

Neural Circuitry and Muscular Contraction during a Countermovement Jump.

The improvement of muscle power output in the lower limbs is relevant to most sports. Therefore understanding how to advance an athletes' rate of force development is probably essential to strength and conditioning coaches. The speed-strength nature of plyometric exercises use the stretch-shortening cycle (SSC) to enhance explosive power (Linthorne, 2001). This article outlines the muscle-tissue function mechanics that are instrumental to the SSC when performing a countermovement jump to educate how plyometrics can improve RFD.

The Countermovement Jump (CMJ)

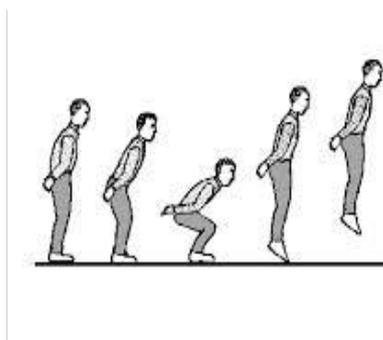


Figure 1. Sequence of CMJ. Standing start - move eccentrically down - immediately recoil concentrically in to a jump. Hands on hip (or behind the back) limits the impact the upper limbs may have on jump height.

The Stretch Shortening Cycle (SSC) of a plyometric movement consists of 3 phases:

- 1) Eccentric phase - loading through a pre-activated muscle-tendon action from a lengthening contraction. (Figure 2).

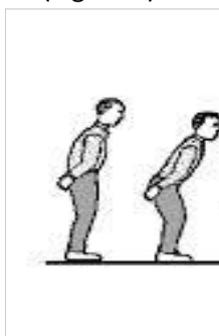


Figure 2. Eccentric phase (Lowering). Hip flexion is controlled by the glutes and hamstring. Knee flexion is controlled by eccentrically contracting quad muscles.

- 2) Amortization phase - The lowest point of the movement. This is the transition from eccentric to concentric. There should be no pause at this stage in a CMJ. (Figure 3).



Figure 3. Amortization phase. A split second moment when eccentric lowering springs into a concentric rise.

- 3) Concentric phase – This is an immediate muscle-tendon shortening reaction (Taube, Leukel & Gollhofer, 2012) that manifests into a jump. (Figure 4).



Figure 4. Concentric phase. Explosive and reactive hip and knee extension movements.

How it Works.

The eccentric loading phase initiates a stretch reflex and primes motor unit recruitment for the concentric reaction (Chimera et al, 2004). Additional force is created from stored elastic energy within connective-tissue components of the muscle (Costangna & Castellini, 2013). Continued plyometric training should desensitise the golgi tendon, which should result in a more explosive jump performance.

Understanding the Component Mechanisms.

- Voluntary Contraction

A voluntary contraction initiates the eccentric phase within the CMJ. A nervous impulse travels from the brain via the central nervous system (CNS) where efferent nerve fibres deliver the action potential to the appropriate motor units (figure 4).

The number of motor units activated depends on the resistance detected (Wilmore & Costill, 2004). For example observe the 2 motor units illustrated in figure 4. If the resistant force is low, then only motor unit 1 need to be activated. If the force detected is greater, then motor units 1 & 2 will be activated.

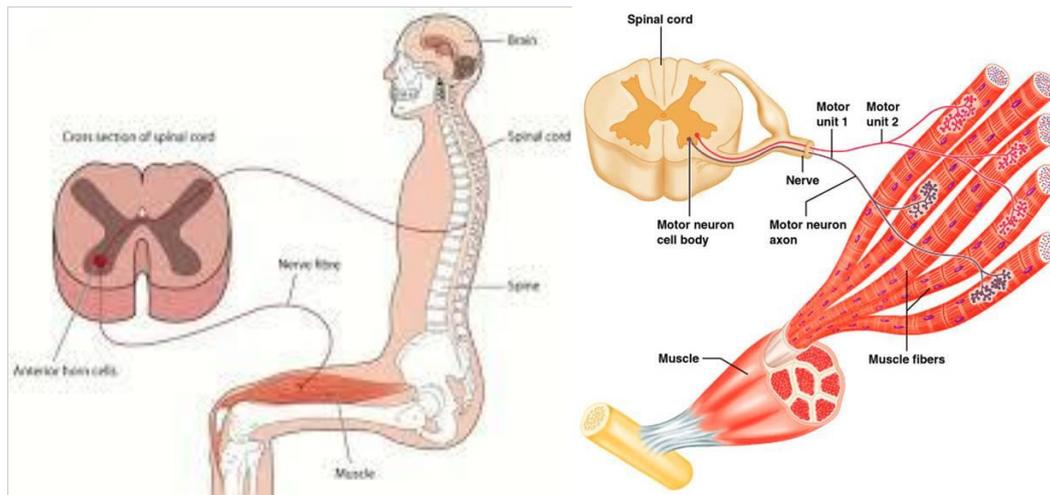


Figure 4. Signal pathway from brain to muscle. A motor unit is a single motor neuron and all the muscle fibres it is attached to. If a motor unit is stimulated, all attached muscle fibres will contract.

- Muscle Spindles

These cigar shaped organs lie parallel to muscle fibres and provide afferent signals back to the CNS about change in muscle length (Rainoldi & Gazzoni, 2011). When lowering into the amortization phase, a muscle-tendon stretch may become too large and an automatic protective response is triggered. In the case of a CMJ this would force the quadriceps muscles into a rapid leg extension (dive into phase 3 – concentric). This movement would be an involuntary muscle contraction as it is a reactionary response, a stretch reflex. (See figure 5).

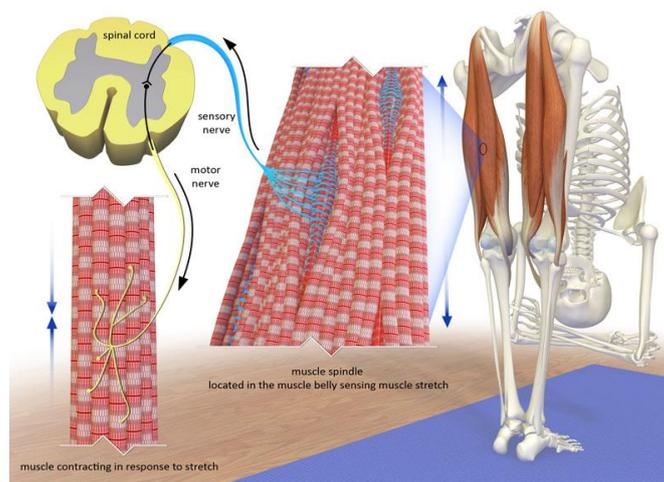


Figure 5. The spindles send messages to the CNS in response to the comfort level of the hamstring during the stretch.

- Golgi Tendon Organs

Golgi tendon organs are a similar device to spindles. They are a tension sensory receptor that is located within the muscle-tendon complex. They are so sensitive, they will respond to a single

muscle fibre contraction, and as such, they will restrict any potential injury threatening movement by exciting antagonist muscles (Wilmore & Costill, 2004). Continued plyometric training should desensitise the golgi tendon to these 'dangers' and facilitate a greater stretch within the elastic components (Twist, Gleeson & Eston, 2008).

The efficiency of the stretch reflex within the SSC is dependent on the transfer of elastic energy and muscle-tendon stiffness collected from the eccentric phase (Taube, Leukel & Gollhofer, 2012).

- Series and Parallel Elastic Components

The stretch of muscle-tendon complex as it lengthens through the eccentric phase is the primary factor to energy storage held in the series elastic components (SEC) (Blazevich, 2011). The SEC is a contractile element within muscle-tendon that operates like a shock absorber as it transfers forces to the skeleton (HILL, 1970). As an individual approaches the amortization phase of the SSC, activated muscles stiffen and the tendon will continue to lengthen to the point of recoil (Blazevich, 2011).

Parallel elastic components (PEC) are a second viscous element or supporting fluid and membrane that exerts a passive force against the contracting muscle (figure 6).

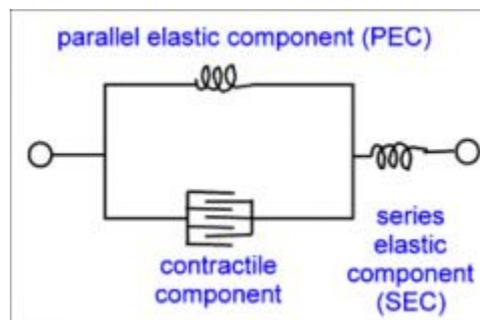


Figure 6. Contractile Components. The SEC spring action transfers loads to the contractile components. The PEC acts similar to a membrane. It naturally moves with the expansion and contraction of the contractile components, but does not transfer any loads.

CMJ and Training Implications.

The use of the CMJ as a demonstration tool provides a number of advantages for plyometric introduction. It outlines the 3 phases of a plyometric movement and emphasises the relationship the force produced by the recoil of the explosive concentric phase has with the loading within the eccentric phase. The movement pattern can be progressed into a series of jumps, hops or strides depending on your athletes' ability to land safely and correctly.

Why is Plyometric Training Important?

The ability of the neuromuscular system to produce increasing forces very quickly throughout muscle contraction is reflected by the rate of force development (RFD) (Aagaard, 2011). Progression of RFD from strength training has positively impacted neuromuscular activity (strength book). However, more explosive training, at lower loads, can also improve RFD (Aagaard, 2011). This suggests that a training continuum running from strength to speed can be established, and that if every aspect of that continuum is trained then RFD should improve (see figure 7).

Due to the explosive nature of the movement, plyometrics may be used to develop the speed-strength section of the continuum.

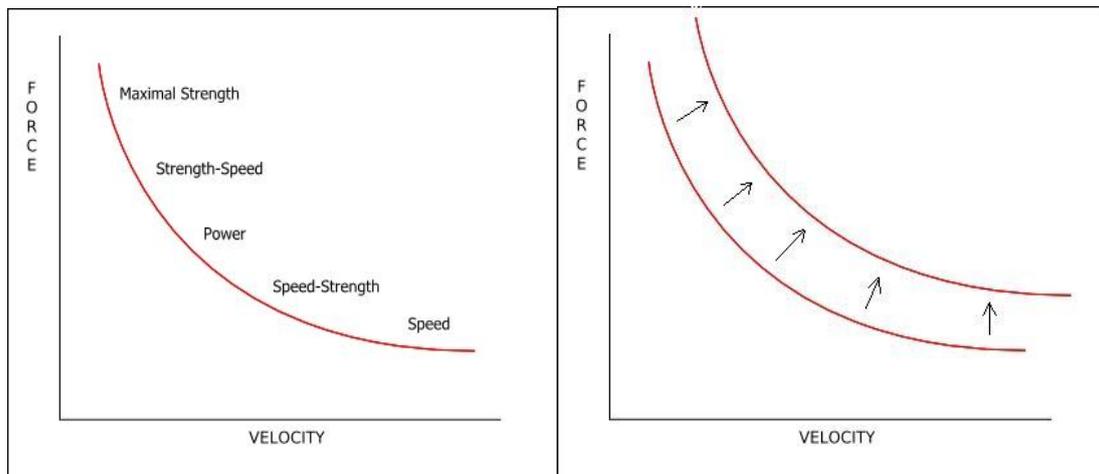


Figure 7. a) Force-Velocity curve that indicates a max strength- speed continuum. b) Arrows suggest that improvement at all stages should enhance RFD.

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