**Overview**

In ground-based sports, the ability to smoothly and rapidly change direction is a sought-after skill, desired by most athletes and coaches. Not all sports require the need for athletes to rapidly change direction. For those athletes who must do so repeatedly, the ability to maintain good body positions during high-speed moments can have a positive influence on the outcome of any game. Improving an athletes’ technical movement strategy can play a major role in improving an athlete’s change of direction speed; However, in sports where braking and re-accelerating faster than an opponent or being quicker than the clock, overcoming high forces becomes an important task. When athletes look good technically, but lack the infrastructure strength to withstand, countering momentum, good technique falls apart, performance falters and athletes become more susceptible to injury.

This paper will discuss the role of strength training, its influence change of direction capabilities and its role in the prevention of common non-contact related injuries. For the purposes of this paper we will be focusing only on the physical aspects of change of direction. This paper will not be covering the cognitive demands of reacting to a stimulus, which turns change of direction movement into agility.

The ability to change direction can be a game changing characteristic in many sports that require athletes to suddenly redirect their movement. (McInnes 1995, Hoffman 1996). Stolen 2005 and Reily 2007 suggests many of the limitations in soccer, football, tennis, basketball, etc. performances are related to an athlete’s ability to express strength and speed-strength. Strength and speed-strength are both physical skillsets and are displayed in: volleyball, as a middle blocker rapidly performs a lateral move before elevating vertically into a powerful defensive block against an offensive attack; in soccer, as an outside back swiftly plants their foot to maneuver while defending a wing, and in basketball; as a player fakes left and crosses over his defender to attack the rim with a slam dunk.

In sport, change of direction during high intensity game situations requires high intensity maneuvering and the ability to do successfully is recognized as a multi-faceted skill. Like all complex skills, change of direction in sport includes many different variables to be performed successfully. This includes; the ability to quickly decelerate while maintaining proper alignment (appropriate vector), hold a stable position (not buckling under the pressure of resisting momentum), physical strength to tolerate high loads involved with stopping momentum, skillfully positioning the body to maximize leverage and store elastic energy and the ability to effectively transfer elastic energy to improve acceleration in the newly desired direction. When these components are done correctly, movement appears to be explosive and fluid. Picture a wide receiver in American football charging up the field and convincing the defensive back he is going deep, then without warning, the receiver lowers his center of gravity and explodes back at a 45-degree angle towards the sideline. When this high intensity change of direction move is efficiently executed, it creates separation as his defender struggles to stay close. This type of
hard deceleration loads the musculotendinous structures with the intention to redirect energy into the new direction for faster acceleration. This athletic maneuver allows the receiver to break away and get open for his quarterback. These explosive transitions in sport help us better understand where muscular strength lies in sport and the role it plays in change of direction performance.

**Defining loads involved with change of direction...**

For athletes to continually improve in their sport specific positions, it requires them to spend thousands of hours in their sport specific situations. By the governing rule of specificity and abiding by the S.A.I.D. (specific adaptation to imposed demands) principle (Seyle 1952), being in the sport specific setting is the ultimate hotbed for learning. It is here where athletes gain a better understanding and better feel for their role and their responsibilities: technical movement, cognitive demand, emotional control, tactical strategy and better connections with teammates. (Giannini 1988, Ericsson 1993)

Sport is demanding and it requires athletes to overcome an array of forces to stay free from injury and perform to one’s maximum ability. So, we must ask; is the athlete able to produce, dissipate, redirect, and reutilize force? **Force is at the core of all sporting action and ultimately, performance in many sports can be determined by how well an athlete can tolerate the forces involved in the sport they play.** Taking the velocity and mass of an athlete as well as the time demands during deceleration can allow for the calculation of force during decelerations. A couple of examples:

<table>
<thead>
<tr>
<th>U13 Soccer Player weighing 40kg(115lbs)</th>
<th>Professional Soccer Player weighing 76kg(170lbs)</th>
<th>College or Professional Baseball Player weighing 100kg(220lbs)</th>
<th>Volleyball Player weighing 73kg(160lbs)</th>
<th>Volleyball Player weighing 91kg(200lbs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traveling at 6.38m/s or 14.27 mph weighing will need to produce 514.23 newtons(115lbs) newtons of force to be able to decelerate in .5 sec.</td>
<td>Hitting top speeds of 9.44m/s or 21.11 mph, may decelerate in .25 sec, the athlete will need 2877 newtons(647lbs) of force to come to a stop.</td>
<td>Running to first base(90ft) in 3.5 seconds reaching a speed of 17.53mph or 7.83m/s. If in a .25 of a second the baseball player is given the opportunity to extend his single into a double he must decelerate 3132 newtons (701 lbs.), redirect the force and accelerate towards second base.</td>
<td>Landing from 20 inches in less than 100 milliseconds, results in landing loads 4599 Newtons(1030 lbs), Landing from 25 inches results in landing loads of 5694 Newtons(1275 lbs), and landing from 30 inches results in landing loads of 6862 Newtons(1537 lbs)</td>
<td>Landing from 30 inches in less than 100 milliseconds, results in landing loads 8554 Newtons(1916 lbs), Landing from 35 inches results in landing loads of 9919 Newtons(2221 lbs), and landing from 40 inches results in landing loads of 11375 Newtons(2548 lbs)</td>
</tr>
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<table>
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<tr>
<th>Deceleration Rates and Forces Occurred (Newtons)</th>
<th>Deceleration Rates and Relative Forces Associated to Body Weight</th>
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![Graph](image1.png)  
![Graph](image2.png)
These numbers help us better understand the forces and demands placed upon the athlete as they participate in sport. Decelerating from higher speeds results in a linear rise in loads.

With this understanding, a stronger relationship to strength and change of direction can be recognized, in addition to an increased awareness of the stresses placed on the body’s internal structural and mechanical systems.

Decelerations during Changing of Directions…

When executing change of direction movements, the single greatest performance factor is an athlete’s ability to **decelerate and redirect force**. Similar to a massive ocean wave crashing into a sea wall, just prior to the cutting action, the body must be physically strong enough to withstand the impact and the forces that come with slowing down and re-directing momentum. Like the sea wall, if the infrastructure of the body is unable to stand firm, brace and accept such high force, significant damage is inevitable.

The graphs above display the increase in force for each athlete when the time allowed to decelerate, decreases.
The ability to accelerate can determine an athlete’s success in the game, but in many ground based sports, the ability to decelerate may be just as important, if not even more important! Typically, performance of acceleration-based activities are determined by an athlete’s ability to extend joints powerfully under load, while performance in deceleration-based activities are determined by an athlete’s ability to be strong and stable while joints under load while joints flex.

Deceleration happens in the lower body as a result of a powerful flexor based movements. Flexion of the ankle, knee, and hip joints. During this triple flexion action, muscles of the lower body use eccentric muscle contractions to overcome and dissipate braking forces. Eccentric strength can be defined as the amount of force developed during the lengthening phase of muscle contraction. If the musculature of the lower body is unable to meet the demands (discussed above) during braking phases of movement, ligaments and tendons must absorb the forces involved. Where there is an increased risk of injury.

Decelerations from high speeds are found in many different sporting disciplines. Sports like soccer, Australian rules football, and rugby expose athletes to large quantities of high speed decelerations. Professional soccer players average 54 high speed decelerations a game (Dalen et al. 2016). Akenhead et al. 2016 reported; 18% of activity during high-level soccer matches are spent accelerating and decelerating. The ability to decelerate is directly associated to an athlete’s eccentric strength capacity and eccentric muscle contractions while countering high loads or high speeds can be damaging to the muscle function.

Damage of Deceleration…

Due to the high quantities of deceleration and change of direction tasks, tissue integrity and resiliency need to be a priority in athletic preparation. Graham-Smith 2016 investigated the relationship between faster agility times with the braking forces involved with decelerating and found athletes who change direction faster can withstand greater horizontal braking forces, compared to athletes with slower agility times.

Eccentric muscle actions under high strain are known to result in significant damage to the mechanical components of muscle (Eston 1995). As a result, tolerating the increased loads involved with high intensity decelerations is a very strenuous task. Eccentric muscle action has also been linked to increased muscle soreness and muscle damage (Eston 1995). This relationship displays the potential for change of direction to be a possible mechanism for significant fatigue during a competition.

Human muscle tissue has a tensile characteristic, meaning it has the ability to stretched and drawn out while being held under tension. Tensile strength is defined as the capacity of a structure to withstand loading during elongation. For example, a rope has a higher tensile strength than a string of yarn and a wire cable has a higher tensile strength than a rope. Tensile strength is important regarding muscle tissue also. As muscle is held under an eccentric contraction while resisting a high load, if the muscle lacks the appropriate tensile strength, the muscle breaks down and small micro tears occur. When the muscle undergoes significant micro tearing, its’ functional capacity is reduced. (Armstrong 1984). As a result, if durability and repeatability of high intensity movements is important then muscle tensile strength should be equally important.
Quantifying the number of decelerations completed during a game and examining the loads associated with decelerating brings increased importance for high eccentric strength attainment in athletes. Young et al. 2012 examined the relationship between movement demands as an indicator of muscle damage in Australian rules football. Using GPS to track movements and speed during matches the authors concluded that the primary cause of muscle damage stems from high-intensity running, high acceleration/deceleration movements, and running with change of direction. Creatine Kinase(CK) is an enzyme found in the heart, brain and all skeletal muscle and CK levels in the blood have been directed linked to muscle damage. As a result, CK is a commonly used blood marker to measure the magnitude of muscle damage (Baird 2012). Young 2012, used CK to indirectly assess muscle damage and found higher CK levels in athletes who performed more accelerations, decelerations, and change of directions during match play.

One major difference between the functions of concentric and eccentric muscle action is: Eccentric muscle contractions are able to withstand more muscular tension in comparison to concentric muscle contractions (Fick 1882). When eccentric muscle actions are held under high tensions, muscle tissue is more susceptible to damage. With long-term eccentric training, that is both consistent and progressive, muscle tissue has been shown to become more tolerant to high tensions. Clarkson 1988 investigated the impact of maximal eccentric contractions and found that after exposing a muscle to high intensity eccentric exercise overtime, they adapt, and they become more resistant to the damage caused by eccentric loading. This enhanced ability to tolerate load leads to muscle tissue being more robust and resilient.

Weaker athletes sustain more muscle/mechanical damage than stronger athletes do (Newton 2008). During long and intense competitions athletes withstand countless high intensity bouts of deceleration efforts (Dalen et al. 2016). When muscles breakdown there is also a breakdown in speed and change of direction performance. Weaker athletes are more susceptible to and accrue more muscular fatigue and tissue damage. The repair of muscle damage has been shown to take longer in weaker athletes. So, when playing in long tournaments, when competing on consecutive days, if the goal is to maintain a competitive advantage throughout a long tournament, the attainment and maintenance of high strength becomes a priority.

It has been found that change of directions in a game or practice setting alone do not provide a sufficient enough stimulus to improve performance. To improve eccentric strength thresholds, a training stimulus must meet and exceed the tissue’s minimal essential stress threshold required to further promote positive muscle adaption. Without out supplemental training; force production, acceptance, and reutilization may not improve (Jakobsen et al. 2012).

Chen et al 2007 investigated the impact of different types of eccentric muscle contractions: maximal and submaximal as it related to muscle performance in the form of isometric maximal voluntary contraction. Chen found the subjects who completed maximal eccentric muscles contractions were recovered to 80% of their initial maximal voluntary contraction 5 days post training. While subjects who completed the submaximal eccentric exercise were 11% recovered from their initial testing.
assessment at 5 days post exercise. It is proposed, the higher the eccentric strain elicited a greater protective response leading to greater and faster adaptation.

Newton et al. 2008 investigated the effects of consistent resistance training on muscle damage in resistance trained subjects and non-resistance trained subjects and found: **Resistance trained subjects were able to recover to base-line performance measures faster.** Resistance trained subjects were back to their baseline performance testing score within 3 days post exercise, while non-resistance trained subjects were still 40% lower than their initial baseline testing at 3 days post exercise. It is proposed that resistance trained subjects were less susceptible to eccentric-induced muscle damage, is suggested this response is attributed to an accumulation of “repeated bout effect”.

Repeated exposure to high intensity eccentric muscle actions build tolerance and creates more robust muscle tissue. This increased resiliency can be thought of like the development of either a callus or a blister on the hand from chopping wood. A lumberjack through repeated exposure to chopping wood for hours a day will build thick calluses on the skin to protect the palm of their hand from constantly being damaged. If a normal individual were to perform a lumberjack’s daily duties they would end up with blisters caused by the repeated trauma to the skin of their palms. **An athlete exposed to a single high volume of eccentric muscle actions will experience significant muscle damage and soreness (blister) if they have not been allowed to build the resiliency (callus) to high intensity eccentric muscle actions.**

**Deceleration and non-contact related Injuries**

ACL injuries occur with a four to six-fold greater incidence in female athletes compared to males playing the same landing and cutting sports (Hewitt 2010). **A positive deceleration strategy is a mix of: good technique, ability to positively accept high force and a high rate of force development to provide joint stabilization quickly is the ideal recipe for high performance and durability.** It is suggested that athletes who rely heavily on elastic energy in their athletic performance and lack high levels of muscular strength may be at greatest risk for injury during hard decelerations. Elastic energy can assist and enable more force production during bouts of acceleration, but elastic energy does not aid in the ability to decelerate. These elastic dependent athletes are explosive,
but they are not strong. Due to their ability to accelerate, a false belief can be established, if we assume these athletes are strong, but the truth may be, they are far from it. Elastic dominant athletes have incredible accelerations which makes them most vulnerable when they lack the strength to decelerate from their high speeds. A lack of strength equals a lack of ability to positively accept and dissipate force (Alentorn-Geli et al. 2009).

If the musculature of the lower body in inadequately prepared to meet the demands during braking phases of movement, ligaments must absorb force and serve as the last line of defense against serious injury. Weaker athletes tend to rely more on ligaments for stability in high intensity situations, than stronger athletes do. This is known as ligament dominance (Hewitt 2010). When high amounts of force sustained over a short period of time leads to higher impulse forces, when this happens, there is a higher likelihood of ligament rupture. (Hewitt 2010).

High Intensity deceleration activities result in muscle breakdown, this impacts the contractile function. This performance detriment can lead to reductions in running speed, inhibited ability to stop quickly and decreased ability to provide structural stability. These are all factors involved with navigating the forces in sport and that may lead to potential injuries.

In a 2008 International Olympic Committee consensus statement regarding non-contact ACL injuries in female athletes. It was concluded; athletes are more susceptible to ACL injury when athletes lack sound deceleration technique and the strength needed to decelerate with greater knee flexion during such high intensity situations. Greater knee flexion during high speed decelerations places higher eccentric stress on thigh musculature.

The Role of a Strength Reserve in Sport…

Strength reserves are very important to repeatedly perform change of direction actions in sport successfully. A high strength reserve builds robustness and provides athletes the capacity to be aggressive with their sporting movements later on in matches. Weaker athletes are more prone to a reduction in their game speed when fatigue is present late in games. With a reduced ability to tolerate high deceleration loads, weaker athletes may be more prone to injury towards the end of games. A strength reserve can be defined as: The difference between maximum strength and the strength required to perform a skill under competitive conditions. (Bompa 2015).

Force to muscle cross-sectional area ratio (F/CSA) is complex ratio, but this ratio may bring valuable insight to better understanding sport requirements. Jones 2008 found that trained weightlifters have a significantly higher F/CSA in comparison to untrained lifters. This investigation provides good support for the need for athletes to be strong. In this study, stronger athletes were more capable and efficient when tolerating and accepting high forces. Greater CSA has been attributed to greater force generating ability, as a result, athletes who possess a greater muscle CSA, may be better equipped to tolerate and accept high forces better than weaker athletes. Athletes who possess a lower strength reserve may undergo higher levels of muscle damage during in match play, this mechanical breakdown results in greater losses in performance. (Young 2012)

Athletes with higher strength reserves are able work at greater intensities, while also staying at a submaximal level (Bompa 2015). These high strength reserves enable muscles to have a higher output, while still continuing to work at a lower intensity levels. A lower reserve means; an athlete must operate closer to their maximum strength levels during match play, such intensity can only be maintained for a brief period.
When an athlete lacks the eccentric strength needed to decelerate quickly from the high speeds of the game, the athlete may suffer severe loses in performance as the game goes on (Jones et al. 2017). An athlete who is eccentrically weaker will be challenged to maintain his/her ability to decelerate due to their lower strength reserve. Additionally, if an athlete is unable to dissipate deceleration forces appropriately, a disproportionate amount these forces will be transferred to the tendinous and ligamentous regions. An inability to positively accept the forces involved with deceleration combined with poor mechanics are of great concern for long-term joint health and can be primary sources of many non-contact injuries in sport (Alentorn-Geli et al. 2009).

Every athlete has an innate governor that will only allow them to approach a deceleration or change of direction with as much velocity as the can slow down. (Jones et al. 2017). In simpler terms; when an athlete is aware he/she may make sudden changes in their direction, an athlete may only run or sprint, as fast, as they have the strength to be able to stop.

**Stretch Loading, SSC and Change of Direction…**

Higher eccentric strength qualities can have a positive influence on an athlete’s movement strategy. Athletes who possess high eccentric strength abilities, are more likely to exhibit more assertive movement behaviors in sport, they do so by adding more intensity into their sporting maneuvers. When athletes can withstand higher eccentric loads, they lack hesitation as they approach high intensity situations for example; they will approach their stopping and change of direction moves with more speed. In change of direction movements, an increased speed and aggressiveness going into a hard deceleration can lead to high stretch loads on muscles and tendons. These higher loads are advantageous for change of direction performance in stronger athletes and may disastrous for weaker ones.

Stretch loads are similar to the type of load placed on a rubber band when it is drawn back and put on a stretch. When a rubber band is put under a high stretch load and then released, there is a powerful and dramatic effect. In sport, when athletes can tolerate these high stretch loads, athletes can leverage these loads and redirect them for the purposes of faster and more powerful propulsion in the newly desired direction. This interaction between muscles and tendons allows the body to effectively dissipate, redirect, and reutilize force.

Deceleration with the intent to stop is much different than deceleration with the intent to change direction. This is the difference between sticking and bouncing described by Zatsiorsky 2006. When sticking, force is dissipated into heat and the energy is lost. In bouncing, the goal is to not resist these external forces, but to reutilize them and possibly increase their movement speed using the elastic properties of the muscle. This complex interaction between the muscle, tendon, fascia and reflexes can aide in speed and quickness by reutilizing and redirecting force, this process is known as the Stretch Shortening Cycle. When a stretch is applied to a muscle, tension is created. Once a muscle is lengthened it holds an elastic tension. This elastic tension creates an increase in stored elastic energy. The stretch shortening cycle occurs when a rapid eccentric (lengthening) contraction is immediately followed by a concentric (shortening) contraction.

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“Deceleration with the intent to stop is much different than deceleration with the intent to change direction.”
Komi 2000 provides a model for SSC movements:
(1) the muscles are pre-activated during the eccentric phase of contraction
(2) the eccentric phase is short and quick
(3) there is an immediate transmission between lengthening and shortening contractions.

Cardinale et al. 2011 discusses the underlying principles for the stretch shortening cycle “If utilized effectively the stretch load provided by the eccentric action can contribute greatly to the production of force in the following concentric action of the muscle. Considering that SSC function is influenced by the rate, magnitude, and load of stretch, and is dependent on a short delay between the eccentric action and initiation of the concentric action. Well-developed technique in deceleration-acceleration sequences involved in change of direction tasks enable athletes to change direction faster.” The countermovement jump can provide insight into the ability to redirect and potentially increase force during the transition between eccentric to concentric.

Vertical jumping is a rapid change of direction activity that happens in the vertical plane. As the athlete descends, force is built-up eccentrically, at the bottom of the decent force can either be lost or redirected into the concentric or propulsion phase of the jump. Cormie et al. reported the rapid force built during eccentric contraction was significantly correlated to the rate of force developed concentrically. This interchange of force provides a powerful mechanism in human movement. Reversible muscle action can increase force and power output and decrease the amount of energy needed for contraction if it occurs directly following the stretch Zatsiorski 2006.

Accentuated Eccentric Load exercises (AEL) have been reported as a viable way to increase stretch load tolerance. Sheppard et al. 2010 used AEL squat jumps with experienced volleyball players overloading the eccentric portion of the jump then upon reaching the bottom of their decent load was released allowing for a transfer of more force into the concentric contraction. The author found improvement in vertical jump ability (COD in Vertical Plane) with these exercises. The author attributes these results to the following adaptations: improved efficiency of SSC and a heightened stretch load tolerance.

Although it sounds ironic, athletes can be explosive and also lack an ability to produce tremendous amounts of muscular force. Athletes with these characteristics tend to rely heavily on the elastic energy and the utilization of SSC in their athletic movements. This can be assessed in athletes by comparing their Countermovement jump performance and their Static Squat jump performance. This comparison allows for the calculation of the Eccentric Utilization Ratio (McGuigan et al 2006). Athletes who perform significantly better on the countermovement jumps are utilizing SSC, where athletes who perform better on the Static Squat Jump are utilizing more of their concentric force production during jumping movements. These athletes are commonly found in sports that are acceleration dominant, such as track sprints, jumps and throws. The challenge the at exists is: Elastic energy and SSC tends to only assist athlete’s in acceleration or re-acceleration based activities. Deceleration requires the ability to positively accept high loads in the form of muscular contraction, it is suggested that athletes who rely heavily on elastic energy in their athletic performance and lack high levels of muscular strength may be at greatest risk for injury during deceleration actions, because they lack an ability to positively accept and disseminate force. (Alentorn-Geli et al. 2009)

In sports, where stopping and change of direction at high speeds is part of the game, such as rugby, soccer, basketball, volleyball, tennis, etc. . . . relative strength and eccentric strength levels become much more of a priority in physical preparation in comparison to sports that do not require such changes
in direction. Athletes in sports where change of direction is not common, athletes may rely more on their ability to utilize SSC for propulsive purposes, while possibly being relatively weak, physically. These athlete’s will face a possibly higher risk of injury due to constant loading of ligaments and tendons to produce force instead of the muscles.

When athletes can take advantage of stretch loads, their movements are more powerful and more aggressive. As an example: an outside hitter with greater eccentric strength and stretch load ability, will approach the net more aggressively as they attack, when a wide receiver is trying to outmaneuver the coverage by the defensive back, a wide receiver with a greater eccentric ability will have an advantage, they can absorb more energy, so when both athletes are running a similar speed, the stronger athlete will be able to stop and cut harder than his opponent, creating greater separation.

**Role of Relative Strength in Change of Direction...**

Force is woven into every aspect of sport. In sport, the efficiency of all athletic actions (accelerating, decelerating and stabilizing) are based upon one’s ability to overcome and tolerate force. Being able to produce, transfer, and accept force is critical for any sport played where speed is a critical element.

Typically, when discussing force production, conversations tend to focus on the production of maximal force. Strength training for most individuals is centered around how much an individual can bench, squat, power clean, etc. However, when investigating strength’s relationship to change of direction the discussion needs to change direction and it should be directed toward how many times a person’s body weight can be lifted versus how much absolute load can be lifted. Relative strength is the amount of weight lifted (force produced) divided by body weight. During change of direction moves, the body may be exposed to forces over five times body weight when decelerating. Athletes without the strength to overcome these forces (eccentric strength) will take more time during change of direction and have an increased risk of injury. Relative strength has a strong link to change of direction in a multitude of sports and change of direction tests (T-Test, 5-0-5, 5-10-5). Athletes participating in football, soccer, rugby, basketball, and softball have had their change of direction performance significantly correlated to relative strength (Watts 2015). In fact, correlation was not found when comparing maximal strength to change of direction. It wasn’t until strength was explored in relationship to body weight that positive connection was established.

Higher physical strength levels enable athletes to get into more efficient and more aggressive athletic positions.

- Rouissi 2017 investigated the relationship between lower body strength and change of direction techniques in 31 young elite soccer players and found: stronger players performed their change of direction actions with more aggressive angles than weaker athletes did.

- Nimphius et al. 2010 provided evidence correlating relative strength levels and the ability to decelerate in softball players and found stronger players can be overcome the resistance of momentum much easier than athletes with lower relative strength levels.

- Keiner et al. 2014. also reported a strong association between relative strength and change of direction across multiple age groups and skill levels of soccer players. Specifically, the higher levels of relative strength allow athletes better control during high speed movements as the effects of momentum are decreased. This translates to better movement efficiency and control of the
torso which is vital in change of direction. Exposure to a high number of high speed change of direction movements place athletes under high workloads throughout a competition. Athlete’s with low relative strength levels are having to overcome greater forces than their stronger counterparts and are more likely to have their mechanics break down as fatigue sets in. Increasing relative strength is a key performance indicator for improving change of direction ability in athletes.

- Spiteri 2013 investigated change of direction performances between 2 types of team sport athletes, 12 stronger athletes and 12 weaker athletes. Spiteri found that athletes who have higher relative peak isometric force testing scores, demonstrated better change of direction performance in comparison to athletes with lower peak isometric force testing scores. The investigation also found that athletes who were stronger have the ability to decelerate and change direction faster, while weaker athletes took more time to slow down.

Plyometric actions are specific movements where a concentric muscle contraction is preceded by an eccentric muscle contraction. Typically, the eccentric contraction is combined with a storage of energy commonly known as a “pre-load”. Cutting during a change of direction action is categorized as a plyometric action due to the eccentric muscle contraction (deceleration) which precedes the concentric muscle action (acceleration). Similar to the cutting action, counter-movement jumping is also considered a plyometric activity. During the countermovement jump, athletes lower their center of mass quickly, then rapidly shift their movement from downward to upward, eventually, to the point of ground take-off. As the athlete drops into their preloading position, they must decelerate the mass involved with the countermovement action (deceleration). It is proposed that athletes who possess high relative strength values, drop into their pre-load with more aggressiveness (Rouissi 2017).

Miyama 2004, investigated the impact of drop jumping tasks on muscle function and damage. The drop jump action involves stepping off of an elevated object such as a box or bench to perform a rapid landing prior to jumping and leaving the ground. The drop jump exercise creates and overloaded resistance an athlete must decelerate against during the vertical braking phase, prior to the ground take-off. Since high intensity eccentric muscle contractions are known to result in increased muscle damage, Miyama’s study investigated the impact these overloaded actions muscle performance. Miyama found a decrease of nearly 40% in maximal force from before to after subjects completed 100 drop jumping movements. It is proposed the negative impact on muscle performance was a result in increased inflammation and damage to muscle tissue.

When an objects center of gravity is lower to the ground, the more stable the object becomes. As an example: Sports cars have a lower center of gravity in comparison to semi-trucks. The lower center of gravity of the sports car provides more stability at higher speeds to perform more aggressive turning maneuvers. As speed increases and aggressiveness of turning increases, a semi-truck becomes more vulnerable and unstable.

Similar to vehicles, an athletes center of gravity plays a key role in the success of change of direction movements. An athlete’s movement strategy determines the position of their center of gravity. The lower an athlete can drop their center of gravity, the sharper and faster shifts in direction will become. In order to lower their center of mass, athletes must rely more on lower body strength to hold the knees and hips in flexed positions. In the investigation by Spiteri, stronger athletes were not only able to decelerate faster than weaker athletes, stronger athletes had a lower the center of gravity in comparison weaker athletes, when performing the change of direction task.
When improving change of direction ability, these studies validate the need and the importance lowering the center of mass during change of direction tasks. As discussed previously, for athletes to lower their center of mass, there is an increased demand placed upon the lower body musculature. Lowering the center of mass requires increased flexion of the knee, hip, and ankle. Moving into these more flexed joint positions requires a greater level of strength. In such scenarios, the length tension relationship (Gordon 1966) of muscle becomes an element to take into consideration. Muscles are stronger when muscle fibers are at shorter lengths and muscles are weaker when they are at longer lengths.

Muscular strength is joint position specific; as joints flex and extend, muscle fibers within muscle bellies are required to lengthen and shorten. As joints extend, the extensor muscle group is shortening, while the flexor muscle group is lengthening. This concept is critical because the length of a muscle dictates the strength of a muscle. Actin and myosin are two primary contractile proteins found deep within muscle and are responsible for mechanical function of muscle contraction. The longer a muscle is elongated, the less leverage there is to generate force. Lessened leverage is a result of less myosin and action overlay. When a muscle is shortened, there is a greater overlay between action and myosin, this improves mechanical leverage and promotes greater strength. This underlying principle is reason for why athletes are much stronger in ¼ squat exercises in comparison to performing parallel squat exercises. In the parallel squat exercise, the athlete must lower their center of mass further and as a result, muscles of the thigh are put in more lengthened position in comparison to the ¼ squat. Muscles can get stronger in lengthened positioned, but it requires a specific focus on strengthening larger ranges of motion than an athlete may undergo or perform when in sport. When an athlete can attain strength in larger ranges of motion, they improve their injury resiliency and can begin to may begin to use lower positions in their change of direction moves, making them more aggressive.

**Strength training in ranges of motion that are just beyond the ranges of motion they perform in sport, may serve as a teaching tool that equips athlete with the strength to perform in new and more efficient ranges of motion.**

**Strength Training for Better Change of Direction…**

*Higher eccentric strength allows shorter change of direction times by allowing them to tolerate greater breaking forces and perform a faster transition into the propulsive phase (De Hoyo 2016).* When most people discuss eccentric strength training, traditionally the topic is focused on slow eccentric strength movement while. During slow eccentric strength exercises, muscles are exposed to long periods under tension during the eccentric yielding/lowering portion of a movement. This can be done with maximal, submaximal and supra maximal weight (greater than the amount that can be lifted concentrically).

Jones 2009 found greater change of direction speeds to be associated with greater linear sprinting and eccentric hamstring strength. In addition, findings suggest that slow-reactive (eccentric) strength is
more closely related to change of direction speed than fast reactive strength. Research continues to present the positive effects of eccentric strength training actions has on sport performance. The eccentric focus has a profound effect on the muscular architecture and recruitment patterns of a muscle. Improvements in muscle architecture from increased cross-sectional area, stronger muscle/tendon junctions and increased fascicle length can improve the muscles resiliency to high speed loading. The adaptations from these exercises can improve the athlete’s ability to dissipate force, but as discussed earlier dissipating force and redirecting and reutilizing force may be different skills. When using slow eccentric or exercises where there is not an intent to rapidly redirect force an athlete can disrupt the function of the stretch shortening cycle and the desired transfer to change of direction may not occur.

Mike et al. 2017 researched adaptations to eccentric exercises comparing contraction durations (2sec, 4sec, and 6sec eccentric). The authors expressed a potential decrease in the SSC with a 6sec eccentric contraction as elastic energy was lost as heat and not transferred to help contribute to concentric force production. This loss of force production and negatively affect the athlete’s ability to express force explosively. Fast or reactive eccentric exercises may provide a superior benefit to improve this redirection and reutilization of force.

In sport, change of direction occurs in many ways: moving linearly to laterally or laterally to linearly with a cutting move, reversing a movement direction as in a side to side motion or when dropping down prior to jumping upward. There are many more examples, but what is important to consider is; all of these sport movements require muscles and joints to make large transitions in their function. During change of direction activities joints must either flex, extend, or rotate.

Change of direction actions are very complex and very unique sport skills (Salaj 2011). When taking a deeper look into change of direction tasks and the role joints and muscles play. During sport actions, as joints move from flexing to extending or from rotating in one direction to another, muscles are also moving from shortening(concentric) or lengthening(eccentric) or from lengthening to shortening, all while under high tension. The ability for muscles to be highly functional as they transition from eccentric to concentric or from concentric to eccentric while holding tension, becomes a very sport motion specific characteristic.

Bouncing exercises utilize an explosive rebound in squatting or lunging movements with additional load, in which the athlete will actively drop into their bottom position. Explosively stop their downward momentum, then fire back up into the starting position. By overloading the musculature through increased rate of loading with the intent to redirect force as quickly as possible, the body is forced to learn to quickly overcome momentum and redirect energy. This shortening of time during the changeover from the eccentric contraction to the concentric propulsion phase can be looked at like the amortization phase in jumping. By loading muscles in this way, practitioners can load muscles around specific joints and train the ability to change of direction against forces that is comparable to what may be seen on the field or court. In addition to positively influencing an athlete’s athletic performance eccentric based excises provide an injury prevention aspect as well.

Older athletes competing in jump based sports, such as volleyball, must tolerate high quantities of landings from practice and competitions. As a result of withstanding these high landing forces, joint trauma and early arthritic symptoms are common. In these situations, high eccentric quadriceps strength has been shown to provide support by helping dissipate force and protect the joints from incurring more damage. Ali 2012 investigated the relationship between quadriceps strength to osteoarthritis and found stronger quadriceps to be a protective mechanism against knee osteoarthritis.
Increasing lower body eccentric capacity to better redirect force is vital, but if the musculature of the trunk is unable to maintain rigidity and proper posture during these intense cutting actions, change of direction performance will still suffer. De Hoyo 2016 investigated the impact from 10 weeks of eccentric overloading on change of direction performance in U-19 football players. This study found substantially better performance in change of direction performance as a result of the 10-week eccentric overloading routine. These results included: ability to tolerate high braking forces better, allowing for shorter ground contact times during braking, reduced time spent braking during cutting action and an increase in propulsive impulse forces.

Similar to how athletes decelerate and change direction on a soccer pitch, basketball court on the football field. Jumping sports such as volleyball demand a great amount of change of direction. Not solely from the activities involved navigating court space during a match, but also during the jumping action. Typically jumps in volleyball take place with a countermovement prior to jump take-off. The counter movement prior to take off is when an athlete drops his center of mass to enhance a preload or high stretch on the lower body muscular. This dropping action prior to a vertical upward motion allows for greater an athlete to generate more force and improve their vertical jump displacement.

Sheppard et al 2008 investigated the relationship between strength and power on jump performance in 21 elite volleyball players. When comparing the physical characteristics of elite volleyball players. Sheppard emphasized the strong need for athletes to be able to tolerate the high loads involved with the “pre-loading” activity that occurs, just before the athlete transitions from lowering their center of mass to raising their center of mass as they begin the upward. Sheppard concluded: athletes who possess good tolerance to high stretch loads (high deceleration loads) are more likely to be more successful in their sport. When performing fast or reactive eccentric exercises it is very important that the athlete’s intent is to change over from eccentric to concentric as rapidly as possible and with a maximal effort. Bobbert 1990, suggests that training should challenge the neuromuscular system to generate as much muscular tension as possible, then reverse the movement action as quickly as the athlete can. Initiating this type of training stimulus will result in an increase in upward acceleration speeds during jumping, shorter ground contact times and higher vertical jump displacements.

Conclusion

Change of direction is viewed as a key performance indicator for various field and court based sports. An athlete’s capacity to decelerate and reaccelerate in multiple directions, multiple times in a game may potentially be the deciding factor between wins and losses. While performance in these areas has been shown to improve with higher levels of strength, performance in injury prevention and increased longevity in their sport is attributed to higher levels of strength.

Improving eccentric, relative strength, stretch load tolerance, and SSC efficiency are key factors for improving the ability to rapidly change direction throughout an athlete’s career. Eccentric and relative strength should be addressed throughout the competition calendar in appropriate volumes within a properly periodized plan to aid in continual development of change of direction.
References:


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