the landing with their toes straight ahead and no inward motion of the knees. As their technique improves, encourage them to add distance to their jumps, but not at the expense of technique perfection.

● **Broad Jump, Max Vertical**- The athlete performs a broad jump and immediately progresses into a maximum effort vertical jump and lands in athletic position. When teaching this jump, the athlete may have a tendency to "float" in a horizontal direction during the vertical jump; encourage the athlete to quickly transfer from the broad to vertical jump.

● **Cross-over Hop, Hop, Hop (Distance)-Athletic Position**- The starting position for this jump is with the athlete in a semi-crouched position on the single limb being trained. The arms should be fully extended behind the athlete at the shoulder. The athlete initiates the hop by swinging the arms forward while simultaneously extending at the hip and knee. The hop should carry the athlete up at a 45° angle laterally toward the opposite leg and should be for maximal distance. They land on the leg opposite of the initial stance leg. Once the athlete lands, they immediately hop in a 45° angle laterally toward the other leg. This is repeated for one hop with the exception that the final landing is on two feet and the athlete maintains the athletic position.

● **Deep Hold Position**- Athlete squats with feet shoulder width apart and holds a position with the knees flexed to 90° and torso erect.

● **Double BOSU (Flat) Rapid Squats Deep Hold**- The athlete places each foot on the flat side of separate BOSUs. The athlete then rapidly descends into a parallel squat position with feet shoulder width apart, then ascends slowly back to the start position.

● **Double Leg Stretch Bend over Dead Lift**- With knees slightly flexed and neutral spine, the athlete flexes the trunk to 90°. The weight is held in front of the shins and targeted to the shoe tops.

● **Dumbbell Bent Leg Dead Lift Pick-up**- (Figure 6) The athlete starts in a stance that has their feet twice shoulder width apart. They descend in squat position to pick up the dumbbell. They secure the dumbbell in an alternated grip and ascend upward.

● **Dumbbell Overhead Squats**- Athlete holds dumbbells overhead and squats to 90° knee flexion while maintaining the dumbbells in the overhead position.

● **Four Corners Drill**- Four cones are lined up in a shape of a square approximately 5 yards apart in each direction. Athlete performs basic pattern of sprint to first cone, lateral slide to second cone, backward sprint to the third cone, and lateral slide to first cone.

● **Ground Base Warm-up (Carioca, Lateral Shuffle, Forward Jog, Backward Jog)- Hold**- Knee flexed to greater than 60° in single-leg stance and flexed to greater than 90° in bipedal stances. Athlete must stabilize their center of mass and maintain postural stability during the specific agility activity, for the prescribed durations.

● **Hop**- Single-leg jump Hop, Hop, Hop (Distance)-Hold- Athlete performs three single-leg hops for distance with no pause between jumps and performs a hold at the end.

● **Jump**- Double leg jump with feet shoulder width apart.

● **Jump into Bounding**- The athlete begins by doing a single maximal effort broad jump. Once they land on a single leg, they should immediately begin the bound exercise. The bounding should emphasize achieving vertical height with minimal horizontal distance. Coach the athlete to drive the non–weight-bearing leg forward and vertically to help to achieve the maximal vertical height. Do not allow the athlete to perform an exaggerated stride out jog (Figure 13).

● **Lateral Box Drop Off-Max Vertical**- The athlete starts with both legs on a box (12 in or less) and drop of the box laterally with both legs simultaneously and lands with both feet shoulder width apart and immediately performs a maximal vertical jump and lands in athletic position.

● **Lateral Lunges**- The athlete starts standing shoulder width apart. The athlete lunges with one foot out at 45° angle and returns to the starting position.

● **Line Jumps (Side to Side)-Speed**- The athlete prepares for this exercise by standing with their feet close together and their knees slightly bent on one side of the line. The athlete should jump sideways over the line keeping their knees bent and staying close to the line. When the athlete lands on the opposite side, they should immediately redirect back to the initial position. Repeat this sequence as quickly as the athlete can while maintaining proper form. When teaching this exercise, encourage the athlete to achieve as many repetitions as possible in the allotted time by jumping close to the lines, shortening the ground contact time, and not using excessive height on the jumps. Do not allow the athlete to perform a double hop on the side of the line. Early in the training, the athlete may focus on the line, but as their technique improves, encourage them to shift their visual focus away from the line to outside cues.

● **Line Jumps (Front to Back)-Speed**- The athlete prepares for this exercise by standing with their feet close together and their knees slightly bent on behind the line. The athlete should jump forward over the line, keeping their knees bent and staying close to the line. When they land on the opposite side, they should immediately redirect back to the initial position. Repeat this sequence as quickly as the athlete can while maintaining proper form. Teach this jump by having the athlete keep their eyes up as much as possible. Looking down at the line will cause them to lean too far forward on the forward jump, making it difficult for them to redirect backward. The athlete can improve speed and efficiency of this jump by learning to maintain core center of gravity control and by preparing to change direction in mid-flight. Encourage the athlete to jump directly over the line and not around the sides.

● **Lunge Jump**- The athlete starts in an extended stride position with the hips pushed forward, and the front knee positioned directly above the ankle and flexed to 90°. The back leg is fully extended at the hip and knee, providing minimal support for the stance. The athlete should jump vertically off of the front support leg maintaining the starting position during flight and landing. The jump is repeated as quickly as possible while still achieving maximal vertical height. To coach this jump, encourage the athlete to keep the back leg straight and use it only for balance support. Vertical power is obtained by the front leg. Stance support percentages are 90% for the front leg and 10% for the back.

● **Max**- The athlete gives maximal effort.

● **Partner Assisted Single-leg Box Butt Touch Squats**- A box is placed behind the athlete and a band (held by a partner) is provided for them to hold onto to assist them with the exercise. The athlete starts on a single leg, performs a squat down to the height of the box, softly touches the box without resting, then ascends up to initial starting position.

● **Power Box Steps**- The athlete stands with the ball of one foot on top of the 6- to 12-in box. The athlete performs a maximal effort vertical hop up and off of the box using the foot that was placed on the box and landing on both feet in the athletic position.

● **Prone Table Manual Resisted Hip Extension**- The athlete begins in a prone position with their pelvis and lower extremity stabilized on the table and their trunk flexed forward off the edge of the table with their hands on the floor

in front of them. The movement is initiated by extending hip and trunk to a neutral position while maintaining shoulders in overhead position. Hold the position for 3 seconds and repeat.

- **Reaction-** The athlete reacts to a cue, such as the strength and conditioning specialist pointing out a random cut direction, using defender reaction cut, or ball retrieval drills.
- **Reaction Step-** The athlete reacts to the strength and conditioning specialist's directional cue with a submaximal effort cut. Focus is on the desired technical performance and not speed of movement.
- **Resisted Lateral Shuffling-** The athlete begins in athletic position with a resistive Theraband anchored to their ankles. They are instructed to maintain the athletic position and shuffle in the prescribed direction. The strength and conditioning specialist can have the athlete move quickly during exercise or can use increased resistance and have the athlete move more slowly and more directed to focus on improved strength.
- **Single-** leg Airex Balance (Knee Slightly Flexed)- Athlete balances on a single leg with the knee slightly flexed and attempts to maintain postural stability for the duration of the exercise.
- **Single-leg Airex Hop (Front/Back)-Hold-** Athlete starts behind the Airex pad and hops up onto the Airex. The athlete should maintain balance and hold the knee in a flexed position. The athlete then hops forward off the Airex, maintains balance with the knee in a flexed position, then hops backward onto the Airex pad. After regaining balance and holding the knee in a flexed position, the athlete hops backward off the Airex onto the ground and maintains balance in a flexed knee position.
- **Single-leg Airex Hop (Side/Side)-Hold-** Athlete starts on one side of the Airex pad and hops laterally onto the Airex. The athlete should maintain balance and hold the knee in a flexed position. The athlete then hops off the other side of the Airex onto the ground, maintains balance, and repeats the exercise in the other direction.
- **Single-leg Dumbbell Bend over Dead Lift (Focus on Balance)-** Balancing on one leg with knee slightly flexed and maintaining neutral spine, the athlete flexes the trunk to 90°. The weight is held in front of the athlete's shins and targeted to their shoe top as they descend during the exercise.
- **Single-leg Hop-Hold-** (Figure 14) The starting position for this jump is with the athlete in a semi-crouched position on the single limb being trained. The arms should be fully extended behind the athlete at the shoulder. The athlete initiates the jump by swinging the arms forward while simultaneously extending at the hip and knee. The jump should carry the athlete up at a 45° angle and provide the maximal distance they can handle while maintaining an upright stance on the single landing. The landing is on the jumping leg and occurs with deep knee flexion (to 90°). The landing should be held for a minimum of 3 seconds to be counted as a successful landing. Coach this jump with care to protect the athlete from injury. Start the athlete with a submaximal effort on the single-leg broad jump so they can experience the difficulty of the jump. Continue to increase the distance of the broad jump as the athlete improves their ability to stick and hold the final landing. Have the athlete keep their focus away from their feet, to help to prevent too much forward lean.
- **Single-leg Squat-Hold-** Athlete squats on single leg attempting to achieve 90° or more of knee flexion.
- **Single-leg X Hop-** The athlete begins facing a quadrant pattern standing on a single limb with their support knee slightly bent. They will hop diagonally, landing in the opposite quadrant, maintaining forward stance, and holding the deep knee flexion landing for 3 seconds. The athlete then hops laterally into the side quadrant again holding the landing. Next the athlete will hop diagonally backward holding the landing. Finally, they hop laterally into the initial quadrant holding the landing. Athletes should repeat this figure eight pattern for the required number of sets. Encourage the athlete to maintain balance during each landing, keeping their eyes up and focus away from their feet.
- **Single-leg X Hop (Reaction)-** Athlete performs the single-leg X hop as described above with the exception that each landing must be held until the athlete receives an unanticipated cue from the strength and conditioning specialist to hop to the next quadrant.
- **Split Squats-** The athlete starts in lunge stance with full support on the front limb with the opposite limb resting on a box behind them. The athlete then squats to 90° of knee flexion on their front limb. Encourage the athlete to lunge their front limb far enough out so that their knee does not cross over their ankle when performing the squat exercise.
- **Sumo Squat Dumbbell Pick-up-** (Figure 6) Stance is wide (approximately double shoulder width) so that weight can be lifted between the legs. The athlete should focus on maintenance of an upright posture with minimized trunk flexion when they descend to pick up the dumbbell. Once they reach the dumbbell, they should grasp it an alternated grip and ascend back to the start position.
- **Supine Swiss Ball Hamstring Curl-** Athlete begins lying in a supine position with shoulders and back on the floor, with hips flexed and both feet on top of the Swiss ball. The athlete then extends at the hip and flexes at the knee attempting to pull the heels to the buttocks.
- **Swiss Ball Bilateral Kneel-** Athlete kneels and balances on Swiss ball with feet off the ground. A spotter should be available at all times in front of the athlete.
- **Swiss Ball Hip Extensions-** The athlete begins in a prone position on the Swiss ball with their hands and elbows on the floor in front of them. The movement is initiated by extending both hips while maintaining shoulders in flexed position. Hold the torso and lower extremity in the overhead position for 3 seconds and repeat.

● **Table Double Crunch-** Athlete starts out supine on a table and flexes trunk simultaneous with hip flexion.

● **Table Double Swivel Crunch-** Athlete starts in a supine position on a table with arms placed on the back of the head. The athlete flexes their trunk simultaneous with hip flexion as the trunk and hip are maximally flexed the athlete rotates at the trunk touching each elbow to the opposite knee.

● **Table Lateral Crunch-** (Figure 16) Athlete starts lying on side with hip located at the edge of the table. The athlete's feet and legs must be anchored during this exercise by the trainer or a stationary object. The athlete will proceed to flex and extend laterally at the waist for the prescribed repetitions.

● **Tuck Jumps-** (Figure 9) The athlete starts in the athletic position with their feet shoulder width apart. The athlete initiates a vertical jump with a slight crouch downward while they extend their arms behind them. The athlete then swings their arms forward as they simultaneously jump straight up and pull their knees up as high as possible. At the highest point of the jump, the athlete should be positioned in the air with their thighs parallel to the ground. When landing, the athlete should immediately begin the next tuck jump. Encourage the athlete to land softly, using a toe to mid-foot rocker landing. The athlete should not continue this jump if they cannot control the high landing force or keep there knees aligned landing.

● **V-Drill-** The athlete starts at the base of three cones that are set up in a "V" shape 5–8 yards apart. The pattern is initiated by sprinting to left cone, backpedaling back to the middle cone, then a turn 90°, followed by a sprint to the right cone, then backpedals to the starting position.

● **Walking Lunges-** The athlete performs a lunge and instead of returning to the start position, they step through with the back limb and proceed forward with a lunge on the opposite limb. Encourage the athlete to lunge their front limb far enough out so that their knee does not advance beyond their ankle during the exercise

● **Wall Jumps-** The athlete stands erect with their arms semi-extended overhead. The athlete then executes repeated quick vertical jumping while reaching upward. This vertical jump requires minimal knee flexion as gastrocnemius and soleus muscles should create the vertical height. The arms should extend fully at the top of the jump. Use this jump as a warm up and an important interactive coaching exercise, as this relatively low-intensity movement can reveal abnormal knee motion in athletes with poor side-to-side knee control.

● **Wall Squats w/Swiss Ball-** A squat exercise that is performed with the aid of a Swiss ball positioned between the back and a stable wall.

● **W-Drill-** The athlete starts at the left hand side of five cones that are positioned in the shape of a "W." The athlete first backpedals at a 45° angle to the next cone, turns and sprints to the next cone, repeating through the series of cones.

● **Wheel Drill-** The athlete stands next to a cone that is encircled by seven other cones that are 3–5 yards away. The athlete moves through the cones using a series of sprints, lateral slides, and backpedals. The athletes should keep their shoulders square to the starting position during the drill.