VersaPulley™ Flywheel-Inertial Training

Science of Flywheel Training and its Role in Athletic Performance, Injury Prevention, and Rehabilitation

The purpose of this paper is to discuss the scientific basis of eccentric training and its role in athletic performance, injury prevention, and rehabilitation as it relates to the VersaPulley™. Unlike traditional weight training where the load is dependent on gravity exerting its force upon the lifted object, flywheel training is driven by inertia. This inertia created during the concentric phase of movement imparts a rotational force into the flywheel. Breaking those inertial forces created during the concentric portion of the exercise creates an eccentric overload. Not only does the versatility of the VersaPulley™ facilitate eccentric overloading in the vertical plane e.g. to enhance movements such as jumping, but it also trains decelerating movements in the horizontal plane. These horizontal movements are pertinent for change of direction and braking abilities of both the upper and lower extremity. The innumerable exercises utilizing the conical flywheel can be used to rehabilitate musculoskeletal injuries, decrease injury risk, and develop strength and power while enhancing sports performance.

“The VersaPulley has tremendous versatility from beginner to elite-performance training”
- Mark Verstegen, Founder|EXOS

Key Benefits of Flywheel/Eccentric Training

Hypertrophy/Strength/Power Development

- Higher muscular forces (2-3 times (B. Johnson, 1972; D. Jones & Rutherford, 1987) or 20-60% greater (Hollander et al., 2007)) produced compared to concentric training (Roig et al., 2009a).
- Lower metabolic cost of work (Roig et al., 2009a).
- More effective at increasing total and eccentric strength (Roig et al., 2009a).
- More effective at increasing muscle mass (Norrbrand, Pozzo, & Tesch, 2010; Roig et al., 2009a).
- Superior adaptations in strength, muscle mass, and power possibly mediated by the higher forces developed during this type of exercise (LaStayo et al., 2003; Roig et al., 2009a).
- Adaptations highly specific to the velocity and type of contraction (Roig et al., 2009a).
- Early and robust neuromuscular adaptations enhance muscle strength, power, and size (Greig, 2008).

- Adaptations can occur at as low as 45% of maximal contraction (Nichols, Hitzelberger, Sherman, & and Patterson, 1995).

- Faster gene expression pattern and induced shift towards a faster muscle phenotype for explosive power (Friedmann-Bette et al., 2010; Hortobagyi et al., 1996; Hortobagyi et al., 2000; Mayhew, Rothstein, Finucane, & Lamb, 1995).

- Improved adaptations associated with increasing the muscle's ability to generate fast, explosive movements (Friedmann-Bette et al., 2010; Hortobagyi et al., 1996; Hortobagyi et al., 2000; Mayhew et al., 1995).

Performance

- Eccentric strength has been proposed as the main determinant for COD (change of direction) ability (P. Jones, Bampouras, & Marrin, 2009).

- Multidirectional eccentric training improves functional performance measures such as COD, linear sprinting and jumping in different axes (Gonzalo-Skok et al., 2016).

- Greater breaking and propulsive forces, impulses, and a lower contact time during side step and crossover cutting (de Hoyo et al., 2016).

- Increased post-activation potentiation in jumping, sprinting, and COD tasks (de Hoyo, de la Torre et al., 2015).

- Increased reactive strength (de Hoyo et al., 2015).

- An 8% increase in vertical jump (LaStayo et al., 2003).

Injury Prevention

- A warm-up strategy including eccentric overload training may acutely enhance physical performance and reduce the likelihood of suffering an injury (de Hoyo et al., 2015).

- Adaptations in the viscoelastic properties of the muscle-tendon complex result in improved ability to absorb and transmit forces, thus improving resistance to disruption (Yu, Furst, & Thornell, 2003).

- Effective at reducing muscle strains (Arnason, Andersen, Holme, Engebretsen, & Bahr, 2008; C. Askling, Karlsson, & Thorstensson, 2003; de Hoyo, Pozzo et al., 2015; Fernandez-Gonzalo et al., 2016; Mjolsnes, Arnason, Osthagen, Raastad, & Bahr, 2004).

- Increases ROM as a result of sarcomerogenesis (Butterfield, Leonard, & Herzog, 2005; Lynn, Talbot, & Morgan, 1998; O'Sullivan, McAuliffe, & Deburca, 2012; Yu et al., 2003).
- Enhanced motor control throughout a larger range of motion (O'Sullivan et al., 2012).
- Improved stabilization of the knee joint through decreasing acute fatigue measured by kinetic parameters (de Hoyo et al., 2015).
- Assists in controlling decelerative and stabilizing forces needed in overhead motions such as throwing, hitting, and serving, which have been cited as a possible contributor to shoulder injuries (Noffal, 2003).

Rehabilitation

- Effective in the rehabilitation of tendinopathies (Alfredson, Pietila, Jonsson, & Lorentzon, 1998; Alfredson, 2003; Langberg et al., 2007; Maffulli & Longo, 2008; Ohberg, Lorentzon, & Alfredson, 2004; Purdam et al., 2004; Roig Pull & Ranson, 2007; Stasinopoulos & Stasinopoulos, 2004; Young, Cook, Purdam, Kiss, & Alfredson, 2005).
- Tenocytes responsible for tendon repair, alter their gene expression patters, protein synthesis and cell phenotypes in response to eccentric loading of tendon (Maffulli & Longo, 2008).
- Reverses the degenerative process of tendons, and produces a more organized and normal extracellular matrix (Kongsgaard et al., 2009).
- Effective in the rehabilitation of muscle strains (C. M. Askling, Tengvar, Tarassova, & Thorstensson, 2014; Mendez-Villanueva et al., 2016).
- Effective in the rehabilitation following ACL injuries (Gerber et al., 2009).
- Effective in the rehabilitation of shoulder injuries (Noffal, 2003).
- Eccentric exercise as low as 45% of 1RM has meaningful adaptations for those who are deconditioned due to an injury (Nichols et al., 1995).

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Flywheel Training

Flywheel training utilizes forces generated from a concentric muscle action to impart rotation into a flywheel. This results in greater inertial forces that must be decelerated by the user creating a stimulus of eccentric overload to the muscle group(s) being exercised. VersaPulley™ is a device that uses flywheel technology for performance and rehabilitation. The device utilizes a rope connected to a cone-shaped flywheel. At the terminal point of the range of motion, the rope is completely untwined, and the inertia of the flywheel recoils the rope, demanding the user to decelerate it during the subsequent eccentric contraction. In a purely rotational inertial system, such as a flywheel, wheel angular acceleration is directly proportional to the torque applied (Pearson, Harridge, Grieve, Young, & Woledge, 2001).

Flywheel devices have been in existence since the late eighteenth century. Research in the area of inertia training dates back to the early 1900's by Krogh 1913, Hill 1920, and Hansen and Lindhard in 1923 (Hansen & Lindhard, 1923; Hill, 1920; Krogh, 1913). The use of such technology in performance was all but forgotten until the late 1980's and early 1990's when NASA (National Aeronautics and Space Administration) began examining ways to maintain lean muscle mass and bone density during extended travel in the zero-gravity atmosphere of space (Dudley, Tesch, Miller, & Buchanan, 1991). This lead to a re-exploration of flywheel technology as a potential method to solving this problem associated with long-duration space travel (Dudley, Tesch, Harris, Golden, & Buchanan, 1991). In the United States, flywheel training wasn't used in the high-performance setting until the advent of the VersaPulley™ in late 1990's. Its earliest adoption was seen within the private performance-training sector around that same time.

Eccentric Contraction Defined

An eccentric contraction of a muscle is classically characterized by the lengthening of a muscle while it's contracting. In other words, the forces being exerted on a given muscle are greater than the amount of force a given muscle can generate. This is also referred to as negative work, in which a muscle decelerates or absorbs potential energy (Hoppeler, 2015). The role of the eccentric contraction also plays a secondary role. When muscles are activated eccentrically immediately prior to shortening, they no longer act as shock absorbers: rather, they perform more like springs (Lindstedt, LaStayo, & Reich, 2001). This is directly related to the stretch shortening cycle (SSC) – the ability of a muscle to store and substantially amplify force and power production (Biewener & Roberts, 2000; Ettema, Huijing, van Ingen Schenau, & de Haan, 1990; Komi & Bosco, 1978). The differences between eccentric and concentric (shortening while contracting) are substantial. Not only does the muscle have different attachment and detachment rates of cross-bridges, but also the amount of forces (2-3 times greater) (B. Johnson, 1972; D. Jones & Rutherford, 1987) and metabolic cost (3.5-6 times less) (Hoppeler, 2015) resulting from an eccentric contraction differ greatly from its concentric counterpart.

DOMS

Eccentric contractions are often synonymous with DOMS (delayed onset of muscle soreness). While eccentric contractions can be responsible for DOMS, they are not always an outcome of this type of muscular contraction. In other words, neither muscle damage nor inflammation are prerequisites for stimulating positive muscle adaptations resulting from eccentric contractions (Clarkson & Tremblay, 1988; LaStayo et al., 2003).

Eccentric Overload

There is a distinct difference between eccentric loading and eccentric overload. To achieve an eccentric overload, forces must be greater than that of a 1RM concentric contraction. For example, during the eccentric phase of the supine leg press, one can lower about 40-50% more weight than one can lift during the concentric phase (Dudley et al., 1991). This is why traditional techniques of training are limited in their abilities to eccentrically overload the muscle.

Eccentric overload training can be a valuable tool to improve these areas, and in a very short period of time. Forces produced eccentrically are 2-3 times greater than those produced either isometrically or concentrically (B. Johnson, 1972; D. Jones & Rutherford, 1987). Since greater maximum force can be developed during maximal eccentric muscle actions compared to concentric or isometric muscle actions, heavy-resistance training using eccentric muscle actions may be most effective for increasing muscle strength (Brandenburg & Docherty, 2002; Hedayatpour & Falla, 2015; Hortobagyi, Barrier, & Beard, 1996; Hortobagyi et al., 1996; Hortobagyi, Devita, Money, & Barrier, 2001; B. Johnson, 1972). Eccentric overload training has also shown to provide sufficient hypertrophic stimulus for gains to be realized in a shorter time than more traditional 1:1 (concentric:eccentric) exercise training (English, Loehr, Lee, & Smith, 2014).

Benefits of Flywheel/Eccentric Training

There is a vast amount of evidence demonstrating the benefits of eccentric training as it relates to the improvement of athletic performance i.e. strength, power, hypertrophy, reduction of injury potential, and the rehabilitation of injuries (Alfredson, 2003; Gonzalo-Skok et al., 2016; LaStayo et al., 2003; Roig, Shadgan, & Reid, 2008). Many of these benefits are a direct result of architectural and physiological changes within the musculo-tendonous complex. These changes include, but are not limited to the remodeling of cytoskeletal proteins (actin, desmin, titin, actinin and nebuline) (Alter, 2004), increased levels of type I collagen (Langberg et al., 2007), and muscle-pennation angle (Sanz-Lopez, Berzosa Sanchez, Hita-Contreras, Cruz-Diaz, & Martinez-Amat, 2016).

Additionally, it is well established that unaccustomed eccentric contractions produce transient muscle damage, soreness and force impairments (Calixto et al., 2014; Proske & Morgan, 2001; Roig et al., 2009a), however, like any stimulus, there is an associated response. In the case of eccentric contractions, the response is a protective effect referred to as the repeated bout effect (RBE). The RBE refers to the adaptation whereby a single bout of eccentric exercise protects against muscle damage from subsequent eccentric bouts (McHugh, 2003; Nosaka & Clarkson, 1995; Nosaka, Sakamoto, Newton, & Sacco, 2001). While a complete understanding of all the adaptations surrounding the RBE is not well understood, it is established that these mechanisms are facilitated by an interplay between a number of mechanical, cellular and neural mechanisms (McHugh, 2003).

More notably, there is an increased "stiffness" of the muscle-tendon unit (Lindstedt et al., 2001), a remodeling of the myofilaments and the adaptation of the viscoelastic properties of the muscle (Yu et al., 2003), recruitment of slow contraction motor units, activation of a large number of motor units (neural adaptation), increased dynamic and passive muscular endurance (mechanical adaptation), longitudinal addition of sarcomeres, adaptation to the inflammatory response, and adaptation to maintain muscle excitation-contraction coupling (cellular adaptation) (McHugh, 2003; Miyama & Nosaka, 2007). The RBE has shown to take effect as recent as 24 hours (Chen & Hsieh, 2001)and up to as many as several weeks and possibly up to 6 months (Nosaka et al., 2001).

Initially it was believed that this protective effect could only occur under higher loads (McHugh & Pasiakos, 2004), however, a more recent study has eccentric exercise with preconditioned loads as light as 40% max (Lavender & Nosaka, 2008).

The RBE is another reason why eccentric training should have significant emphasis in a training program.

As mentioned above, the aforementioned adaptations stimulated by eccentric training lead to improved stiffness within the musculo-tendonous unit. This favorable adaptation enables a muscle to absorb and transmit greater forces. This is essential for when a muscle cannot absorb such forces, the surrounding structures (ligaments, bones, cartilage, and other soft tissues) must assist with this dissipation of forces – a dissipation to which they are not intended to handle.

While it would seem that an increase in passive muscle stiffness would limit joint range of motion, evidence leads us to believe the contrary. In fact, according to a systematic review by O'Sullivan in 2012, long-term eccentric training revealed improved flexibility (O'Sullivan et al., 2012). This improvement is attributed to an increase in the number of sarcomeres distributed in series, also known as sarcomerogenesis (Butterfield et al., 2005; Lynn et al., 1998; Yu et al., 2003). It has been proposed that sarcomerogenesis along with adaptations to the passive elements within the muscle create a shift in the muscle length-tension curve that consistently occurs with eccentric training (O'Sullivan et al., 2012). The resulting benefit includes greater motor control throughout a larger range of motion ultimately leading to improved performance and protection against injury.

Eccentric/Flywheel Training for Strength, Power Hypertrophy, Performance

Elevating performance and reaching one's ability begins with addressing the limiting factors. Once mobility and stability are optimized the functional groundwork has been laid to develop other performance parameters; these limiting factors are typically found in the areas of hypertrophy, strength, and power.

What are the benefits to strength, power, hypertrophy, and injury prevention when adding eccentric overload training? By adding something into a program that hasn't been done, significant increases in performance gains are seen. However, that can be said about any strength-related stimulus. But what is the benefit of introducing eccentric training into a training program, and does that benefit far outweigh the cost of not doing so? – What does the science indicate?

> *"With VersaPulley, you are not blindly training power. I can measure absolute maximum outputs and also sustainable power outputs."*
>
> - Jacques Devore | Founder Sirens and Titans Fitness, LA

The higher forces generated (2-3 times greater than those produced either isometrically or concentrically) (B. Johnson, 1972; D. Jones & Rutherford, 1987) through eccentric training, have shown it to be a superior method in developing both strength and hypertrophy (Hollander et al., 2007). Because it's more effective than concentric training at increasing total and eccentric strength, (Roig et al., 2009b) it should be used to enhance the effects of the typical training seen in most weight rooms around the world. Studies have shown that eccentric overload training is superior to eccentric underload in its ability to stimulate increases in strength (English et al., 2014), but even more significant was the speed in which training adaptations took place. When compared to traditional concentric/eccentric training, eccentric overload was the only training regimen to increase lower-body lean muscle mass and show improvement in bone mineral density after only 8-weeks of similar training (English et al., 2014).

Further studies examining eccentric overload training and its effects on muscle hypertrophy showed similar effects (de Souza-Teixeira & de Paz, 2012; Hedayatpour & Falla, 2015; Mayhew et al., 1995; Ojasto & Hakkinen, 2009; Tesch, Ekberg, Lindquist, & Trieschmann, 2004; Vikne et al., 2006; Walker et al., 2016). Eccentric overload training provides a sufficient hypertrophic stimulus for which gains can be realized in a shorter period of time compared to more traditional 1:1 exercise training (English et al., 2014). Greater hypertrophy was also reported following chronic resistance training comprising of coupled eccentric and concentric actions or eccentric actions compared with concentric actions only (Hather, Tesch, Buchanan, & Dudley, 1991; Higbie, Cureton, Warren, & Prior, 1996; Hortobagyi et al., 1995; Norrbrand et al., 2010) – this is another reason why utilizing eccentric overload training in conjunction with traditional weight training should be heavily considered. Put simply, greater muscle hypertrophy is a result of enhanced protein synthesis, which is a product of higher mechanical loading of the muscle. This type of mechanical loading is created by eccentric muscle actions (Norrbrand et al., 2010).

From a power development and application of force vantage point, higher muscle forces can be produced during eccentric contractions compared with concentric (Roig et al., 2009b). And while all types of training can improve power in multiple planes of movement, the specificity of training adaptation principle mainly prevails (Gonzalo-Skok et al., 2016). One particular study examined this specificity by programming exercises in both the vertical and horizontal planes. The results are likely what one would expect. Those who trained vertically improved in all planes, but made the most gains vertically (vertical jump), and those who trained multi-directionally also improved across the board, but gained the most multi-directionally (acceleration and change of direction) (Gonzalo-Skok et al., 2016). Research from 2016 indicated that those who train using eccentric overload were able to produce a significantly greater breaking and propulsive contact time (de Hoyo et al., 2016). This suggests that eccentric overload could be a fundamentally important mechanism underpinning change of direction ability (de Hoyo et al., 2016).

In short, neuromuscular and functional changes induced by exercise are specific to the mode of exercise performed (Hedayatpour & Falla, 2015). Therefore, by not performing exercises that encompass eccentric overload as a stimulus, an entire cascade of neural, physiological, and muscular adaptations will be neglected and underdeveloped.

Eccentric/Flywheel Training for Injury Prevention

The majority of non-contact injuries occur during the deceleration or eccentric phase of movement (LaStayo et al., 2003). Based on the increased risk of injury during these movements, many have called for the use of eccentric exercise in the prevention and rehabilitation of athletes (LaStayo et al., 2003). For example, an imbalance of concentric to eccentric strength of the internal to external rotators of the shoulder or the quadriceps to hamstrings of the knee, compromises the joint's stability thus increasing the contact and compression forces at these joints. Based on this, some have proposed that impairments in load-attenuating abilities are one such predictor of joint and ligament injuries (Hewitt, Stroupe, Nance, & Noyes, 1996). Another common injury to occur during the eccentric phase of movement is a muscle strain. Muscle forces produced during the lengthening behavior can be extremely high. If these forces needed for deceleration exceed that of the muscle-tendon system, injury to the muscle, myotendinous unit, the tendon itself, and the osteotendinous insertion may occur (LaStayo et al., 2003). Therefore, training and

> *"The VersaPulley forces an athlete to control their power through the entire range of motion."*
>
> \- Robert Taylor, Jr. | Founder & Owner | SMARTER Team Training

rehabilitation programs that lack eccentric overloading increase the risk of potential injuries from the movements athletes will encounter during their respective sport.

Eccentric/Flywheel Training for Musculoskeletal Rehabilitation

Tendinopathies

Eccentric training has been utilized in the rehabilitation of injuries for decades. Stanish et al. introduced the concept of eccentric training in the treatment of tendon injuries in the mid 1980s (Stanish, Rubinovich, & Curwin, 1986). Since then, there has been ample research to support the use of eccentrics in the rehabilitation of tendinopathies (Alfredson et al., 1998; Alfredson, 2003; Langberg et al., 2007; Maffulli & Longo, 2008; Ohberg et al., 2004; Purdam et al., 2004; Roig Pull & Ranson, 2007; Romero-Rodriguez, Gual, & Tesch, 2011; Stasinopoulos & Stasinopoulos, 2004; Young et al., 2005). Ironically, tendinopathies develop from higher than normal repetitive eccentric muscle forces placed on the tendon, resulting in an impaired healing response. The tendon reveals a high concentration of glycosaminoglycans and an irregular fiber arrangement (Movin, Gad, Reinholt, & Rolf, 1997), which classifies a tendonopathy as a degenerative process rather than an inflammatory one. An eccentric force applied to the tendon can be therapeutic if the load is applied in a slow progressive manner. Progressive loading creates mechanotransduction, the process by which a cell converts mechanical stimuli into biochemical signals (Maffulli & Longo, 2008). Tenocytes responsible for tendon repair alter their gene expression patterns, protein synthesis and cell phenotypes in response to eccentric loading of the tendon (Maffulli & Longo, 2008). As a result, mechanical loading is theorized to reverse the degenerative process and produce a more organized and normal extracellular matrix (Kongsgaard et al., 2009). In a study by Ohberg et al., ultrasonography of the Achilles tendon revealed a decrease in tendon thickness and a normalized tendon structure following an eccentric calf training regimen (Ohberg et al., 2004). Rehabilitation programs utilizing eccentric exercises to treat tendinopathies have not only demonstrated improved outcomes with regard to pain and function, but also a return to previous levels of activity including sport (Alfredson et al., 1998).

Muscle Strains

A muscle strain is by far the most common muscle injury suffered in sports and mainly occurs during the eccentric phase of movement (Noonan & Garrett, 1999). Sports which are characterized by explosive running, quick change of direction, or ballistic high-force eccentric contractions, often result in muscle strains to the hamstrings, quadriceps, or adductors. While there have been a multitude of suggestions as to the reasons these injuries occur, athletes with a history of recurring hamstring and adductor muscle strains have been shown to possess greater impairment of their eccentric strength (2-fold) as compared to concentric strength, suggesting that improvement in the former may minimize the risk of injury (LaStayo et al., 2003). Similarly, sprinters who suffered hamstring ruptures were significantly weaker in eccentric contractions of the hamstrings at varying velocities (Jonhagen, Nemeth, & Eriksson, 1994). Because a much greater force (2-3 times) can be produced eccentrically than either isometrically or concentrically (B. L. Johnson, Adamczyk, Tennoe, & Stromme, 1976; D. Jones & Rutherford, 1987), eccentric training has the capability of "overloading" the muscle to a greater extent and enhancing muscle mass, strength, and power (Brandenburg & Docherty, 2002; Hortobagyi et al., 2001; B. Johnson, 1972; Komi & Buskirk, 1972; LaStayo et al., 2003) when compared to concentric exercise (LaStayo et al., 2003). The result is a muscle-tendon unit that is able to absorb more energy before the point of failure thus protecting the joint and its surrounding tissues. In addition to the musculotendinous unit's ability to handle increased loads, the joint is more capable of producing force at the outer limits of motion where muscle strain injuries typically occur.

It is imperative that the rehabilitation of muscle strains incorporates eccentric exercises not only to stimulate appropriate adaptations within the injured tissues and normalize the neuromuscular response, but also to do so as quickly and efficiently as possible. In a study by Askling et al, sprinters and jumpers who were treated with a muscle-tendon lengthening rehabilitation protocol following an acute hamstring strain returned on average 37 days sooner (49 versus 86) or 43% faster than those who completed a standard rehabilitation program (C. M. Askling et al., 2014). Furthermore, a study by Mendez-Villanueva evaluated eccentric hamstring exercises that emphasized either extension of the hip or flexion of the knee. The hip extension kick using the conic pulley flywheel was most effective at recruiting the proximal region of the biceps femoris long head, one of the most commonly strained hamstring muscle, while the straight-leg dead lift was most effective at targeting the semitendinosis and biceps femoris (Mendez-Villanueva et al., 2016). As such, a variety of eccentric exercises is recommended in the rehabilitation of hamstring strains in order to reach all four muscles that comprise the hamstrings (Mendez-Villanueva et al., 2016).

Anterior Cruciate Ligament Sprains

Noncontact ACL injuries are likely to occur during the deceleration/acceleration phase of movement resulting in an excessive quadriceps contraction and reduced hamstring co-contraction and may be more pronounced with a valgus load combined with internal rotation (Shimokochi & Shultz, 2008). Research into non-contact ACL injuries has found these acute changes in biomechanical fatigue to occur following strenuous protocols (de Hoyo et al., 2015). As such, training as well as rehabilitation must include an appropriate stimulus to combat decelerating forces as well as prevent fatigue.

The best-established method of stabilizing a ligament-impaired joint during a potentially destabilizing activity is to recruit a powerful muscular synergist to restrain the joint (LaStayo et al., 2003). At the knee, the hamstring's eccentric activity provides a posterior pull on the tibia to offset the anterior force of the quadriceps (Shimokochi & Shultz, 2008). Along with their role of stabilization of the knee, they are eccentrically activated prior to initial limb contact in movements such as cutting, stopping, and landing maneuvers (Nyland, Shapiro, Caborn, Nitz, & Malone, 1997). This "presetting" of the hamstrings along with eccentric quadriceps activity during the loading phase, is crucial for proper shock absorption. According to Gerber et al., the

application of progressive high-force eccentric resistance is one such intervention that has been shown to safely increase muscle volume and strength in various populations including individuals who have undergone ACL reconstruction (Gerber et al., 2009).
As rehabilitation progresses, a return to sport specific movements is vital for a successful transition to activity. A study by de Hoyo et al. tested the effects of an eccentric overload bout on change of direction and performance in soccer players (de Hoyo et al., 2015). They found that "eccentric overload training produced greater performance during change of direction tasks without showing acute fatigue (proprioceptive disturbance) measured through kinetic parameters." Incorporating eccentric training to specifically overload the musculature responsible for controlling deceleration forces at the knee, is critical in the rehabilitation following ACL reconstruction (Gerber et al., 2009).

Shoulder Injuries

Extensive eccentric forces occur at the shoulder during the deceleration phase of throwing a baseball, serving a tennis ball, or spiking a volleyball. It has been reported that the distraction forces from throwing a baseball at the glenohumeral joint are equal to one to one and a half times body weight (Fleisig, Andrews, Dillman, & Escamilla, 1995). For this reason, muscles in the shoulder must undergo high decelerative eccentric contractions to preserve healthy joint arthrokinematics (Ellenbecker, Davies, & Rowinski, 1988). According to Noffal, et al., eccentric strength of the external rotators should be greater than the concentric internal rotator strength to not only overcome the decelerative forces, but other segmental forces associated with the dynamic nature of throwing (Noffal, 2003). According to Wilk et al., treatment of shoulder injuries should include restoring the adaptations that result from repetitive throwing (Wilk, Andrews, Arrigo, Keirns, & Erber, 1993). One such adaptation appears to be an imbalance of concentric internal rotation strength over eccentric external rotation strength. Therefore, subsequent to developing base-line posterior shoulder strength, a rehabilitation and reconditioning program must include progressive eccentric loading to restore balance at the shoulder. The resulting adaptations of the muscle-tendon complex enable the shoulder to absorb and transmit the forces produced during sudden contractions (Yu et al., 2003) or deceleration of the limb. For overhead athletes returning from a shoulder injury, eccentric training is essential to complete the rehabilitation process and prepare the athlete for the movements they will encounter on the field or court.

The Traditional Training Gap

The current and most widely used and accepted methods of rehabilitation and improving performance for athletic activities are gravity-dependent tools. This equipment includes, but is not limited to barbells, dumbbells, kettlebells, etc. While offering constant concentric and eccentric load in exercises emphasizing vertical actions, they rarely encompass horizontal/lateral actions offering eccentric overload (Tous-Fajardo, Gonzalo-Skok, Arjol-Serrano, & Tesch, 2016). Furthermore, a person's ability to complete an eccentric-isometric-concentric cycle under maximal load is limited by the force production in the concentric phase

(Hortobagyi et al., 2001). This means that traditional weight training creates an ideal environment for concentric strength and eccentric underload. Even with the addition of tools such as bands and chains, an eccentric overload is not achieved, and attempting to do so in this setting would be unsafe and expose those training to an unnecessary risk of injury.

VersaPulley™

The VersaPulley™ is an inertial flywheel-training device relied upon by many of the world's top teams, universities, therapists, and trainers to prepare their athletes for the highest levels of competition. What differentiates the VersaPulley™ from its competitors is the ability to perform exercises in both a horizontal and vertical application. This allows its users to train at any load, at any speed, and in any plane within an infinite amount of exercise variation.

While any flywheel device will allow anyone to train at any point (eccentrically and concentrically) along the force/velocity curve, most allow for only vertical movement. Developing eccentric strength in multiple planes and at multiple loads allows for greater performance and injury prevention gains.

The increasing benefits and contribution of the VersaPulley™ to training are continually being substantiated in scientific research (de Hoyo et al., 2015; Fernandez-Gonzalo et al., 2014; Norrbrand, Fluckey, Pozzo, & Tesch, 2008; Norrbrand et al., 2010; Norrbrand, Tous-Fajardo, Vargas, & Tesch, 2011; Nunez, Suarez-Arrones, Cater, & Mendez-Villanueva, 2016; Owerkowicz et al., 2016; Pearson et al., 2001; Romero-Rodriguez et al., 2011; Tesch et al., 2004; Tous-Fajardo, Maldonado, Quintana, Pozzo, & Tesch, 2006), and are being incorporated into regular training programs. The benefits of this device include eliciting a greater overall amount of muscle activity than traditional overload exercises (Norrbrand et al., 2010), and the ability to freely move in multiple planes for a "specific" training stimulus (de Hoyo, Sanudo et al., 2015; Lohnes CA, Fry AC, Schilling BK, Weiss L., 2007; Young et al., 2005). Additionally, the stimulus provided by employing flywheel devices may provide a more potent hypertrophic exercise stimulus than gravity-dependent weights (Norrbrand et al., 2010).
In most team sports, players are required to repeatedly perform short, explosive, efforts such as accelerations and decelerations during changes of direction (de Hoyo et al., 2015). The capacity to dissipate the forces during abrupt deceleration (breaking ability) is critical to injury prevention, while the ability to decelerate and reaccelerate in a short period of time (reactive strength) is paramount to enhanced performance.

> *"The deceleration and acceleration loading for multi-plane movements the VersaPulley provides is unmatched."*
> - Julio Tous | Performance Training and Conditioning Coach FC Barcelona

The VersaPulley™ is designed to create those moments of eccentric overload, allowing the athlete to be exposed to these stresses in a non-impact, concentrically-driven and eccentrically--overloaded environment. VersaPulley™ accomplishes this using our patented MV2 technology – resistance-generating rotating inertial flywheel.

Our device picks up where traditional gravity-based weights, chains, bands, air-powered machines stop. While all of these methods are important to the training, rehabilitation, and reconditioning of athletes, these methods offer mostly constant concentric and eccentric load in exercises emphasizing vertical actions. They rarely encompass horizontal/lateral actions offering eccentric overload (Tous-Fajardo et al., 2016)– which is exactly why the VersaPulley™ was developed.

- Largest exercise selection for training and rehabilitation among flywheel devices.
- Can implement coach assisted concentric assistance for eccentric overloading.
- Exercises can be prescribed in sagittal, frontal, and transverse planes.
- Patented MV2 technology – resistance-generating rotating inertial flywheel.
- Allows its users to train at any load, at any speed, and in any plane within an infinite amount of exercise variation.
- High/low adjustment and long rope length allows for a myriad of movement-based lower body and upper body exercises.
- Ability to quantify loads via IPU (inertial power units).

Summary

Training and rehabilitation programs of any type should be tailored for the goals and needs of the individual (Bettendorf, 2010). Whether one is training to improve strength, power or change of direction, rehabilitating from an injury, or improving resilience, the VersaPulley™ is a safe and effective training tool. Implementation of eccentric overload strength training has been lacking in traditional strength and conditioning program designs (Hollander et al., 2007). Eccentric overload training with the VersaPulley™ should be an integral part of any comprehensive rehabilitation or training program seeking to improve performance or decrease injury potential. Because of its high/low capabilities, the VersaPulley™ allows for the prescription of exercises in all planes of motion, creating training stimuli from the general to the specific.

Research will continue to be conducted to further drive elucidation to the benefits of flywheel inertia-based training and eccentric overload within the rehabilitation, reconditioning, and performance enhancement realms.

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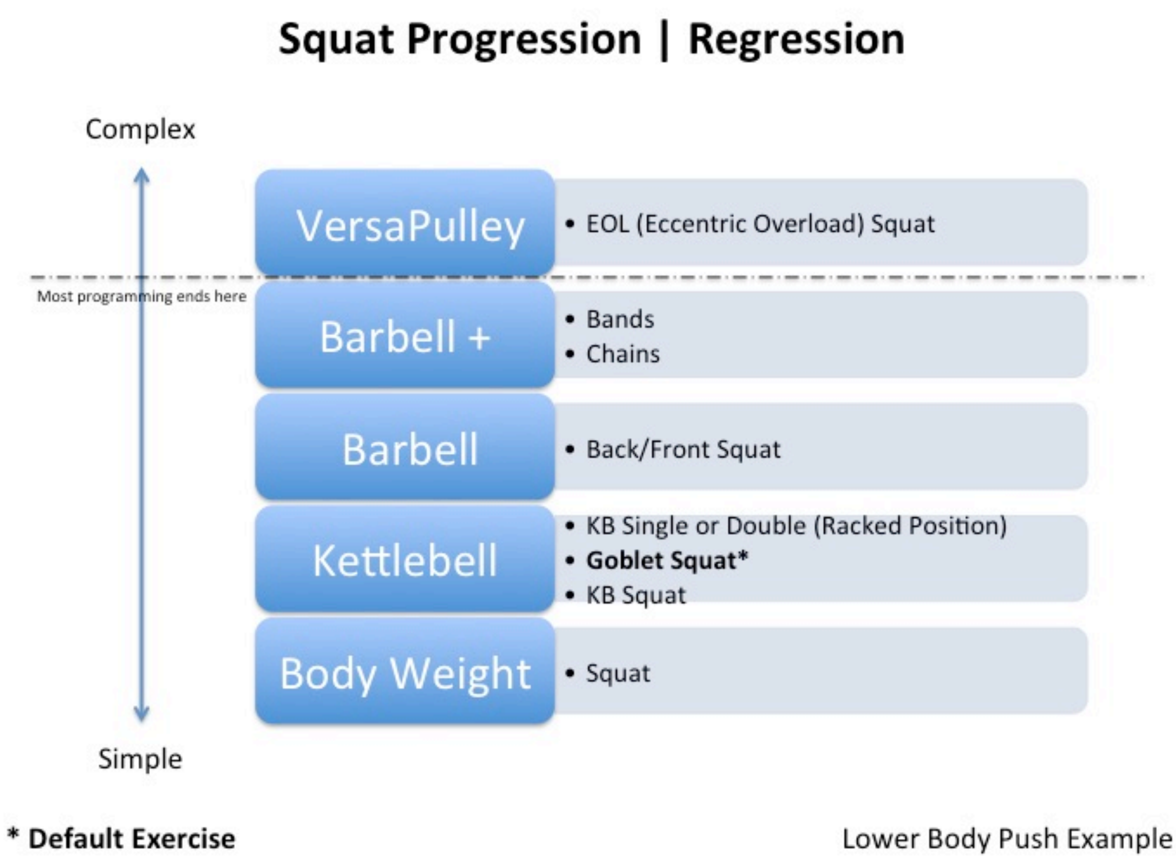
Appendix

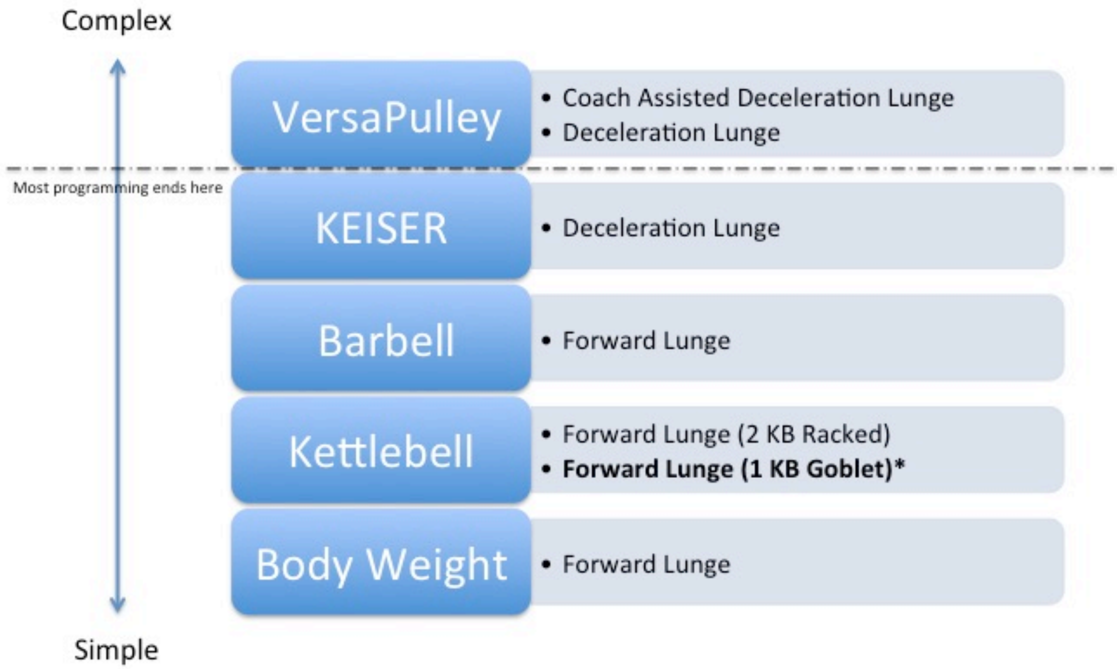

Squat Progression | Regression
Complex
VersaPulley
• EOL (Eccentric Overload) Squat
Most programming ends here
Barbell +
• Bands
• Chains
Barbell
• Back/Front Squat
Kettlebell
• KB Single or Double (Racked Position)
• Goblet Squat*
• KB Squat
Body Weight
• Squat
Simple
* Default Exercise
Lower Body Push Example

RDL Progression | Regression

*** Default Exercise**

Lower Body Pull (Hip Hinge) Example

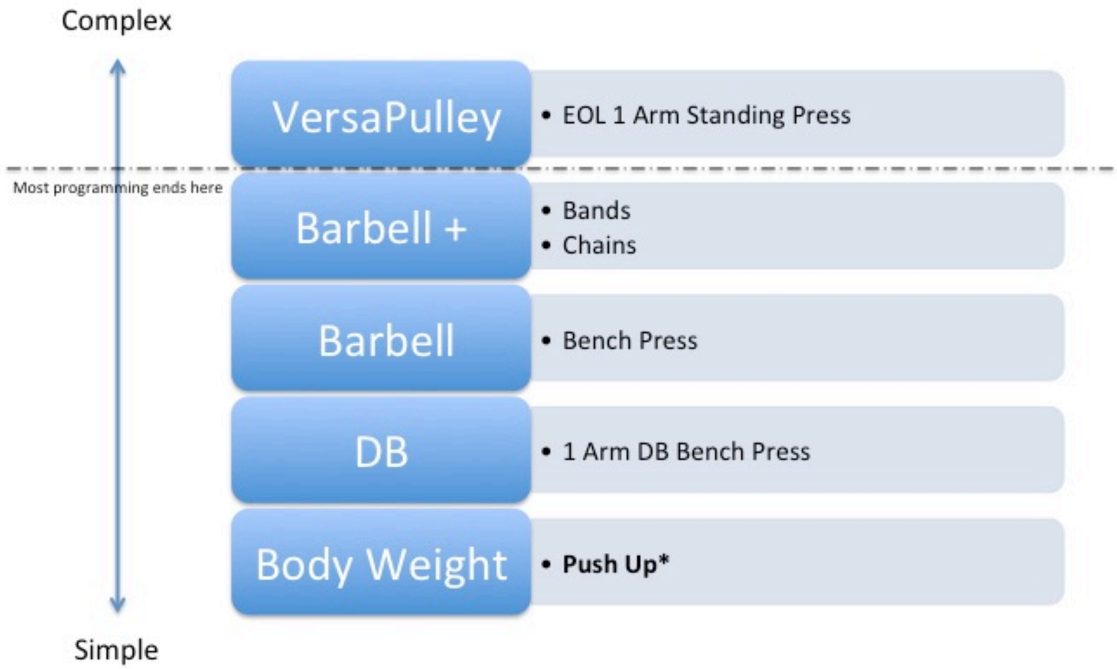
Forward Lunge Progression | Regression



*** Default Exercise**

Lower Body Unilateral Example

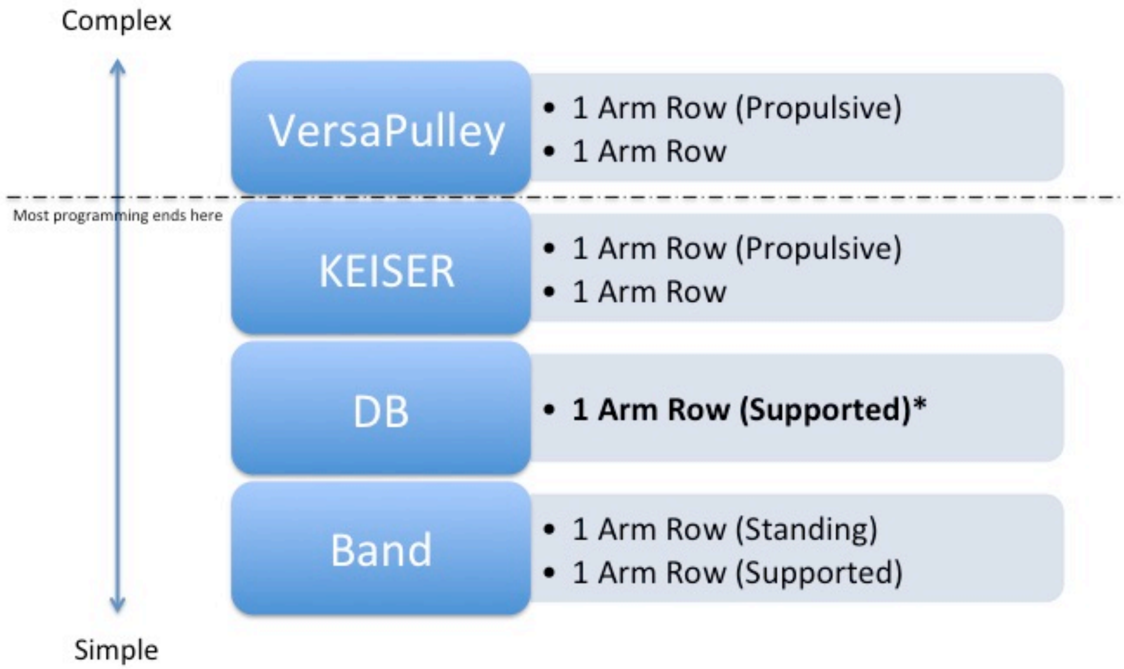
Push Progression | Regression



*** Default Exercise**

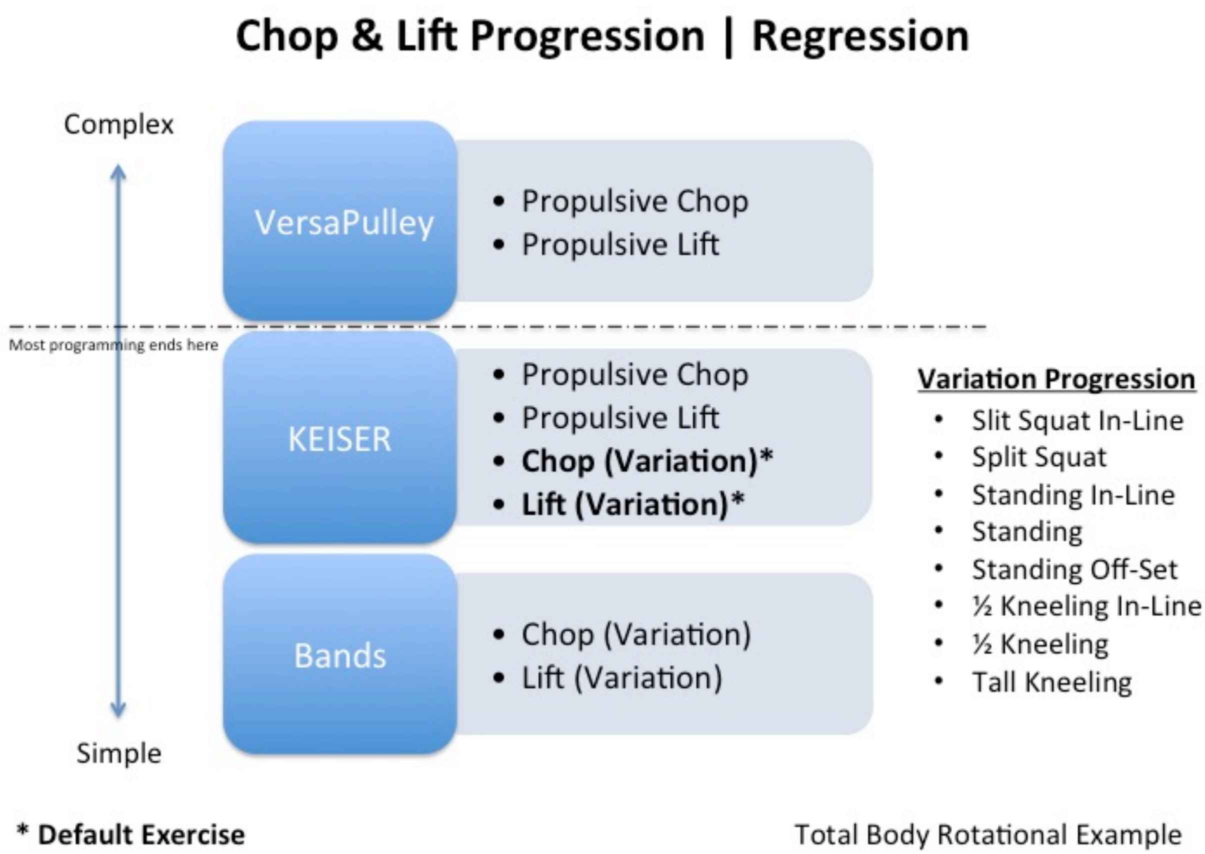
Upper Body Push Example

1 Arm Row Progression | Regression



*** Default Exercise**

Upper Body Pull Example


Chop & Lift Progression | Regression
Complex
VersaPulley
• Propulsive Chop
• Propulsive Lift
Most programming ends here
KEISER
• Propulsive Chop
• Propulsive Lift
• Chop (Variation)*
• Lift (Variation)*
Variation Progression
• Slit Squat In-Line
• Split Squat
• Standing In-Line
• Standing
• Standing Off-Set
• ½ Kneeling In-Line
• ½ Kneeling
• Tall Kneeling
Bands
• Chop (Variation)
• Lift (Variation)
Simple
* Default Exercise
Total Body Rotational Example

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