Rate of Force Acceptance as an Injury Prevention Strategy in Athletic Populations

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SUMMARY

In the pursuit to better create injury prevention strategies, it is important to dissect and learn more about the mechanisms of injury. In the training environment, high performance practitioners typically associate the concept of rate of force development (RFD) with acceleration characteristics mainly in the form of concentric focused exercises (e.g. sprints, jumps, throws, and pulls). Although the literature shows a strong relationship between athletic activities, RFD, acceleration, and concentric based movements, the underlying factor associated with injury is often ignored. Research suggests that injures are typically correlated with eccentric muscle actions (11,15,21,22,23). The premise of this article is to bring awareness to the rate of accepting forces rapidly for injury prevention.

INTRODUCTION

The ability to rapidly generate muscular force is a factor that separates athletes at various levels. Rate of force development (RFD) is the ability to produce rapid force movements under significantly short time periods. It is defined as the slope of the force-time curve obtained for any given type of muscle action (1). Although there have been several important findings correlating rate of force development to athletic performance (14), injury prevention is another underlying factor under the performance umbrella. Since decelerating based movements typically occur eccentrically, it is important to attain a high level of strength and eccentric rate of force acceptance (RFA) to help prevent injuries.

IMPORTANCE OF ECCENTRIC RATE OF FORCE ACCEPTANCE ON INJURY

Human musculature acts to manipulate forces in one of three conditions to produce skeletal movement: Eccentrically absorbing (muscle lengthening), isometrically redirecting (no change in muscular length), and concentrically applying (muscle shortening). The inability to tolerate high forces rapidly in either of these muscle actions is a commonly overseen mechanism of injury. However, since practitioners typically associate performance with speed and quickness, it is important to understand that these movements are primarily concentric based and focused on acceleration. Noncontact movement injuries have been linked with all causes of severe injures (2). Straining injuries are amongst the highest ranking and tend to result from stretching forces leading to structural changes within the tissue (19). Existing evidence have shown noncontact athletic activities such as jumping, landing, turning, twisting, running, and kicking to play a prominent role for injury occurrence (11). These activities share a common denominator: the ability to match and overcome initial ground contact forces under 250ms driven strictly from eccentric muscle actions (22); an underestimated factor associated with injury. For example, planting the foot on the ground requires the ability to maintain strength and stability within all joints as the initial ground contact is made. Hence, the importance of eccentric RFA. In other words, athletes must be able to match the speed at which contact is made and apply a force great enough to meet and overcome the initial onset of stimulus.

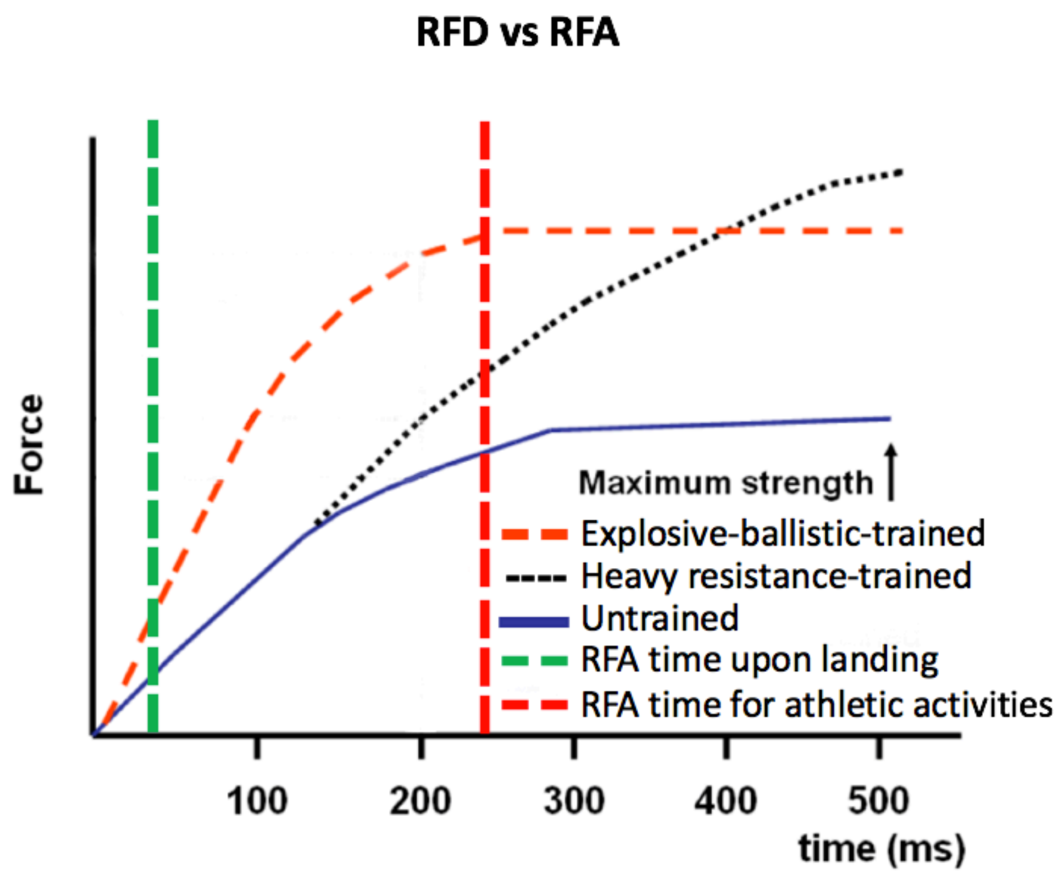


Figure 1.

Graph illustrating the difference between rate of force development and rate of force acceptance.

NERVOUS SYSTEM AND RATE OF FORCE ACCEPTANCE ON INJURY

Human movement is a process; it is also the product of many complex biological systems. Without the deep interaction and simultaneous involvement of these systems, human movement could not take place (20). To better understand these systems, we can use the following analogy: the nervous system functions in a manner that is similar to how a driver operates a vehicle. Just as a driver controls the direction and speed of the vehicle, the central nervous system is responsible for controlling the speed and direction of human movement. If and when, the nervous system loses control, it can result in excessively higher forces being placed on ligamentous structures (10). It has been shown that stronger athletes produce more force at critical time intervals of 50ms, 90ms, and 250ms (15,21,23), which increases their chances of avoiding injury. Since athletic demands of sport occur less than 250ms (22), the ability to generate peak forces under this time frame will allow a high force tolerance for muscles, tendons, and ligaments during athletic participation. An athlete who takes less than 250ms (22) to produce peak force is potentially at a higher risk of not being physically prepared to take on the impact of high forces associated with athletic competition. In other words, an athlete who is running, cutting, or decelerating, must overcome high external forces to help avoid vulnerable positions.

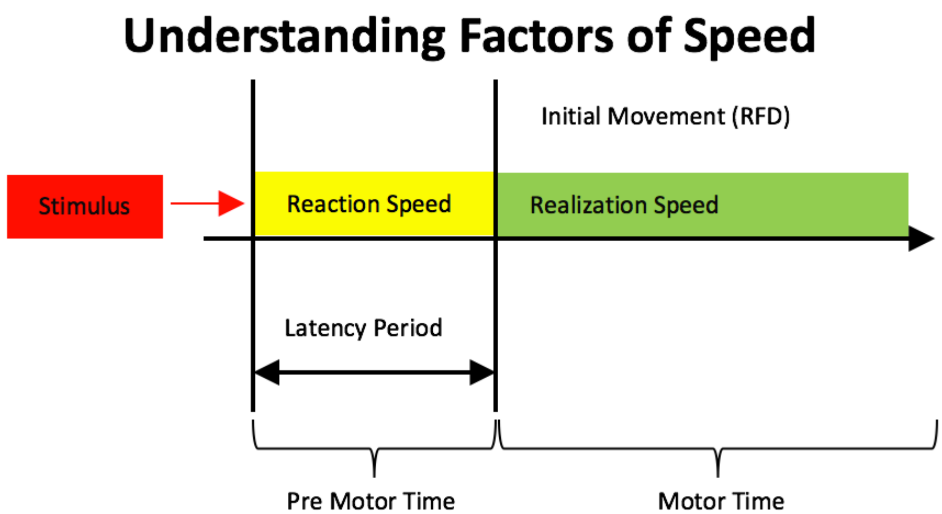


Figure 2.

Basic areas of speed abilities representing the specific periods of time that are associated with speed. For example, a gun firing (stimulus) for a sprinter followed by their ability to react to initial stimulus (latency period), and finally their initial movement (realization speed).

STRENGTH'S ROLE ON RATE OF FORCE ACCEPTANCE

The evidence suggests that strength serves as the foundation for all other essential athletic characteristics (24). By building a solid strength foundation, athletes are suited with a concrete strength base allowing factors relating to athleticism to adapt more efficiently. In sport, athletes are constantly exposed to environmental factors that create potential for injury (18). Landing, decelerating, or changing direction, requires eccentric strength to slow down the forces involved with momentum. Not only is eccentric strength required when participating in athletic activities, but also the neural capacity for recruitment during athletic demands (RFA). Studies have shown eccentric landing forces peaking between 0-30ms upon ground contact (4). Two-footed landing forces have been found to range from 3.5-7.1 times body weight (8). As athletes reach higher velocities, the magnitude of these loads increase exponentially (18). In order to tolerate these factors, the quality of our brakes (eccentric strength) and RFA must exceed the demands at which external forces act on the human body.

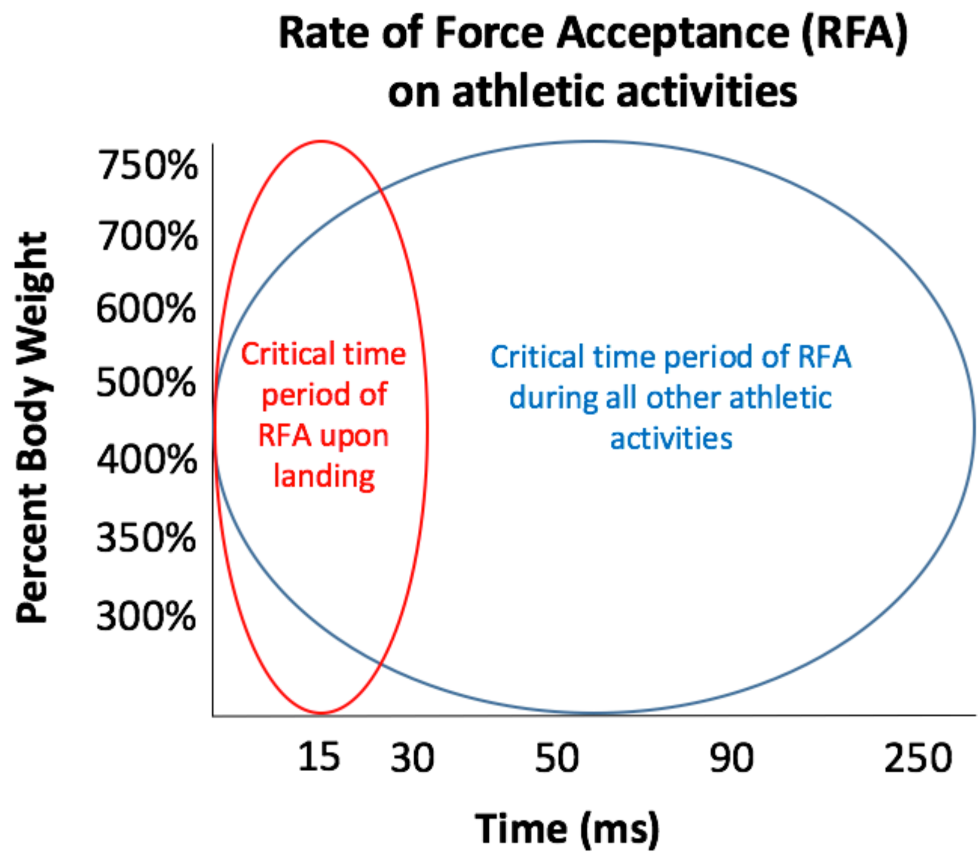


Figure 3.

Graph showing importance of eccentric rate of force acceptance during athletic competition (4,15,21,23).

MECHANISM OF BACK INJURY: *ECCENTRIC LANDING*

In jumping based sports, athletes are exposed to a potential spinal whiplash affect upon landing. This potential affect requires a certain level of strength and RFA in upper and lower body muscles to prevent spinal flexion while receiving vertical landing forces. Preventing lumbar flexion during these activities is not only a result of lower body musculature (e.g. glutes, hamstrings, quadriceps, etc.), but also those attaching directly to the vertebra: multifidi, quadratus lumborum, longissimus and iliocostalis (7); all of which help an athlete maintain an upright torso when strength and eccentric RFA are expressed. Figure 2 shows the favorable position (left) allowing the transfer of forces (compressive and shearing) into the hips helping protect the spine and rest of the skeleton (6). Figure two (right) shows an athlete who lacks strength or the ability to eccentrically recruit muscles quickly (RFA) under a high load matching ground contact times of 0-30ms (4). This forces us to explore strategies to improve our stability during vulnerable times by increasing the rate at which we can accept force.

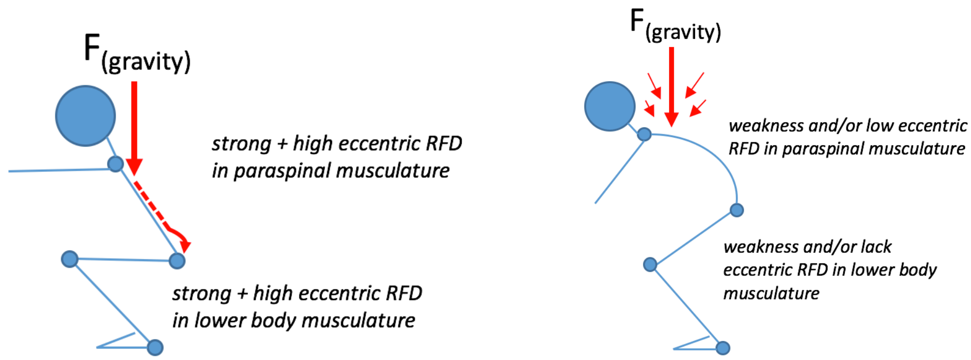
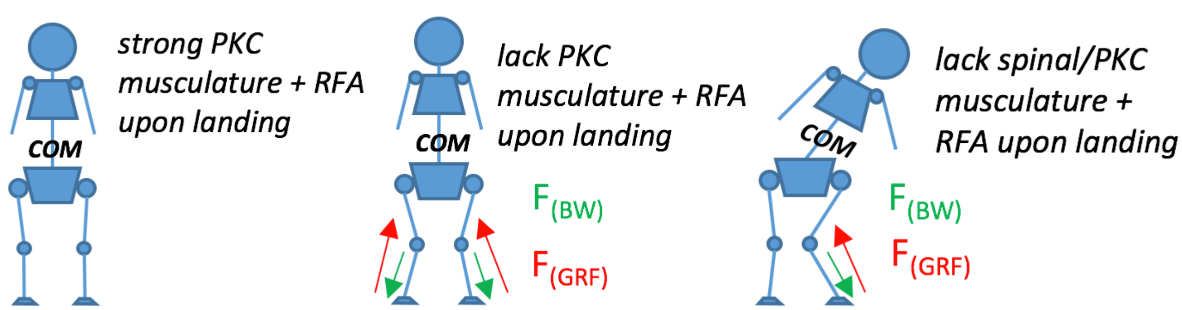


Figure 4. ***Left:*** *favorable position with stronger lower and upper muscular accepting high forces quickly.* ***Right:*** *vulnerable position with a weaker lower body resulting in less force absorption from the legs and more use of the back to absorb force (17).*

MECHANISM OF KNEE INJURY: *ECCENTRIC LANDING AND CHANGE OF DIRECTION*

With an estimated high of 80,000 anterior cruciate ligament (ACL) injuries occurring annually in the United States (7), it is important to understand the mechanisms in order to help prevent them. Evidence suggests that most ACL injuries occur during noncontact movements such as decelerating, pivoting, or landing (9). Ligament dominance is a condition where muscles lack the ability to absorb ground reaction forces (10). This leaves joints and ligamentous tissue no other option but to absorb these forces resulting in potential ligament ruptures. Musculature responsible for stability of the knee comprise of the gluteals, hamstrings, gastrocnemius, and soleus (10). Weakness or inability to fire these muscles quickly is a common mechanism of ACL injury. Newton's third law of motion states that for every given action there is an equal and opposite reaction. When a volleyball player is landing from a jump or a soccer player is changing direction, there is an equal and opposite force directed toward the body's center of mass (COM) (figure). These reaction forces are two to three times the initial force (10). If our trunk (typically the center of mass) is shifted away from ground contact by lateral flexion or trunk instability, GRF will follow in the direction of the trunk (COM) causing force vectors to place a valgus force on the knee (figure 3).



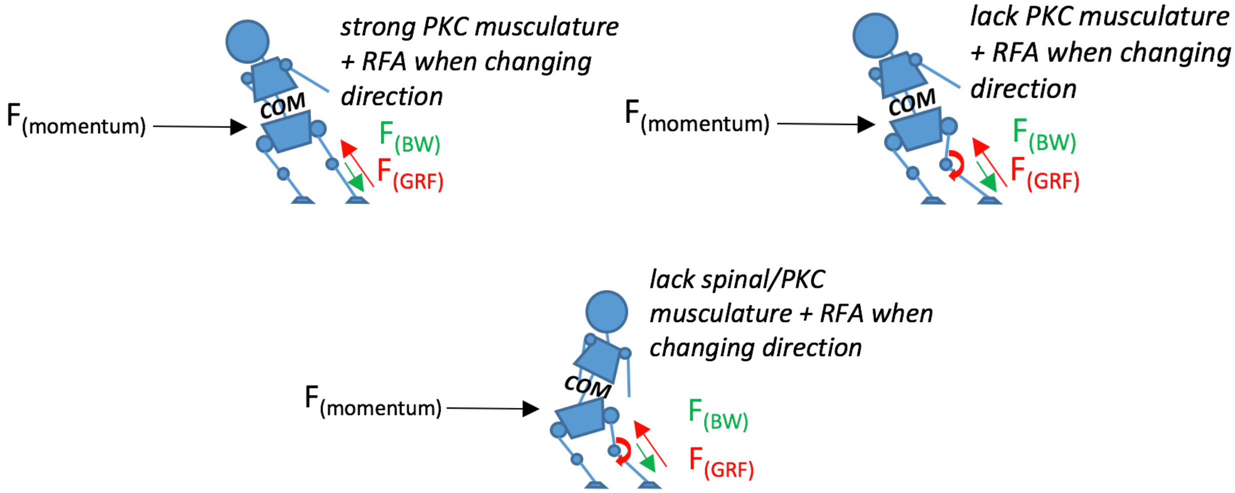


Figure 5. *Mechanisms of ACL injury upon landing and changing direction. PKC = Posterior Kinetic Chain (spinal erectors, hip external rotators, and hip abductors); RFA = Rate of Force Acceptance; BW = Body Weight; GRF = Ground Reaction Force*

UNDERSTANDING RATE OF FORCE DEVELOPMENT: *IMPORTANCE OF INTENTION ON NEURAL RERUITMENT*

To better understand eccentric, we will discuss concentric. Although rapid movements are important, the intention to move rapidly is another underlying factor. By observing the force-time curve, we can expect higher accelerations during a lighter loaded movement versus the contrary. Studies have shown that training with light loads of 15-35% of one's repetition maximum (RM) helps improve the high velocity portion of a force-time curve (12,16), while training with heavy loads (90% 1RM) improves the high force portion assuming maximal intentional dynamic efforts (12). In other words, lighter loads lead to faster athletic movements while heavier loads lead to higher force production. However, since movement velocities are determined by impulses applied by the musculoskeletal system to accelerate external load (16), contrary research evidence exists. Behm and Sale compared isometric/isokinetic protocols to help explain the justification behind intentional explosive movement on velocity-specific responses of an isometric versus isokinetic ankle dorsiflexion (5.23 $rad \cdot s^{-1}$). While attempting to move quickly under both scenarios, respectively, results showed similar high velocity-specific responses during both protocols (3). Therefore, attempting to move quickly under higher resistances was concluded to be a better method for improving rate of force development as the heavier loaded protocol yielded the generation of higher force (3). Though it is unclear which training method will elicit greater rate of force development adaptations, both mechanisms are important. Strength professionals are constantly working to improve the ability to tolerate forces at unpredictable intensities for the sake of injury prevention. Therefore, by training with light/heavier loads (15-35% and 85-90% 1RM respectively) and producing maximal dynamic efforts with intent, we are stimulating two underlying factors relating to injury prevention: speed of force and the ability to elicit force tolerance at high speeds. By stimulating these types of adaptations, we are not only preparing athletes to tolerate forces at a rate less than 250ms (22), we are also prepping them to express higher percentages of their overall strength during these vigorous times.

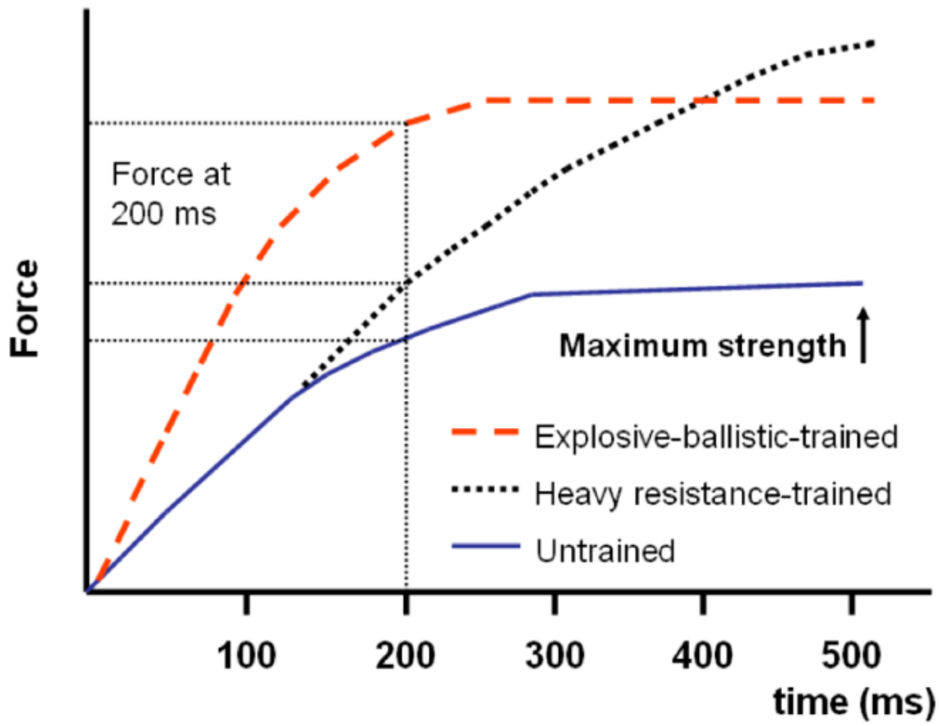


Figure 6. *Rate of force of force development (25) – Founded on the idea of concentric activity: By examining the graph, we can see that maximum concentric force output is reached at higher time intervals whereas lower concentric force outputs are seen during lower time intervals.*

UNDERSTANDING FORCE VECTORS

Force is generated by the ability to either push or pull against a given object. In order to describe how objects act in relation to one another, forces possess vectors that contain a magnitude and a direction. In an athletic environment, athletes work to manipulate three external forces to produce movement: contact forces (forces transferred from one object to another), non-contact forces (e.g. gravitational force acting on an object or person), and air resistance (13). By understanding force vectors, we can begin to appreciate the need to position our bodies in favorable ways to absorb, redirect, and apply forces more efficiently. By doing so, we can improve qualities relating to athletic performance and injury prevention. By improving our body positioning, we can achieve positions that improve the vectors in which we receive and apply force. For example, by lowering our center of mass and positioning our levers appropriately when changing direction, we improve efficiency. The ability to manipulate force vectors is a highly sought after characteristic of elite athletes.

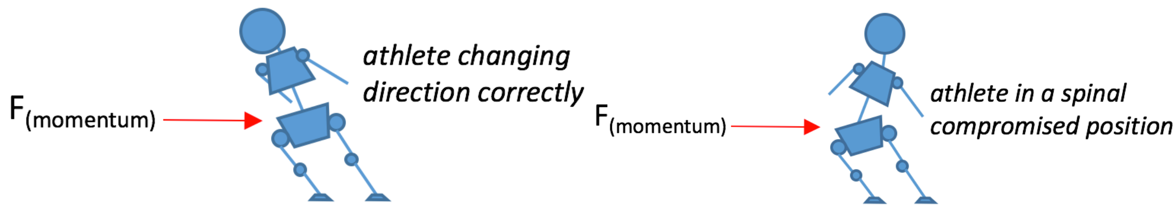


Figure 7.

Left: *Athlete maintains proper force vectors giving them the advantage to change directions more efficiently.* ***Right:*** *Athlete lacks the ability to maintain rigidity leading to the inability to maintain proper force vectors.*

CONCLUSION

Although producing high forces is important, perhaps the most important factor for injury prevention in sport is the ability to decelerate against the forces occurring in less than 250ms (22). It is important to respect and train concentric action to improve athletic abilities (e.g. speed, power, and quickness), but the research discussed in this article supports the idea of also working to improve the speed at which we can absorb force. Moreover, these training qualities feed off one important element: Strength. Newton's second law states that higher forces result in higher accelerations (f=ma). Without a higher force production, athletes are limited to the demands of external force tolerance. Furthermore, by emphasizing eccentric muscle actions under light and heavy loads, respectively, we are assuring that two underlying factors relating to injury prevention are stimulated: speed of force and percentage of total force applied during decelerating demands. Applying these vital factors to our understanding of force vectors increases the likelihood of our athletic population to stay injury free and equipped with the prerequisites for enhancing all other athletic abilities. We can apply corrective exercises, monitor training loads, and prescribe self-care strategies in hope to limit potential for injury, but if we are not training to tolerate high eccentric force actions, we will continue to see injuries within the athletic population.

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