Jump Training Analysis: An Application in Strength and Conditioning

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Abstract

Force development is a crucial part of sports performance. Jumping is a mechanical movement used in various sports to analyze force production. Strength and Conditioning coaches work with athletes on improving sports performance through a variety of exercises. The mechanical principles utilized in jump training will help coaches train athletes to excel. Research has analyzed the various components of jumping that could substantially improve the rate of force development. Studies about the mechanisms of jumping will consist of devices used to measure force, phases of the jump, neuromuscular control of jumping and exercises to help athletes improve. The following thesis will include a review of jumping as well as an application strength and conditioning coach's use in the weight room.

Jump Training Analysis: An Application in Strength and Conditioning

Introduction

Jumping is a complex movement used in a variety of sports (Floyd, 2015). Athletes can improve performance through jump training. Jump performance is affected by force development and can be improved through training. Jump training has different components that influence athletic ability. Strength and conditioning coaches have the opportunity to help athletes increase sport performance. Once a coach understands the science behind jump training, he has the knowledge to program specific workouts to develop athletes. Through plyometric, high intensity, and resistance training athletes will improve in jump performance.

Force plates are essential in understanding and measuring force development in athletes. This device is used to measure ground reaction force (Liebermann et al., 2002). Sensors, located in the plates measure the force production through a force time curve. Different types of force plates are used in laboratories and weight rooms, but both plates demonstrate the mechanics and benefits from jump training.

Jumping involves three different phases (descent, amortization, ascent and flight). Altogether, these phases will produce force. (Akl, 2013). Force production involves two distinct phases: the early and late phase. Each phase has a specific purpose and training modality. The initial phase of force is the first fifty milliseconds of a movement (Folland, Buckthorpe, & Hannah, 2014). This phase is directly responsible for neurological firing and intrinsic muscle properties. A twitch will occur in the muscles at the moment of movement. The twitch is an activation of the agonist muscles which initiates movement.

The contraction of the agonist muscle will send a message to the brain to activate more muscle fibers (Folland et al., 2014). However, the twitch is not powerful enough to generate force to jump. After the twitch, the late phase of force occurs. The last phase of force development is directly related to muscle recruitment and strength (Andersen, L., Andersen, J., Zebis & Aagaard, 2010). Rather than neural drive, this phase refers to the muscles activated. The twitch is responsible for the initial muscle activation, but most force development is a result of muscle recruitment.

Jump training uses different muscular properties to enhance jump performance. Muscle fiber type is the most influential in assessing jump performance (Andersen, L. et al., 2010). Jumping utilizes fast twitch muscle fibers, also known as type II. Aside from muscle fiber type, muscle recruitment has a vital role in jump training. Increasing the neuromuscular recruitment patterns will increase the motor units activated with the muscle, which will improve jumping and force. Muscle elasticity also impacts jump training. Increasing the muscle length will improve jump performance (Andersen, L. et al., 2010). This is known as the stretch shortening cycle.

The stretch shortening cycle helps with the quick transition between the descent and ascent phases of jumping. There are three distinct phases of the stretch shortening cycle: eccentric, amortization, and concentric (Baechle & Earle, 2008). The eccentric phase involves the lengthening or stretching of the muscles. Once the muscles are fully stretched, there is a short pause, this is the amortization phase. After the amortization phase, the muscles will quickly contract which is the last phase (Baechle & Earle, 2008). Altogether, the stretch shortening cycle is responsible for an explosive muscular contraction that directly affects the twitch, eccentric, amortization, and concentric phases of jumping.

The hip, knee and ankle are all responsible and are important in jump training. There is a variety of muscle groups used throughout the movement, and each muscle has a specific function based on the joint action. The hip joint is the most significant contributor to force in jumping (Vanrenterghem, Lees, & De Clercq, 2008). The knee does not produce as much force as the hip but still contributes by contracting the quadriceps (Vanrenterghem et al., 2008). The ankle joint is responsible for the last phase of jumping because it is the last joint action before the flight phase (Vanrenterghem et al., 2008). Each joint has a specific role in jump training and impacts the athlete's performance.

Athletes are assessed based on their ability to perform. The squat jump and countermovement jump are two assessments used to measure jump performance. A squat jump measures the concentric ability of an athlete, because the athlete starts at the bottom of the squat and explodes upward (Riggs & Sheppard, 2009). The countermovement jump utilizes the stretch shortening cycle and is able to give a more accurate assessment of force production in jump training (Afifi & Hinrichs, 2012). Both assessments are very helpful in determining force production and will help strength and conditioning coaches assess athletes in the weight room (Baechle & Earle, 2008).

Strength and conditioning coaches are able to enhance force development through jump training. Jump training can incorporate a variety of exercises, training methods and different tools used in the weight room. Hip dominant exercises are used to help strengthen the posterior chain (Conteras et al., 2017). These exercises consist of hip thrust, kettlebell swings, deadlifts and Olympic movements. Different training modalities will affect the phases of force development. Plyometric training is geared toward the early phase of force development (Dal Pupo, Detanico, & Giovana dos Santos, 2012). High intensity training develops the late phase of force development (Andersen, L. et al., 2010). During high intensity training, coaches either use light or heavy weights to train the athlete. A coach has access to many different training tools in the weight room. Tools will add resistance to the exercises and increase the difficulty of the workouts.

The different exercises, modalities, and tools are all used to help athletes in sport performance. Jump training is one specific way to help athletes develop in their sport. Coaches are able to use the mechanical principles in jump training to improve force, which will improve different areas of a sport.

Force Plates

Force plates are specific devices used to measure the ground reaction force of an object. Force plates consist of upper and lower metal plates which are light materials (Liebermann et al., 2002). There are sensors installed on the plates which are usually strain gauges or piezoelectric crystals. The sensors placed inside the plates have the ability to measure forces in all three-dimensional planes. The force plates measure the deformities throughout the plates and if the force is equally placed across the plate the center of pressure is in the middle of the multilateral system (Liebermann et al., 2002).

Different types of force plates are used but most labs either use the moveable or standard force plate. The standard force plate is placed on the ground and is immoveable.

Laboratories utilize standard force plates, but they are very expensive. These types of plates eliminate outside vibrations because they are located in the ground (Walsh, Ford, Bangen, Myer, & Hewett, 2006). The portable force plate is the same concept, but instead this plate is not in the ground. The main differences between these two force plates are that the standard can be a little safer when performing jumping exercises (Walsh et al., 2006). Since the standard plate is embedded in the ground there is not a difference in height between the plate and the ground. This type of plate is very helpful when jumping because if a person misses the force plate, he will not be at risk for injury due to uneven terrain. However, the portable force plates are generally double in size of the standard plate to compensate for the risk of damage (Walsh et al., 2006). Walsh and others studied the differences between the two force plates to determine the validity of the portable force plate. The study concluded that the mobile force plate and standard force plate have high correlation (Walsh et al., 2006). Since both types of force plates are very accurate, the deciding factor is the price. The standard force plate is much more expensive and useful in laboratory settings rather than athletic performance. Portable force plates are more functional for athletic performance, because they can be moved around to different areas and are just as reliable as the standard plates (Walsh et al., 2006).

Jumping and Force Development

The vertical jump is one the most widely used tests for assessing an athletes force and power (Akl, 2013). Along with contributing athletic assessments, the vertical jump is used in various sports for athletic performance. Sports such as basketball, volleyball, and football all utilize jumping as a sport movement. In order to be successful in these sports, the jumping motion is required. However, the speed and power acquired through jumping is transferrable to most sports. Jumping can be described as three biomechanical movements: downward phase (eccentric), upward (concentric) and flight. Force development is the product of the three movements, caused by the muscular loading of the first two movements. A stretching of the muscles will cause a quick contraction producing the individual to jump. In most explosive sports there is a certain amount of time the athlete has to reach maximal force. It takes about three hundred milliseconds for an athlete to reach full maximum force, however most sports only allow two hundred and fifty milliseconds (ms) to reach maximal force capacity (Andersen et al., 2010). Specifically in track athletes, long jump will take 110-160 ms, 180-220 ms for high jump and 80-120 ms in sprinters. In order to reach maximal isometric force, athletes have to increase isotonic (muscle length) contraction (Arslan, 2005). Isotonic exercises increase blood circulation causing less fatigue in the muscles. Increasing the blood circulation allows the athletes to reach maximal isometric force before the muscles fatigue too much (Arslan, 2005). Altogether, it can take up to four hundred milliseconds or longer for an athlete to reach maximal force (Marcora & Miller, 2000). During this time, force development can be described as two phases: early and late phase (Andersen, L. et al., 2010).

Early Phase of Force Development

The early phase of force development is described as the first fifty milliseconds of a movement (Folland et al., 2014). This phase is mainly contributed to the neural firing in the body and intrinsic muscular contraction (Oliveira, F., Oliveira, A., Rizatto, &

Denadai, 2013). The initial movement is caused by the brain telling the muscles to move, after that the late phase begins. Training the early phase can be challenging because it is such a minute amount of time. Also, training the neurological aspect of sports is difficult because it will affect the muscle fibers that are used in the later phase (Andersen, L. et al., 2010).

At the moment of movement, a twitch is sent to the muscles and this activates the neural drive (Folland et al., 2014). The twitch is responsible for twenty to thirty-six percent of the movement during the first fifty milliseconds. Even though this twitch is responsible for muscle movement, it does not give enough force to reach maximal force capacity (Folland et al., 2014). For the muscles to reach maximal force capacity, an evoked octet pulse is needed. Activating the octet pulse will allow for the muscle tendon units to fully engage in the movement generating a greater amount of force than a twitch (Folland et al., 2014). Even though the octet pulse will produce a greater amount of force the twitch is still needed to activate the muscles. The twitch is one of the most important factors in explosive force, because it is responsible for the initial movement. Once the twitch is sent to the muscles, the muscle tendon units are able to respond with the pulses resulting in the octet (Folland et al., 2014). This process will allow for the maximal force production.

Training adaptations need to be made to improve the early phase of force development, however training the early phase will affect the later phase as well (Andersen, L. et al., 2010). Since the early phase is utilizing the first fifty milliseconds of a movement, training will need to focus on the muscle twitch rather than increasing muscle fiber recruitment. The two main training methods for improving the early phase of force development is plyometric and performing explosive movements as fast as possible (Dal Pupo, Detanico, & Giovana dos Santos, 2012). Plyometric exercises utilize quick bursts of various exercises. These exercises force the muscles to move as quickly and forcefully as possible. The second training method utilizes the speed of movement regardless of the weight. The goal for this training is that the athlete is moving the weight as fast as possible whether it is light or heavy. This will help develop that twitch because it is forcing the body to move quickly in short bursts. However, one downfall to this type of training is that it will affect the speed of the later phase (Oliveira, F. et al., 2013). The body might be able to generate force quickly through these training adaptations in the first fifty seconds, but during the remainder of the movement, force will decrease. The latter portion of the force development is caused by different muscle movements and training adaptations.

Late Phase of Force Development

In contrast to the early phase, the late phase of force development is caused by muscle recruitment and maximal muscle strength (Andersen, L. et al., 2010). The late phase is anything longer than fifty milliseconds to the end of the movement. To development maximal force during this phase, the body needs to recruit as many muscle fibers as possible. Unlike the early phase, which uses the reflexive neural drive, the late phase is voluntary muscle recruitment. Someone can be performing a vertical jump and have the initial twitch which will be responsible for movement, but after that twitch the individual is responsible for utilizing as many muscles as possible to increase force.

High intensity resistance training is used to help develop the late phase (Andersen, L. et al., 2010). This type of training uses many different muscles in order to perform high speed movements. Andersen, has conducted research showing an eleven percent increase in force at 250 milliseconds as a result of high intensity resistance training. However, this research also showed a decrease in the heavy myosin chain of type IIX muscle fibers which are responsible for the early phase. Training to improve the phases of force development is difficult because the training methods have counteracting results. The goal for training these different phases is to have a balance between the training regimens to hopefully increase both phases.

Muscular Properties Attributed to Force Development

The phases of force development will impact jump training, but there are muscular properties that affect jumping as well. Muscle fiber type is the biggest contributor to force development (Andersen, L. et al., 2010). Type II muscle fibers are responsible for fast movements, but type IIX are the quickest and most explosive. There are also type I muscle fibers which are responsible for long distance. During explosive movements the goal is to develop as many type IIX muscle fibers because they will be the most beneficial in generating force quickly. However, muscle fiber type cannot be changed. The chemical makeup of a muscle fiber cannot change, but training can cause the muscle fibers to take on characteristics of others (Baechle & Earle, 2008). Genetics also impact force development. No one is made up of all type IIX or all type I muscle fibers; there is a mix, but generally one may have more type IIX compared to type I. Even though an athlete might have more type I fibers, this does not mean they cannot be fast (Baechle & Earle, 2008). Type I fibers will never transform into type IIX fibers, but training can help type I fibers take on certain characteristics of type IIX fibers (Baechle & Earle, 2008). Training can help muscle fibers adapt, but it will never change the fiber type.

Muscle cross sectional area impacts force. The more muscle fibers recruited and used, the more explosive the movement that will result (Andersen, L. et al., 2010). As stated before, muscle cross sectional area and recruitment have a great impact on the late phase of force development. Training to increase muscle cross sectional area is based on high intensity and resistance. These two training adaptations have the possibility to increase force development because it is increasing the muscle fiber size. Increasing fiber size will yield a greater possibility to improve force since the muscle is now stronger and larger. For example, the gluteus maximus is able to generate significantly more force than the biceps because it is a larger muscle with more fibers to contract.

In accordance with muscle size, the length and tendon elasticity will impact force development (Andersen, L. et al., 2010). Tendon elasticity is the ability for that muscle to be stretched but then return to normal (Baechle & Earle, 2008). If that muscle is unable to stretch it will compromise the potential of that muscle to produce force. If a muscle can only stretch to half of the needed length, the force production will decrease because the muscle is not utilizing all the fibers available. A lack of tendon elasticity will also have an effect on the stretch shortening cycle, which will be discussed in more detail in the remainder of the paper. Each joint angle has a mechanical advantage depending on which is most forceful and effective (Andersen, L. et al., 2010). For instance, a bicep curl is most forceful when the elbow is at 90 degrees and is least forceful at 180 degrees. At 90 degrees the muscle is stretched to the point to produce maximal force, whereas the 180 degree elbow will cause a decrease in force because of the angle (Andersen, L. et al., 2010). Resistance training may have an impact on the joint torque angle, because of increasing muscle fibers and length.

Stretch Shortening Cycle

The stretch shortening cycle (SSC) is the basis for plyometrics (Baechle & Earle, 2008). Execution of the SSC in sports incorporating jump performance, will determine the success of one's maximal vertical (Riggs & Sheppard, 2009). This cycle is utilized in every explosive movement and incorporates functional movements and neurological responses (Baechle & Earle, 2008). The eccentric phase is the stretching of the agonist muscle. During this phase the elastic energy is stored in the muscle and the muscle is stimulated. Amortization is the pause in the between the eccentric and concentric phase in jumping. To increase force production this phase length is critical. The goal of the amortization phase is to be very quick. If this phase is too long, the elastic energy that is stored from phase I will dissipate and the stretched muscle will not produce as much force. During the amortization phase, the neurons are firing telling the muscles when to contract. Once the muscles begin to contract, phase III begins. Phase III is the concentric phase because it is the final phase as the muscles are contracting. During this phase the elastic energy that had been stored from phase I has now been released. Once this energy is released is causes a reflex, producing the neurons to stimulate the muscle group.

The stretch shortening cycle has a great impact on performance, but it directly affects rate of force production. This cycle will help increase sport performance in general, but when it is trained and utilized correctly it will greatly impact force. Since the cycle utilizes a stretch, an increase in the stretch will recruit more muscle fibers (Baechle & Earle, 2008). As more fibers are recruited, this will increase the concentric phase because there is an increased number of muscles being utilized. The most common way to identify the impact of the SSC on sport performance is through different jumps (Akl, 2013). In a study conducted by Akl (2013), he researched the impact of the SSC on athletes during the eccentric and concentric phases. This study concluded that if the athlete starts in a static position without using the SSC, force decreases forty-two percent. However, if the individual uses the SSC to their advantage during a movement, it will increase force by twenty-eight percent.

Joint Analysis in Jumping

Jumping involves three major joints: hip, knee, and ankle. These joints are responsible for the movement and force produced in a jump (Vanrenterghem et al., 2008). Each joint will incorporate different muscles during the motion. Furthermore, the muscles that are activated throughout the movement will change depending on the phase of the jump (Robertson, Wilson, & Pierre, 2008). The two main phases involved in jumping are the descent and ascent. The descent phase will consist of the lengthening of the muscles, whereas ascent is the contraction. The muscles involved include: vastus lateralis, vastus medialis, medial hamstring, lateral hamstring, gluteus, gastrocnemius, tibialis anterior, soleus, and hip extensors (Afifi & Hinrichs, 2012). Each muscle utilized will be discussed according to joint and order of movement.

Hip Joint

The hip joint is the first movement in jumping and is also responsible for jump performance (Vanrenterghem et al., 2008). An increase in jump performance is caused by an improvement in hip extensor muscles. Studies have shown that if trunk flexion is decreased and the individual is more upright, there has been a 27% reduction in hip flexion. As a result, the torque generated from the hip joint decreased 40% (Vanrenterghem et al., 2008). Vanrenterghem also concluded that the hip joint was the only joint that has a direct effect on jump performance. Changes can occur in the ankle and knee joint, but this will not affect jump performance as much. Therefore, the use of the hip joint musculature is crucial in jump training (Deane, Chow, Tillman, & Fournier, 2005).

In the eccentric phase of the jump, the hip extensors are the main muscles that are utilized (Robertson et al., 2008). The gluteus maximus contracts eccentrically during the movement. Even though the gluteus only contributes 25% of the muscle activity during the descent it is greatly involved in the countermovement of the ascent. As the individual is in the concentric phase of the jump, the gluteus maximus and hamstrings (posterior chain) are contracting concentrically (Ford, Myer, Brent, & Hewett, 2009). The posterior chain is responsible for the countermovement, which initiates the SSC (Robertson et al., 2008). Since the posterior chain activates the countermovement, the hip extensors are the first muscles to contract. During the ascent the hip extensors are responsible for the greatest amount of force. These muscles can generate more than three hundred newtons of torque during one single jump (Robertson et al., 2008).

Knee Joint

The knee joint does not produce as much force as the hip, but it is still important in jump performance. The first initial movement of the knee is the unlocking phase, this action will cause flexion and initiates the eccentric phase (Robertson et al., 2008). The gastrocnemius and hamstrings are responsible for the unlocking motion. Once the knee is flexed, the following movement is caused by the vastus lateralis and rectus femoris. The rectus femoris is mostly used as the individual reaches maximal depth, until then, this muscle assists the hip flexors and stabilizes the knee (Robertson et al., 2008).

Once the individual is in the ascent phase of jumping, the knee joint produces the least amount of power (Robertson et al., 2008). The knee extensors are responsible for producing the contraction during this phase. In order to increase knee joint torque during the ascent, the individual would have to decrease trunk flexion (Vanrenterghem et al., 2008). However, this will only increase knee torque by 8% and will cause a decrease in hip joint torque.

Ankle Joint

The ankle is the final joint action in jumping (Robertson et al., 2008). The ankle performs two distinct movements while jumping: dorsiflexion and plantarflexion. Dorsiflexion occurs as the individual is in the eccentric phase. As the ankle begins this movement the tibialis anterior is contracting in order to cause ankle flexion. During the descent the soleus will be lengthening, but is not contributing a lot of muscle activity.

However, as the subject reaches maximal descent muscle activity in the soleus will increase to fifty percent (Robertson et al., 2008).

Once the individual reaches maximal descent, the muscle spindles are activated and potentiate the concentric phase through the stretch reflex. Plantarflexion occurs once the individual starts the ascent (Robertson et al., 2008). Regarding knee activity, the plantar flexors generate more power than the knee. However, these muscles will not reach maximal potential until the end of the movement. The muscles used in jumping contract in order of recruitment. Muscle recruitment begins with the hip extensors and the gastrocnemius is the last. Order of contraction is a direct relationship with the form of jumping.

Jump Performance Assessments

Training for any sport requires assessments in order to gauge the improvement of an individual. Two of the main tests in jump training are squat jumps and countermovement jumps. Both tests are able to give sufficient information on the individuals jump performance, but there are variations for each test. The squat jump forces the individual to start in the descent position and explode into the jump, whereas the countermovement jump allows the athlete to descend and the quickly transfer into the ascent. Even though the tests are a good representation of jump performance, there is a specific purpose for each assessment.

Squat Jump

The squat jump (SJ) is a very popular test to assess an athlete’s vertical jump (Riggs & Sheppard, 2009). The purpose of training the squat jump is to help develop muscle recruitment patterns in the ascent phase of jumping (Riggs & Sheppard, 2009).

Since this jump starts in the descent position it is measuring the individual's concentric power. The squat jump uses a ninety degree knee angle, however, studies have shown that a seventy degree knee angle incorporates the hip and ankle joints more (Akl, 2013). The ninety degree knee angle relies predominately on the hip and ankle to produce power. However, knowing the muscles involved in each phase concludes that the knee extensors do play a part in the force produced. A squat jump that uses the seventy degree knee angle is able to utilize all three joints to generate force.

The stretch shortening cycle is not utilized in the SJ because the muscles are not using the eccentric phase to produce the elastic energy. The muscles are lengthening, but the individual is in the static position too long that the energy dissipates into heat (Baechle & Earle, 2008). Even though neurons are still firing during the concentric phase of jumping, the individual is not utilizing the stretch reflex. The squat jump is a good exercise for training the vertical jump, but it is unable to generate a great deal of power

Counter Movement Jump

The counter movement jump (CMJ) is another test that is widely used to assess power (Riggs & Sheppard, 2009). Unlike the squat jump, the purpose of the counter movement jump is to train lower body reflexive strength and power (Riggs & Sheppard, 2009). This type of jump incorporate a quick descent into the squat before exploding into the vertical jump. This assessment is widely used in volleyball and basketball players. Since this jump uses a quick descent the knee angle is not the same as the squat jump. The optimal knee angles are between 100-130 degrees for the countermovement jump (Akl, 2013). Even if the knee angle in the CMJ is the same as a SJ, the CMJ will be more explosive because of the SSC. The CMJ continues to produce more force, because of the mechanical factors in the SSC. The lengthening and quick firing of the muscles allow the body to react faster and produce more force than a static jump.

Application to Strength and Conditioning

The role of the strength coach is to teach and asses the athletes to improve and strengthen game performance. However, the coach has to make sure the facility is safe and lifting techniques are correct (Baechle & Earle, 2008). Resistance training has an inherent risk and the coach does not want to add to that risk through the facility or techniques. The athletes are not aware of the dangers in the weight room so the coach needs to be aware of the possible injuries.

Apart from safety in the weight room, the coach has the opportunity to develop the athletes. There are many different training methods and exercises that can be used in the weight room. A strength and conditioning coach is responsible for understanding each type and assessing the sport in order to understand the best method. Specifically, force development is a major aspect of every sport and is needed for success. There are different exercises, training modalities and training tools a strength and conditioning coach can utilize to help improve jump performance.

Exercises to Enhance Jump Training

Research has determined different methods to improve jump performance. Many of the different studies use hip dominant exercises to conclude which one will produce the best results. The main exercises that have been studied are: hip thrust, front squat, kettlebell swing, deadlift, and Olympic lifts. All of these exercises have been studied and have produced positive results on jump training, but there were a few that were able to produce optimal results.

One specific study compared the hip thrust to the front squat (Conteras et al., 2017). It was believed that the hip thrust would specifically help horizontal sport movements and the front squat would help with the mid-thigh pull. The groups performed the sprint and mid-thigh pull before the six week training. After the training, the groups were tested again to see if there were results based on training methods. Hip thrusts proved to have a direct relationship with improving the 40 yard dash and broad jump. Hip thrusts are a great exercise to incorporate into a training regimen because they target the posterior chain musculature to help develop the strength needed in jumping.

Since jumping utilizes the hinge movement, the kettlebell and deadlift are two specific exercises to train those muscles (Maulit et al., 2017). Kettlebell swings are a much more explosive movement, which is more like a jump than a maximal deadlift. However, a kettlebell is not able to incorporate as much strength training as a deadlift can. Maulit and others conducted research to see if a kettlebell swing and explosive deadlift training would yield the same results and they did. For this study, the researchers used 10-12% of the maximal isometric mid-thigh pull for the kettlebell and 30-40% of the one repetition maximum for the deadlift.

Olympic lifts can be used in a weight room, but they require a great deal of skill and motor functioning (Arabatzi, Kellis, & De Villarreal. 2010). However, if an individual is able to perform these lifts, it will increase jump performance. Arabatzi et al. researched the influence Olympic lifts have on jump performance and found that these lifts will increase power production and improve mechanical parameters. Olympic lifts will help the individual utilize a greater range of motion in order to develop a greater hip moment (Arabatzi et al., 2010). These types of lifts will help individuals develop muscle coordination as well as maximal muscle output.

Overall, there are many exercises to help jump performance, but some exercises can produce greater results. A strength and conditioning coach is able to use different types of exercises in order to help their athletes improve jump performance. Apart from different exercises a coach incorporate, a variation of training modalities will improve performance as well.

Plyometric Training

As stated previously, plyometric training is used to develop the early phase of force development because it is associated with the neurological firing (Dal Pupo et al., 2012). Plyometric training consists of short quick movements that involve a prestretch and a countermovement (Baechle & Earle, 2008). A lot of the plyometric training used for force development in jumping would be vertical jumps, long jumps, multiple jumps, bounds, box jumps, and depth jumps. These exercises can be used to train the initial movement of the jump. Also, these training drills can be altered in order to match the sport that it is being used for. For instance, a sprinter will be moving in the horizontal position when starting in the blocks. Therefore, training the vertical jump would be beneficial, but the long jump would help develop the horizontal movement better (Giroux, Rabita, Chollet, & Guilhem, 2016). The goal for plyometric training is to develop the SSC. One of the most important phases of the SSC is the amortization phase, and plyometric training is trying to shorten that phase as much as possible.

Plyometric training can cause the individual to become fatigued quickly, which will lead to an increased risk for injury. Programming for plyometric training will vary, but this type of training is measured by foot taps or jumps (Baechle & Earle, 2008). The measurement for jumps is dependent on the ability of the athlete, and the strength coach is responsible for making sure each athlete is doing the appropriate repetitions. For instance, a beginner has about 80-100 contacts, intermediate uses 100-120 jumps, and the advance will have about 120-140 jumps. Plyometric training does not usually take an entire training cycle, but rather is worked in throughout the different seasons for the athlete. Plyometrics is a great training tool to use in order to develop the early phase of force development, because it utilizes the SSC in order to produce force.

High Intensity Training

High intensity training (HIT) is used to develop the late phase of force development. This type of training will range from resistance training with light weight or training with heavy weights (Andersen, L. et al., 2010). Both training methods will develop the late stage because HIT helps recruit more muscle fibers. Light weight resistance training will focus on using around thirty percent of the individual’s body weight to perform the exercises (Vaverka et al., 2013). The lighter weight will allow the individual to still move the weight quickly, but allow development of explosiveness throughout the movement. Apart from the light weight training, the heavy weight training will improve force development as well. Heavy weight training will allow the athlete to increase muscle size, which will help with muscle recruitment during the jumps (Andersen, L. et al., 2010). Heavy resistance training will not focus as much on the speed of movement, but focus on developing the overall strength of the movement. Training for this method will use loads of around 70%-95% of the individual's one rep max (Baechle & Earle, 2008). The differing percentages will focus on different training adaptations, but increasing the percentages will increase muscle recruitment.

Using a combination of HIIT and plyometric training is extremely beneficial to the athletes, but it has to be programmed correctly in order to produce results (Baechle & Earle, 2008). Training both aspects of force development will improve force; however, the relationship between training methods is inverse. For example, training heavy high intensity resistance for the lower body would require light upper body plyometric training. If the training days do not have an inverse relationship, athletes will become fatigued and injuries may occur.

Training Tools

A strength and conditioning coach has many different training methods that can be used for force development, as well as many different training tools. Most training tools used are for developing the early phase of force development, because they are using a light resistance for short quick movements (Feeney, Stanhope, Kaminski, Machi, & Jaric, 2016). Coaches can use a variety of different training tools: vests, chains, and sleds. Each tool is able to train a different aspect of force development. Vests are used a lot for jumping, chains are used during traditional squats, and sleds can be used for sprinting.

Vests are a great training tool to develop vertical and horizontal jump through plyometrics (Khlifa et al., 2010). The ideal vest weight can range between 10-11% of the individuals body mass (Khlifa et al., 2010). Incorporating a short term plyometric training program has proven to increase vertical jump up to ten percent (Khlifa et al., 2010). Khlifa et al researched the effects on weighted vests on jump training. The study concluded that many of the increases in vertical jump could be identified through the stretch shortening actions seen in the countermovement jump (Khlifa et al., 2010).

Chains can be used for a variety of different lifts, but for jump training it will be used for the squat. Incorporating chains into a squat will help develop muscle stimulation, motor recruitment and firing rates (Mcmaster, Cronin, & McGuigan, 2010). Chains rely on the gravitational effect of resistance, therefore while the weight is being lifted chains add an increasing resistance throughout the lift (Mcmaster et al., 2010). Specifically, chains are used to develop strength through the “sticking point” of an exercise (Mcmaster et al., 2010). Increasing motor recruitment will help develop overall strength in order to help athletes increase power for jump training (Mcmaster et al., 2010).

Weighted sleds are used specifically for sprint training (Clark, Sterne, Walts, & Miller, 2010). Incorporating sleds into training can be beneficial, but in order to keep the mechanical properties of sprinting only ten percent of the individuals body weight should be used (Clark et al., 2010). Clark et al. conducted a study to research the effects of weighted sleds on sprint velocity. The subjects would be analyzed on the stride length, stride rate, and flight time. The different distances used were 18, 36 and 50 meters (m).

Overall, the individuals improved sprint velocity, but weighted sleds improved the acceleration phase (0-10m and 0-20m) of sprinting significantly (Clark et al., 2010).

The key with using different training tools is the resistance used and how is it affecting the technique of the movement (Vaverka et al., 2013). If the resistance is set too high, that athlete will not be profiting because the weight cannot be moved quickly. Also, adding different objects to a lift can alter the technique. Technique can be affected because the weight is too high and the athlete has to compromise form in order to perform the exercise. Training tools have the ability to help improve athletic ability through jump performance if they are used properly in a weight room.

Sport Performance

Strength and conditioning coaches do not train athletes specifically to sport movements, but rather movement patterns (Baechle & Earle, 2008). Jumping is an explosive movement whose pattern is used in a variety of sports. The triple extension that is used in jumping is seen in volleyball, basketball, track and field, and football. Strength and conditioning coaches use mechanical movements to train sport performance. For example, a baseball coach will not have the baseball team in the weight room swinging weighted bats to help develop power and speed when batting. Instead, the coach will have the athlete strengthen the core through rotational exercises, the posterior chain through hip hinge movements and stability through unilateral exercises. The first step in programming is the need analysis of the sport. The coach has to understand the movement, physiological and injury analysis of a sport before developing a program.

This is the most critical step in programming, because if the movements do not align with the sport analysis the athlete will not improve in competition.

Future Research

We have reviewed the information on force development, but there are certain aspects that still need more scientific evidence. Research on muscle fiber type in force development has been done, but a more specific understanding of which fiber type during each phase is still needed (Dal Pupo et al., 2012). However, it can sometimes be difficult to get a biopsy of the muscle in order to determine which fiber type is being used. Along with understanding the different fiber type roles in force development, training modalities to develop force needs to be studied with further research. More research on different training programs and training styles is needed in order to find which will help develop force the best (Oliveira, F. et al., 2013).

In addition to those topics, anterior cruciate ligament injury is very prevalent in jumping. Injuries can happen because of fatigue (Chappell, Herman, Knight, & Kirkendall, 2005). Training to help reduce fatigue is needed. Genetics impact injury prevention as well (Chappell, Yu, Kirkendall, & Garrett, 2002). There are specific differences between males and females that increase injury risk, but there is still not a definite reason for the injuries. Research is needed to identify the reasons behind these injuries in order to help strength coaches train athletes to prevent them.

Conclusion

Force development is a vital component in many sports. Jump performance is one of the assessments that is used to understand force development in many athletes. There are many different aspects to jumping and an enhanced understanding of these will improve jump performance. Jumping has two different phases incorporated into the movement and both these phases have different roles. The early phase is primarily the neurological aspect and stretch shortening cycle and the late phase is the muscle recruitment. The muscles that are used in this movement will vary depending on the phase of jumping, but each muscle plays an important role in the jump training. Just as the muscles are important, the knee angles have an influence on the force development as well. Knee angle varies depending on the type of jump. Counter movement jumps generate more force because the stretch shortening cycle is being utilized throughout the movement.

The strength and conditioning coach plays an important role in each of the aspects of force development. The coach is responsible for understanding the development of force and translating force development into jump performance. A strength and conditioning coach has the opportunity to help develop excellent athletes through varying training methods, but it is the coach’s job to understand the correlation between movement patterns and sport performance. Improved sport performance is not derived from direct sport movements, but rather biomechanical movement patterns. Jump training can be improved through understanding the principles of jumping, the correct techniques in training methods and a strength coach who is well read in the values of training movement patterns.

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