Improving Sprint Performance, Vertical Jump and Change of Direction in Soccer Players

by Dan Benton

Introduction

The game of soccer is often known for its physical demands of endurance fitness, where elite players will run anywhere between eight and twelve kilometers (km) per game (Ali, 1991; Bangsbo, 1991; Wisloff, 2004) and reach intensities close to their anaerobic threshold (Hoff, 2002; Arnason, 2004; Wisloff, 1998). Within an aerobic setting these athletes take part in intermittent bouts of high intensity movements including jumping, sprinting, kicking, tackling, turning, changing pace, and maintaining balance and control of the ball while under defensive pressure (Wisloff, 1998). Coaches and athletes often focus on technique and tactics in order to improve soccer performance at the expense of fitness and applied physiology (Wisloff, 1998). The ability to jump higher, sprint faster, and change directions quicker than an opponent can be the difference in winning and losing a soccer game. These types of physical attributes are crucial in the ability to play soccer at the higher levels (Wisloff, 2004; Casajus, 2001) so improving soccer players explosive power will prove to be useful in improving their performance.

While strength and power share importance with endurance in soccer (Wisloff, 1998), not much attention is given to improving the short explosive bursts of jumping, sprinting and changing direction (Siegler, 2003; Casajus, 2001). Conditioning during practice is often comprised of interval runs with rest periods (McMillan, 2005), which will help improve cardio fitness but will not improve explosive power. In addition, soccer is such a skillful sport that technique and tactics often take priority over fitness and strength training (Wisloff, 1998). However, soccer is also a physical sport, so training to sprint faster, jump higher, and change directions quicker should not be left out of a soccer team's weekly training regimen. While it should not be the top priority, strength and plyometric training should be of importance during a practice session because of the physical benefits that carry over into playing soccer. The vertical jump is a simple test that can indicate a player's explosive power (Sayers, 1999; Leard, 2007). The vertical jump test has been shown to be a valid measure of power output in athletes (Hamilton, 2008; Sayers 1999; Leard, 2007; Aragon-Vargas, 2000; Markovic, 2004; Johnson, 1996) and may also translate to sprint performance (Wisloff, 2004). Squat strength has also been positively correlated to vertical jump height (Wisloff, 2004; Hedrick, 1996).

Research has supported that power output can be improved through strength training and plyometrics (Christou, 2006; Kotzamanidis, 2005; Whitney, 2005; Wisloff, 2004, Perez-Gomez, 2008; Adams, 1992; Moore, 2005), but many youth soccer teams are limited in their access to a weight room as well as time for strength training. The purpose of this project is to design a strength and plyometric training program that any soccer team can do on a soccer field with limited equipment to improve leg strength, vertical jump, sprint performance and change of direction.

Literature Review

The physical demands for the game of soccer have been described by several as an aerobic sport with short intermittent bouts of high-intensity (Casajus, 2001). At the higher levels these short burst of energy need to be explosive, as they often come during crucial moments in the game (Seigler, 2003; Casajus, 2001; Wisloff, 1998). Jumping, sprinting, and changing direction are all explosive movements that require a combination of strength and speed, which can be defined as power output (Wisloff, 2004; Wisloff, 1998). Power output can be measured quite accurately using the vertical jump method (Hamilton, 2008; Sayers 1999; Leard, 2007; Aragon-Vargas, 2000; Markovic, 2004; Johnson, 1996), while a strong correlation has been found between vertical jump height and sprint performance (Wisloff, 2004). When strength training and plyometrics are used properly they can improve the vertical jump (Adams, 1992; Moore, 2005; Perez-Gomez, 2008). This can be beneficial to athletes and coaches who want to develop an explosive edge in the game of soccer.

Physiological Energy Demands of Soccer Players

The body has three main energy systems: The ATP-PCr system for immediate energy (0-30 seconds), the anaerobic system used for short-term energy (30-180 seconds), and the aerobic system used for long-term energy (>3 Minutes) (Baechle & Earle, 2000; McArdle, 2007). The ATP-PCr and anaerobic systems both use fast twitch Type II muscle fibers while the aerobic system uses slow twitch Type I fibers. The ATP-PCr is the main energy system used for power output in movements such as jumping and sprinting (Baechle & Earle, 2000; McArdle, 2007). Although it is known for its long periods of running, the game of soccer involves all three of these energy systems in some capacity (Casajus, 2001).

Soccer is a sport characterized by high intensity, short-term actions, with pauses of varying length in between each action (Ekblon, 1986; Bangsbo, 1994). During the game's two 45 minute bouts of play, athletes on all levels are involved in walking, jogging and sprinting (Ali, 1991), elite players cover a distance of anywhere between 8-12 km depending on their team role (Ali, 1991; Bangsbo, 1991; Wisloff, 2004). 90% of the energy released by elite soccer players is aerobic (Hoff, 2001; Casajus, 2001) with intermittent moments during the game where they reach intensities close to anaerobic threshold, 70-80% VO2 max, or 80-90% of maximal heart rate (Hoff, 2001; Bangsbo, 1994; McMillan, 2005; Wisloff, 1998). Traditional exercise protocols, especially at the youth levels, have focused on increasing aerobic endurance by using faster interval runs with slow jogging or rest periods (McMillan, 2005; Siegler, 2003). However, little attention has been given to the explosive, high intensity aspect which is so crucial in soccer (Siegler, 2003; Casajus, 2001).

While much of a soccer player's work rate is aerobic, Araz (1991) found that about 3% of the game is spent sprinting resulting in a distance covered of one mile (1.6 km). A sprint can occur about every 90 seconds, each lasting an average of two to four seconds (Reilly, 1976; Wisloff, 2004). This may not sound like much but these few seconds can be the most critical moments in a soccer game. Decisive actions such as sprinting or jumping are explosive movements that take just seconds to execute , which is why power output is so important (Casajus, 2001). In addition, elite soccer players perform about 50 turns (changes of direction), which requires sustained forceful contractions in order to maintain balance and control of the ball while under pressure from a defensive player (Wisloff, 2004). Change of direction (COD) has been reported to be the most important performance variable for predicting player selection in soccer (Gil, et al., 2007) and for distinguishing between elite and sub-elite soccer players (Reilly, et al., 2000; Brughelli, 2008). Vertical jump height has also been considered a relevant indicator of performance in soccer (Wisloff, 2004) and may also be a discriminating variable in male soccer players at different levels of competition (Arnason, 2004; Mujika, 2009). This means that maximal strength and power are equally important with endurance at the elite level (Wisloff, 2004).

Measuring Power Output

Muscle power output is defined as the ability of a muscle to exert high force while contracting at a high speed (Baechle & Earle, 2000). While jumping is an important movement in the game of soccer, the vertical jump test can be used to assess the lower body's maximal power output (Aragon-Vargas, 2000; Hamilton, 2008; Hedick, 1996; Johnson, 1996; Leard, 2007; Markovic, 2004; Sayers, 1999; Salaj, 2007; Umberger, 1998; Wisloff, 2004; Yamauchi, 2007). This test is one of the most common ways to measure maximal power output because it has been shown to be a valid (Aragon-Vargas, 2000; Johnson, 1996; Leard, 2007, Markovic, 2004) and reliable measure of maximal power output in athletes (Aragon-Vargas, 2000; Hamilton, 2008; Markovic, 2004). This information is important because most of the research uses vertical jump testing to measure improvements in power output related to strength training and plyometrics. Two common tests are the squat jump and countermovement jump. The squat jump (SJ) requires the participant to jump as high as possible starting from a squatting position without a counter movement. The countermovement jump (CMJ) allows the participant to use more natural countermovement before jumping in order to activate the stretch reflex in the muscles. This stretch reflex will be discussed in further detail later on. In addition, there is a relatively strong correlation between the vertical jump and sprint performance, which is not surprising considering they both derive from maximal strength (Wisloff, 2004).

Brughelli, Cronin, Levin and Chaouachi (2008) did a review of resistance training studies on agility and change of direction (COD), and they suggested that power would be better classified to the direction of force application. While the vertical jump is a measure of power output, horizontal or lateral jumping may translate better to sprinting and agility because the athlete is propelling the body forward or side to side instead of straight up. Brughelli et al. (2008) noticed that the studies with vertical jump training alone did not show any improvements in COD. Two plyometric studies which included unilateral and bilateral (one leg and two leg) vertical, horizontal (Malisoux et al. 2006) and lateral jumps (Miller et al. 2006) did, however, report significant improvements in COD. These two studies, which will be discussed later in further detail, suggest that unilateral and bilateral horizontal plyometrics are more beneficial toward improving agility and COD performance than vertical plyometrics alone.

Improving Power Output

There are two main training methods that are believed to help improve maximal anaerobic power. One training method is plyometrics which refers to movements that enable a muscle to reach maximal force in the shortest time possible. The purpose of this exercise is to increase power production through the elastic components of the muscle and tendons as well as neuromuscular response of the stretch reflex (Baechle & Earle, 2000; McArdle, 2007). The other training method is strength training, which involves resistance through a movement often provided by weights. The purpose of this exercise is to over load the muscles using resistance in order to strengthen the muscle and increase motor unit neural activation resulting in increased force production (Baechle & Earle, 2000). These two training methods will be discussed in further detail. While reaching near maximal loads using weights is ideal for strength training, this program will not include weights, so other methods have to be used to increase strength.

Plyometrics

Plyometric training is considered to bridge the gap between strength and speed in order to optimize power production (Adams, 1992). When used properly, plyometrics has consistently been shown to improve muscular force and power production (Chu, 1998; Baechle & Earle, 2000;; McArdle, 2007). Plyometric exercises are quick, powerful movements such as jumping that enable the muscle to contract as fast as possible with maximal force. This type of training helps develop the muscles ability to produce force at high speeds using a pattern of muscle contraction known as the stretch-shortening cycle (SSC) (Rimmer, 2000; Baechle & Earle, 2000; McArdle, 2007). The SSC involves an eccentric stretch of the muscle immediately followed by a more forceful concentric contraction resulting in an explosive movement (Chu, 1998; Rimmer, 2000; Baechle & Earle 2000; McArdle, 2007). This increased force production is mechanical and neuromuscular (Baechle & Earle, 2000). The mechanical aspect of plyometrics is called the series elastic component (SEC) which is provided mainly from the tendons and connective tissue of the muscle. This elastic energy is stored by the rapid stretch of the muscle tendons and then released when followed by an immediate contraction increasing total force production. The neuromuscular component involves an involuntary response to external stretches of the muscle activating the proprioceptive organs of the muscle called muscle spindles (Baechle & Earle, 2000; Bosco, 1982). This is known as the stretch reflex and is activated when the muscle spindles are externally stimulated by a stretch in the muscle which sends a signal to the spinal cord. The spinal cord then sends a signal back to the muscle causing a reflexive muscle contraction. Both the mechanical and neuromuscular actions are thought to contribute to the increased force production in the muscles during pylometric exercises (Baechle & Earle, 2000; Bosco, 1982).

The Biomechanics of the Jumping

Since plyometrics involve mostly jumping exercises, it is important to examine how the major leg muscles are used to produce lower body power and how they work together while performing a jumping movement. The vertical jump is predominantly a leg and hip driven movement. The most important muscles that are used for this action are the semitendinosus, semimembranosus and long head of the biceps femoris of the hamstring group, the rectus femoris of the quadriceps group, and the gastrocnemius of the calf (Umberger, 1998). The net joint movement of these muscles results in the take off phase of the vertical jump, beginning with the extension of the hip followed sequentially by extension of the knee and plantar flexion of the ankle. The importance of these muscles is that they cross two different joints, the hip and the knee and the knee and the ankle, which allow them to transfer mechanical energy exerting a greater force-velocity. About half of the total mechanical energy generated by the hip extensors is transferred distally through the rectus femoris and the gastrocnemius, these two muscle groups act like cables to help extend the knee and plantar flex the ankle. The action of the hamstrings is to extend the hips and flex the knee. The purpose of the rectus femoris is to flex the hip and extend the knee. The gastrocnemius performs the action of flexing the knee and plantar flexing the ankle. While these muscles appear to be counteracting each other, the combination of these actions results in greater force. During the take off phase of the jump, the extension of the hip by the hamstrings overpowers the attempted flexion of the hip by the rectus femoris. Because the rectus femoris is overpowered by the hamstrings at the hip, the energy is transferred distally to extend the knee. Similarly the attempted knee flexion of the gastrocnemius is overpowered by the extension of the knee by the rectus femoris, which results in a transfer of energy distally to plantar flex the ankle. Thi proximal-to-distal transfer of mechanical energy just describe, is thought to be critical to the optimal performance of the vertical jump (Umberger, 1998).

The Effects of Plyometrics on Soccer Players

Several studies on the effects of plyometrics on male and female soccer players of many ages have had beneficial results. Meylan and Malatest (2009) found improvements from an eight week plyometric training program in early pubertal (13 years) soccer players of 10 meter sprint time, agility, and three vertical jump tests. Diallo, Duche, and Praagh (2001) examined the effects of ten week plyometric training program on prepubescent (12-13 years) male soccer players and found performance improvements in maximal cycling power, countermovement jump, squat jump, multiple five bounds, repeated rebound jump for 15 seconds, and 20 meter running velocity. Thomas, French, and Hayes (2009) found that either depth jump or countermovement jump plyometrics improved agility time and vertical jump height but not sprint performance in 17 year old male soccer players. Campo, Vaeyens, Philippaerts, et al. (2009) examined the explosive strength and kicking speed of female soccer players aged 20-26 years following a 12 week plyometric training program and found improvements in countermovement jump height and drop jump height after six weeks and kicking speed after 12 weeks.

A study by Meylan and Malatesta (2009) examined the effects of an eight week plyometric program on the explosive actions of youth soccer players. Twenty-five early pubertal (13 years) soccer players participated in the study and were divided into a training group (n=14) and a control group (n=11). All the children were in-season and played in the same league training twice a week for 90 minutes and performing the same soccer drills. For eight weeks the training group substituted some of the soccer drills with plyometric drills consisting of jumping, hurdling, skipping, bouncing, and ladder footwork for about 20-25 minutes. Six pre and post training tests were used to measure explosive actions: 10-meter sprint test, agility test, squat jump height, countermovement jump height, jump height after ground contact test, and multiple five bounds test. Significant improvements were observed in the training group after eight weeks in 10-meter sprint time, agility, countermovement jump height, and ground contact. The training group decreased their 10-meter sprint time by -2.1% and their agility time by -9.6%. Jump height increase by 7.9% for the countermovement jump test and by 10.9% in the ground contact test.

Diallo, Dore, Duche and Vanpraagh (2001) studied the effects of plyometric training on prepubescent (12-13 years) soccer players. Twenty boys were divided into either a jump group or a control group. The jump group trained three days a week for ten weeks performing depth jumps of 30-40 cm and plyometric exercises including jumping, bouncing, hurdling, and skipping. All participants continued their soccer training during the study. The groups were tested for maximal cycling power (Pmax), countermovement jump (CMJ), squat jump (SJ), drop jump (DJ), multiple 5 bounds (MB5) and repeated rebound jump for 15 seconds (RRJ15). Running velocities were also tested using 20, 30, and 40 meter distances. After the ten week training period, the jump group significantly increased Pmax, CMJ, SJ, MB5, RRJ15, and 20 meter running velocity.

Thomas, French and Hayes (2009) compared to types of plyometric training on the muscular power and agility of youth soccer players. Twelve male semiprofessional soccer players age 17.3 +/- 0.4 years participated in a six week plyometric training program. They were divided into either a depth jump group (DJ), which performed exercises always beginning from a drop height of 40 cm., or countermovement jump group (CMJ) that performed exercises from the ground always beginning with a flexion of the knees called a countermovement. The program was twice a week before normal training and progressed from 80 foot contacts per session to 120 by the end of the training program. The participants were tested before and after the six week training program for vertical jump height, 20 meter sprint speed with 5 meter splits, and agility using the 505 agility test. The results showed that DJ and CMJ both improved in vertical jump height and agility but there were no changes in sprint performance.

Campo, Vaeyens, Phlippaerts, et al. (2009) studied the effects of plyometric training on explosive strength and kicking speed of female soccer players. Twenty adult (23.0 +/- 3.2 years) female soccer players were divided into two groups, a plyometric group (PG) and a control group (CG). The CG continued regular soccer conditioning which was replaced by plyometric training in the PG. Plyometric training was 12 weeks, three days a week which included hurdle jumps, drop jumps and horizontal jumps. Tests included the countermovement jump, drop jump height, and kicking speed. PG saw significant improvements in both the countermovement jump and drop jump height after only six weeks while, significant improvements were made in kicking speed after 12 weeks.

These studies prove that soccer players of all different ages can benefit from plyometrics. The players in these studies increased explosive actions including vertical jump height, multiple jumps, short distance sprint performance, agility, change of direction, and kicking speed.

Plyometrics on Improving Sprint Performance

Rimmer and Sleivert (2000) more specifically examined the effects of plyometrics on sprint performance. Twenty-six male rugby players with a mean age of 24 +/- 4 years and no recent history of plyometric training were divided into a plyometric group (n=10) a sprint group (n=7) or a control group (n=9). An eight week, two days per week training program was designed for both the training groups. The plyometric group performed sprint-specific plyometric which included all vertical and forward horizontal exercises. The sprint group performed 25-55 meter maximal sprints. Both training groups performed the same amount of sets of either plyometrics or sprints. Participants were tested pre and post training for sprint times of 10 and 40 meter distances. Stride length was measured using a high-speed video camera and tape strips positioned on the track at 20-cm intervals within 2 meters on either side of the finish line. Ground contact time was measured using force platforms place at the 7 and 37 meter marks. The plyometric group decreased their 10 meter sprint time significantly from 1.96 +/- 0.10 seconds pre test to 1.91 +/- 0.08 seconds post test. The plyometric group also significantly decreased their 40 meter sprint time from 5.63 +/- 0.18 seconds pre test to 5.53 +/- 0.20 seconds post test. The sprint group decreased their sprint times but where not significant. The sprint group times for the 10 meter sprint decrease from 1.95 +/- 0.06 seconds pre test to 1.93 +/- 0.05 seconds post test while the 40 meter sprint times decreased from 5.62 +/- 0.14 seconds pre test to 5.55 +/- 0.10 seconds post test. No significant changes were observed in either training group in stride length or frequency. Ground contact time decreased by 4.4% at the 37 meter mark in the plyometric group. This may be the reason for the significant decreases in the 10 and 40 meter sprint times.

Kotzamanidis (2006) studied the effects of plyometric training on the vertical jump and running performance of prepubertal boys (11.1 +/- 0.5 years). Thirty nonathletic boys were equally divided into either a training (JUMP) group or a control (CONT) group. The JUMP group participated in a ten week, biweekly plyometric training program which included one or two leg exercises specific to improving running velocity and the vertical jump based on Diallo et al. (2001). Jumps per session gradually increased from 60 to 100 by the end of the ten week program. The sprint test consisted of a timed 30 meter distance with intermediate phases of 0-10, 10-20, and 20-30 meters that were assessed as well. The vertical jump was tested using a Squat Jump recorded on a force plate. The JUMP group significantly increased running velocity in the 0-30, 10-20, and 20-30 meter distances but not in the 0-10 meter distance. JUMP group also significantly improved in the squat jump as well.

Harrison, Keane, and Coglan (2004) examined the torque-velocity and power-velocity relationships of quadriceps muscle function, stretch shortening cycle function, and leg-spring stiffness in seven sprinters and seven endurance runners. The subjects performed single leg squats, countermovement jumps, drop rebound jumps and an inclined sledge and force plate apparatus to measure stretch shortening cycle function and muscle stiffness. The results showed that on average sprinters generate more torque across all velocities compared to endurance runners. The sprinters also performed significantly better on all jumps than the endurance runners but there was no difference between the groups in prestretch augmentation. The results suggests that even though sprinters perform better than endurance runners in jumping activities, the stretch shortening cycles indices were similar in both groups. The ability to use the stretch shortening cycle is important in endurance runners as well as sprinters which suggests that endurance runners may benefit from including plyometric activities in their training.

Plyometrics on Improving Change of Direction or Agility

Miller, Herniman, Ricard, Cheatham, and Michael (2006) studied the effects of a six week plyometric training program on agility. Twenty-eight volunteers were divided into either a training group (age 22.3 +/- 3.1 years) or a control group (age 24.2 +/- 4.8 years). The training group participated in a six week plyometric training program twice per week with a training volume ranging from 90 to 140 foot contacts per session. The volunteers were tested before and after the six week training program to determine agility outcomes using the T-test, the Illinois agility test, and a force plate test to measure ground reaction times. The training group significantly improved their agility times in the T-test and the Illinois agility test as well as their ground reaction times.

Malisoux, Francaux, Nielens, and Theisen (2006) examined the effects of eight weeks of stretch shortening cycle exercises on the SJ, CMJ, and the 6x5 meter shuttle run. Eight recreational men (23 +/- 1 year) who never before followed a plyometric program volunteered for the study. The training program was three sessions per week and included squat jumps, drop jumps, countermovement jumps, single and double leg hurdle jumps and triple jumps. Results showed significant increases in SJ, CMJ, and the 6x5 meter shuttle run.

Plyometric Exercises

The plyometric exercises that were chosen for this training program were selected from the research because they have been used to improve sprint performance, vertical jump height, and or change of direction. As suggested earlier by Brughelli et al. (2008), power would be better classified to the direction of force application. This means that the direction of the plyometric jump improves performance in that direction. For example bounding improves sprinting because the direction of force is forward while a lateral hop improves lateral change of direction because the force is side to side (Chu, 1998). Finally, jumps that are vertical will improve vertical jump height because the force is directed upward (Chu, 1998).

Strength Training

Strength training is a very traditional exercise method, and when it is used properly, can improve force production (Baechle & Earle, 2000). Force production is directly related to the number of myosin cross bridges attached to the actin filaments in the muscle sarcomere at any given time. Maximal force of the muscle is related to the number of sarcomeres in parallel forming what is called the cross sectional area. Velocity of shortening on the other hand is related to the number of sarcomeres in a series. Strength training that uses high-resistance for near maximal muscle contractions and a low number of repetitions with full recovery periods between sets will increase the cross-sectional area of the muscle. To increase the maximal force of the muscle contraction the concentric movement of the exercise should be performed as fast as possible. Strength training should not only mimic similar movements of the sport but also strengthen the specific muscles used in those movements (Baechle & Earle, 2000).

The squat is an ideal exercise that mimics the movements of the legs in a similar way to jumping so it is considered a main exercise for increasing the force production of the muscle used in a vertical jump (Adams, 1992; O'Shea, 1985). The quadriceps and hamstrings are the primary movers of the squat, while the lower the squat is performed the more the gluteals are included (O'Shea, 1985). The first two movements of the vertical jump, hip and knee extension are similarly used in the squat and are considered the driving force of the vertical jump (Umberger, 1998). Overloading these muscles during a squat increases muscular strength and force (Baechle & Earle, 2000; Adams, 1992). A few studies have shown a positive correlation between maximal squat strength and vertical jump (Wisloff, 2004; Hedrick, 1998).

Wisloff (2004) examined the correlation of maximal squat strength with sprint performance and vertical jump height in elite soccer players. Seventeen elite male soccer players (age 25.8 +/- 2.9 years) from a professional team in Norway were tested for 1-RM half squat, vertical jump, 10 and 30 meter (m) sprint times. The results confirmed that a strong correlation exists between the 1-RM half squat and vertical jump height ($r = 0.78$, $p<0.02$), 10 m sprint time ($r = 0.94$, $p<0.001$), and 30 m sprint time ($r = 0.71$, $p<0.01$). Vertical jump height was also correlated with both 10 m ($r = 0.72$, $p<0.001$) and 30 m sprint time ($r = 0.60$, $p<0.01$).

A case study was done using the U.S. Air Force Academy football team to determine if there is a pattern between 1-RM scores in the squat or clean and performance in the vertical jump (Hedrick, 1996). Data from forty five football players was collected each year between 1993 and 1995 to evaluate increases in strength, power, and speed resulting from a regimented resistance training program. The data showed that an increase in the 1-RM of either the squat or clean is positively correlated with increases in vertical jump. Athletes who increased their 1-RM in the squat by 0-50 lbs increased their vertical jump an average of 4 cm. Those who had a 1-RM increase of 50-100 lbs averaged a 6.35 cm increase. A1-RM increase of 100-130 lbs averaged a 6.6 cm increase. Those that displayed an increase in 1-RM of more than 130 lbs resulted in an average of 10.41 cm increase in vertical jump. Similarly athletes who increased their clean 1-RM from 0-20 lbs averaged a 3.66 cm increase in vertical jump. Athletes who had a 1-RM increase of 20-45 lbs averaged a 3.89 cm increase. Athletes that displayed a 1-RM increase of 45-60 lbs averaged a 6.5 cm increase. Ahtletes who had an increased 1-RM of more than 60 lbs resulted in an average of 9.5 cm. This case study shows that the larger increase in squat and clean 1-RM results in a larger average increase in vertical jump height. It is important to note that each participant in this case study also participated in plyometric training (Hendrick, 1996).

While the squat is traditionally done in a weight room using weights for resistance, a weight room will not always be available for many soccer teams. Another form of strength training needs to be included that requires little or no equipment but is also effective and specific to the strength needs of soccer.

The Lunge

The lunge is a strength training exercise that is very specific to any type of runners such as soccer players (McCurdy & Conner 2003; Jonhagen, Ackermann &

Saartok, 2009). Unilateral Support Exercises (USEs) consist of all the weight or resistance being supported on one leg (McCurdy & Conner 2003). The lunge is considered a partial USE because the back leg serves as a support leg while the front leg bears a majority of the weight. A squat would be considered a Bilateral Support Exercise (BSE) as the weight is evenly distributed between both legs. While USEs and BSEs both recruit the hip and knee extensor muscles, USEs require greater activation of the hip abductors (gluteus medius, gluteus minimus, and tensor fasciae latae) to stabilize the pelvis in the frontal plane (McCurdy & Conner, 2003). The lunge is also considered a closed kinetic chain exercise. Open kinetic chain exercises can strengthen a muscle group by isolating either the flexors or extensors. Closed kinetic chain exercises on the other hand, improve the functionality of the leg muscles by strengthen the quadriceps and hamstrings at the same time (Hefzy, Khazim & Harrison, 1997).

Jonhagen, Ackermann & Saartok (2003) studied the effects of a six week training program using either the walking forward lunge (WFL) or jumping forward lunge (JFL). Thirty-two junior male soccer players, ages 17-20 years were divided into a WFL, JFL or control group. The WFL group significantly improved concentric hamstring strength over six weeks while the JFL only slightly improve hamstring strength. Both the WFL and JFL groups improved 30-m sprint times but only the JFL group was significant compared the baseline. The WFL and JFL groups showed no significant improvement in quadriceps concentric strength; however the control group was weaker in the quadriceps after the six weeks.

The Nordic Hamstring

The Nordic hamstring is an eccentric exercise that can be done with the assistance of a partner but requires no extra equipment. Eccentric hamstring strengthening has been shown to increase maximal running speed and isokinetic hamstring strength in elite soccer players (Askling, Karlsson and Thorstensson, 2003). It has also been shown to reduce the risk of hamstring injury in soccer players (Askling, et.al., 2003; Arnason, Anderson, Holme, Engebretsen and Bahr, 2008; Sayers and Sayers, 2008). The Nordic hamstring was found to be more effective in developing maximal eccentric hamstring strength than the traditional hamstring curl exercise in well trained soccer players, (Mjolsnes, Arnason, Osthagen, Raastad and Bahr, 2004). Though it is more common to strengthen the hamstrings concentrically using strength training equipment, eccentric strengthening is equally important to both optimal performance and injury prevention (Sayers and Sayers, 2008).

Twenty-one well trained soccer players volunteered for a ten week training program and were assigned to either the hamstring curl (HC) group or the Nordic hamstring (NH) group (Mjolsnes, Arnason, Osthagen, et al., 2004). The HC group progressed from two sets of six reps to three sets of eight to twelve reps for the first four weeks then increased the load by 2.5 kg if the participant could do three sets of twelve. The NH group progressed from two sets of five to three sets of eight to ten after four weeks then one set each of twelve, ten and eight reps for the last six weeks. The load was increased in the NH group by withstanding the forward fall longer and then, after the participant could to do all twelve with the full range of motion, the load was increased further by increasing the speed of the starting motion. After the ten week training program the NH group showed significant improvements in hamstring strength while the

HC group showed no changes. The NH group showed an 11% increase in eccentric hamstring strength at 60 degrees and a 7% increase in isometric hamstring strength at 30, 60, and 90 degrees of flexion.

In a study by Arnason, Andersen, Holme, Engebresten, and Bahr (2008) hamstring strains were registered prospectively during four soccer seasons between the years 1999-2002. Seventeen to 30 elite soccer teams from Iceland and Norway participated in the study with 48% of the teams selected to use the intervention programs. The intervention programs occurred during the 2001 and 2002 seasons, consisting of warm-up stretching, flexibility and/or eccentric hamstring strengthening using the Nordic hamstring exercise. The first two seasons were used as a baseline of hamstring strains. There were no differences found in hamstring strain incidences between the teams that used the flexibility training program and the teams that did not {relative risk (RR) = 1.53, P = 0.22} or the baseline data (RR = 0.89, P = 0.75). Teams that used the Nordic hamstring eccentric training program experienced lower incidences of hamstring strains compared with the teams that did not use the program (RR = 0.43, P = 0.01) or the baseline data for the same intervention teams (RR = 0.42, P = 0.009).

Effects of Combined Strength Training and Plyometrics on Power Output

Strength training has been shown to improve maximal strength of the muscle while plyometrics have been shown to improve the speed of the muscle. When strength training and plyometrics are combined into the same training program, the effects are often greater than just strength training and plyometrics alone. A few studies that look at these similar effects have been with club soccer players and active college age physical education students (Adams, 1992; Perez-Gomez, 2008; Rahimi and Behpur, 2005; Whitney, 2005).

Adams (1992) examined the effects of the squat, plyometrics, and a combination of squat and plyometrics training on power production. Forty eight male college students who had little or no power lifting and plyometrics experience with but had at least one year of strength training experience volunteered for the study. Power production was measured using a vertical jump test. Forty eight college students were ranked highest to lowest based on their vertical jump score then divided into four groups by ranking and then matched randomly to one of four groups: squat (S), plyometric (P), squat-plyometric (SP), and control (C). The training groups trained two days a week on Tuesday and Friday for six weeks. The S group progressed from four sets of eight reps of parallel squats at 70% of 1 RM to two sets of two reps at 100% of 1 RM throughout the six week training program. The P group performed depth jumps, double-leg hops and split squats increasing the depth jump height from 50.8 cm to 114 cm throughout six weeks. The SP groups performed the same exercises as the S and P groups but their volume of work was reduce by 25 percent in order to keep the volume and intensity of the training schedule equal with the S and P groups. Results showed a vertical jump increase of 3.30 cm in the S group, 3.81 cm in the P group, and a significant increase of 10.67 cm in the SP group. These results show that a combined squat and plyometric training program can increase vertical jump more than squats or plyometrics alone.

A study by Rahimi and Behpur (2005) also examined the effects of strength training and ploymetrics alone and combined on the vertical jump, squat 1 RM, and 50 yard dash. Forty-eight male college students age 19.27 +/- 1.36 years were divided into four groups: plyometric training (PT), strength training (ST), combined strength and plyometric training (PST), and control (C). A pre and post test were taken of the participants vertical jump height (jump and reach method), the squat 1 RM, and the 50 yard dash. The PT group training protocol included depth jumps, split squat jumps, rim jumps, and box to box depth jumps. The ST group training protocol included squats, leg press, leg extention, and leg extention. The PST group performed all the exercises that both PT and ST groups but with a reduced volume of 25% similar to Adams et al. (1992). The three training groups trained twice a week for six weeks. Results of all three training groups showed significant improvements pre to post test in the vertical jump height and the squat 1RM. Significant improvements in the ST and PST groups pre to post test were found in the 50 yard dash. However, the PST group experienced significant increases in vertical jump and significant decreases in the 50 yard dash times compared to the PT and ST groups. This study shows that combined strength and plyometric training elicits better improvements compared to strength training and plyometrics alone.

Whitney (2005) did a study using collegiate club soccer players and the effects of two different twelve week, tri-weekly training programs. Fifteen participants (five men, ten women) were split into two groups. Both training groups performed traditional resistance training (TRT) which included squats on a Smith machine, straight-leg calf raises on a leg press machine and machine hamstring curls. Three sets of six repetitions (reps) were performed for each exercise while alternating each exercise in supersets to mimic how athletes typically train in the weight room. The plyometric exercise group (PEG) did 15 minutes of plyometric training then 30 minutes of TRT. The Olympic-style lifting group (OSLG) performed three sets of six reps of the hang clean and three sets of six reps of the Romanian straight-leg dead lift equaling out to about 15 minutes followed by 30 minutes off TRT. A pre and post test of the counter movement jump and reach method was performed using the Vertec for testing vertical jump height. Both groups showed significant improvement in vertical jump over the twelve week program. The PEG experienced a 7% (2.8 cm) increase from pre to post test while the OSLG experienced a 9% (4.23 cm) increase.

Another study showed the effects of combined strength training and plyometrics on vertical jump height (Perez-Gomez, 2008). Forty two physical education students were divided into two groups. A training group (TG) consisting of 16 students age 23.4 +/- 0.5 years participated in the training program. A control group (CG) consisting of 21 students age 24.3 +/- 0.5 years did not participate in the training program. Five students were excluded after failing to complete the study leaving 16 students in the strength training group. The TG trained three days a week for six weeks following a periodized training program. After a warm up the TG started by executing bilateral plyometric exercises combined with unloaded drop jumps from a height of 40-60 cm and explosive hurdle jumps. After the plyometric exercises the TG performed weight training consisting of bilateral incline leg press, leg extension, half squat, and leg curl. Students were instructed to jump as high as possible and to minimize contact time with the ground during the plyomtric exercises and also to lift the weight as quickly as possible during the strength training exercises. Intensity, reps and sets increased throughout the six week training program. A force plate was used to measure vertical jump while the students performed squat jumps (SJ) and counter movement jumps (CMJ) both with hands on the hips. Statistically significant increases in TG in the countermovement jump were found in vertical jump height, vertical velocity at takeoff, maximal instantaneous vertical velocity, and maximal instantaneous power. TG also improved 1-RM performance in the half squat, incline leg press, and leg extension. This study also found a statistically significant increase in the percentage of Type IIa muscle fibers from 46.0% +/- 2.0 to 49.6% +/- 1.9 in the TG.

Another study used high school aged (17.0 +/- 1.1 years) male soccer players to determine the effects of a combined high-intensity strength and speed training program on running and jumping ability (Kozamanidis, 2005). Twenty three male soccer players were split into a strength training (STR) group (n = 11) and a combined strength and speed training (COM) group (n = 12) and a third group served as a control (CON) group consisting of similar aged PE students (n = 12). The groups were tested before and after the 13 week program. Individuals were tested for strength in the 90 degree half squat, step ups on a bench, and leg curl on a machine as well as for height in the squat jump, drop jump, and countermovement jump. The strength training program increased from 8 RM to 6 RM to 3 RM on all exercises though out the 13 week program. Exercises consisted of half squats, step ups, and leg curls. Immediately following the strength training the combined group performed a speed training program consisting of 4-6 repetitions of 30 m sprints. Results showed a significant increase in the strength of both COM and STR groups in the half squat, step up and leg curls. Significant increases of squat jump and drop jump were found only in the COM group.

Conclusion

Explosive movements such as jumping and sprinting and change of direction are crucial parts of the game of soccer (Seigler, 2003; Casajus, 2001; Wisloff, 1998). These explosive movements can be defined as power output. The vertical jump test is valid and reliable indicator of power output that can translate to vertical jump performance as well as sprint performance in soccer players (Aragon-Vargas, 2000; Hamilton, 2008; Hedick, 1996; Johnson, 1996; Leard, 2007; Markovic, 2004; Sayers, 1999; Salaj, 2007; Umberger, 1998; Wisloff, 2004; Yamauchi, 2007). Strength training and plyometrics are two ways that can improve the vertical jump, sprint speed, and change of direction in soccer players (Meylan, 2009; Diallo, 2001; Thomas, 2009; Campo, 2009, Perez-Gomez, 2008). When combined together into the same training program, strength training and plyometrics may improve vertical jump height, sprint performance, and change of direction more than strength training and plyometrics will by themselves (Adams, 1992; Perez-Gomez, 2008; Rahimi and Behpur, 2005; Whitney, 2005). However, many soccer teams do not have access to a weight room to perform proper strength training using weights for resistance. By incorporating several scholarly books and peer review journal articles, a strength and plyometric training program has been developed that will improve vertical jump height, sprint performance, and change of direction in soccer players using minimal equipment.

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