RSI REVISITED PART 1

A Comprehensive Manual By:

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THE REACTIVE STRENGTH INDEX REVISITED

PART 1

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In 2012 my colleague Dr Tom Comyns and I wrote about the reactive strength index (RSI) in the NSCA's Strength and Conditioning Journal.[1] This was by no means the first mention of RSI in the published literature, and since then interest in this metric has continued in published research and practical applications in strength and conditioning. This three-part series will revisit RSI and bring coaches up to speed on its origins, discuss the latest research, and highlight practical applications in training, assessment, and athlete monitoring.

PLYOMETRICS & THE STRETCH SHORTENING CYCLE

Plyometrics features exercises typically involving rapid, powerful jumping or hopping movements preceded by a preloading countermovement. Examples of plyometrics include depth jumps, hurdle jumps, and bounding exercises. The literature shows plyometric training to have numerous beneficial effects. These range across injury prevention, power development, sprint performance, change of direction and agility development, and running economy. Few—if any—morphological changes occur in response to plyometric training. It's not a driver of muscle hypertrophy. The adaptations which take place in response to effective plyometric training are primarily at the level of the central and peripheral nervous systems.[2]

The stretch shortening cycle (SSC) is the basis of plyometric exercises. The SSC is a natural type of muscle function in which a muscle is stretched immediately before contraction. This eccentric/concentric muscular contraction produces a more powerful output than purely concentric action. You can test this with your athletes. Very few will produce impressive jump height in a concentric-only "squat jump" compared with a typical "countermovement" vertical jump. The SSC is a natural form of muscle function, and it aids our efficiency and performance in everyday activities such as running, throwing, and jumping.

A number of biomechanical factors are thought to contribute to the SSC. These include storage and utilization of elastic energy, increased motor unit recruitment, increased force development throughout the eccentric phase of the SSC, and reflex mechanisms from the muscle spindle.[3] I won't delve into these involved, precise mechanisms in detail here but Dr. Jacob Wilson and I explored them in our 2008 review in the Journal of Strength and Conditioning Research. You can check out that review via the NSCA.[4]

The precise mechanisms that contribute to performance in any given plyometric exercise seem to be dependent on the manner in which that exercise is performed. For example:

- For the muscle spindle reflex to be initiated, a fast rate of eccentric stretching must occur.
- For elastic energy to contribute, there must be a short transition period between the eccentric and concentric phases.
- For enhanced motor unit recruitment to contribute, there must be a fast eccentric phase and a short transition period between the eccentric and concentric phases.
- To allow for an increased force development the eccentric phase must be slow.

Some of these movement characteristics are mutually exclusive. We need a fast eccentric stretch to harness the power of the muscle spindle reflex but a slow eccentric phase to allow increased force development throughout the eccentric phase. These can't both happen in the same plyometric exercise.

Considering these factors, legendary German sport science researcher Dr. Dietmar Schmidtbleicher suggested the SSC can be classified as either slow or fast.[5] Fast SSC is characterized by short contraction or ground contact times (<0.25 seconds) and small angular displacements of the hips, knees, and ankles. These are springy, reactive jumps. A typical example would be depth jumps or repeated hops in place. Slow SSC involves longer contraction times (>0.25 seconds), larger angular displacements, and is observed in maximal effort vertical jumps. Assessment of ground contact times or contraction times (the time taken to move through the eccentric and concentric phases) helps guide practitioners toward the type of SSC being utilized.

THE IMPORTANCE OF GROUND CONTACT TIMES IN PLYOMETRIC TRAINING

Though both are assessed in jumping activities, research shows slow SSC and fast SSC are poorly related to each other. Athletes may have impressive slow SSC abilities and exhibit huge vertical jumps, but this is not a clear indicator of fast SSC ability. Previously, I examined both slow and fast SSC in collegiate cross country skiers via a countermovement jump test and a drop jump test.[6] Despite the seeming similarities of these tests—both are bilateral and involve forceful extension of the ankles, knees and hips—I observed only a weak correlation in performance. The best vertical jumpers are not necessarily the best at utilizing the fast SSC.

Leinster Rugby, one of Europe's premier professional rugby teams, have presented great data on this conundrum at their annual S&C conference. They have shown that their best performing athletes on CMJ testing are not their best performers in fast SSC activities. As part of his MSc thesis, the head of fitness at Leinster Rugby, Dan Tobin, has also demonstrated that while slow SSC and fast SSC qualities are not strongly related to each other they both contribute to accelerative speed—suggesting they are both important, but distinctly different, physical qualities. In a classic research paper, Warren Young demonstrated an improvement of 20% in fast SSC performance following a six- week plyometric training program. Despite this rapid SSC improvement there was minimal improvement in either vertical jump height (slow SSC) or leg extensor strength.[7]

This has important implications for strength and conditioning coaches. Training one of these SSC qualities will not necessarily improve the other. If fast SSC ability is a limiting factor in an athlete's sports performance, it needs to be assessed and trained in its own right. Vertical jump testing and training just won't cut it. Not all "jump" training methods are created equal.

As mentioned, the primary differences between fast and slow SSC are that the fast SSC involves a fast, short eccentric phase and a rapid transition time between the eccentric and concentric phase. Slow SSC typically has a longer eccentric phase and a slower transition. The magnitude of performance enhancement from the SSC "reflex" increases dependent on the speed of the eccentric phase and decreases with transition time.[8] As a result, much greater joint moments, power outputs, and rates of force development are observed in fast SSC plyometrics. We see greater jump heights and total force in slow SSC plyometrics due to the increased time allowed to develop force.

As we explore the research, a picture emerges. Slow SSC is more closely related to relative maximal strength abilities,[9] while fast SSC is more representative of reactive strength qualities.

But what is reactive strength and why is it important?

REACTIVE STRENGTH AND THE RSI

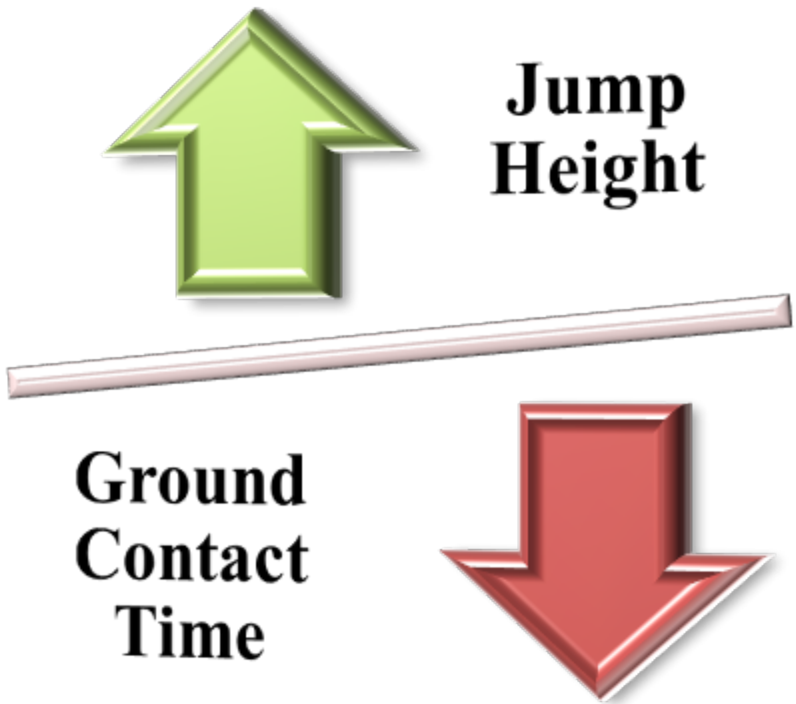
Reactive strength is a representation of the fast SSC function. It shows athletes' ability to change quickly from an eccentric to a concentric contraction and their ability to develop maximal forces in minimal time. It has also been described as a measurement of stress on the calf/Achilles muscle/tendon system. A detailed research study from 2011[10] outlines the importance of this physical quality. A group of Australian researchers sought to determine the biomechanical and performance factors that differentiate sprint acceleration ability in field sport athletes. They tested 20 male field sports athletes in a range of strength, power and biomechanical tests and compared this to the athletes' acceleration speed over 0-5m and 0-10m.

The faster athletes in this study had significantly shorter ground contact times from stride to stride in 10m sprints in comparison with their slower counterparts. Fast players also demonstrated significantly greater reactive strength compared to slower ones. In fact, reactive strength testing was the biggest differentiator between the slow and fast athletes across a range of tests and measures including the CMJ, bounding tests, and the 3RM back squat. The authors suggest that reactive strength qualities may help explain the lower ground contact times attained by the athletes with better acceleration in the short sprints. The quality of reactive strength translates into allowing faster athletes to be "able to (tolerate) higher eccentric loads, and convert this into concentric force over a shorter period of time." The application of more force in a shorter period of time is pure gold in terms of athletic performance.

Warren Young and his research team also examined the relationship between reactive strength and change of direction ability in Australian Rules Football players.[11] They assessed reactive strength in a plyometric drop jump exercise, and the change of direction test involved players accelerating and cutting left and right through speed timing gates. The researchers found that reactive strength (along with 10m speed ability) was correlated to players' change of direction ability. Players faster in the change of direction test demonstrated much higher reactive strength abilities (>25% difference) than their slower counterparts. The authors say "reactive strength of the leg extensors is important for change of direction speed performance." This makes sense —the push-off involved in rapid change of direction tasks involves a fast SSC muscle action of the hip, knee, and ankle leg extensors. They conclude by stating

> *"Training designed to improve acceleration and reactive strength may transfer to enhanced change of direction speed performance. In sports that contain skills requiring COD speed, such as running between bases in baseball . . . physical conditioning to develop the relevant fitness qualities is recommended."*

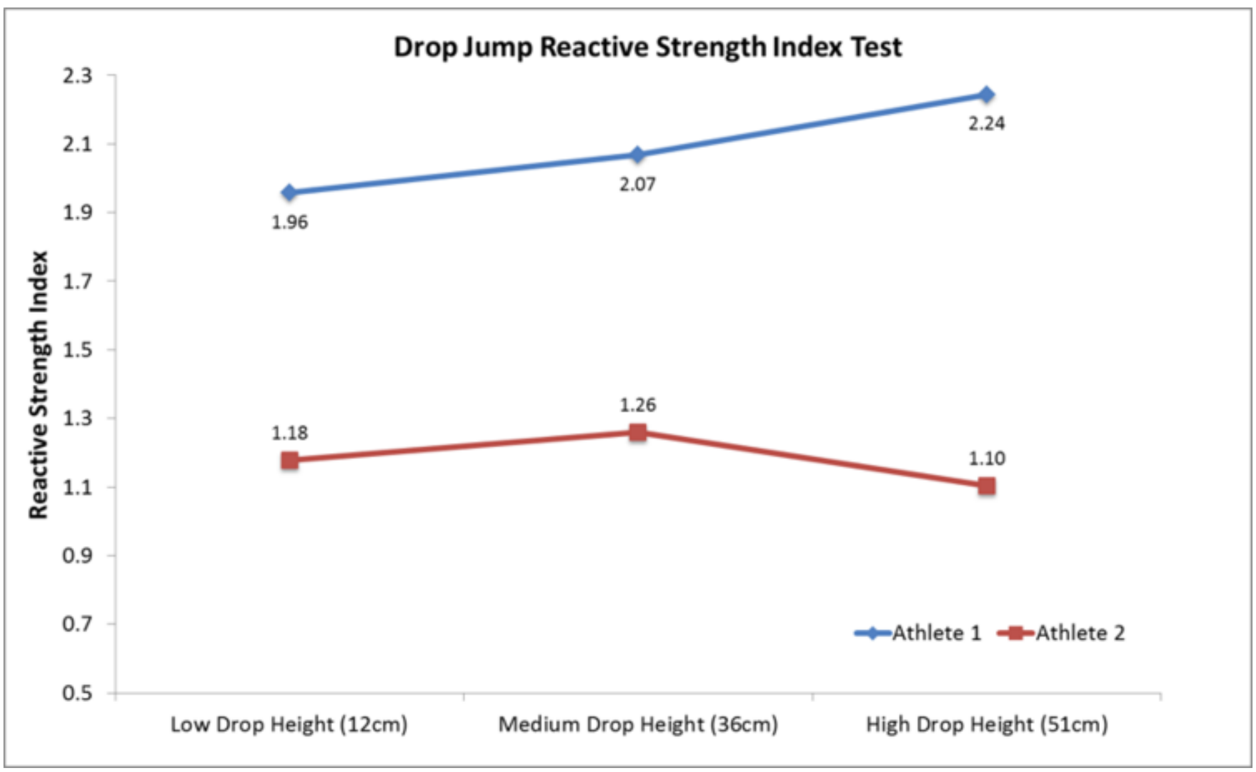
Reactive strength is assessed primarily through the RSI. It is a simple ratio involving two metrics: How high can you jump? How fast can you jump? The index is calculated by dividing the height jumped with the ground contact time. For example, an athlete jumping 50cm (0.5m) with a contact time of 200ms (0.2s) would score an RSI of 2.5 units. The RSI can be improved by increasing jump height or decreasing ground contact time.



Typically RSI has been measured using plyometric drop jumps on jump contact mats. The mats measure ground contact time in the drop jump directly and calculate jump height based on the athlete’s “flight time” (Jump height = (gravity*(flight time)2)/8). The RSI can also be derived using higher spec (and higher cost) force plates or more affordable wearable inertia sensors such as PUSHTM.

Assessing ground contact times and the RSI can be a great tool to assess and inform fast SSC plyometric training. It can also serve as an excellent motivational tool within sessions to increase athlete engagement and encourage maximal effort on fast SSC plyometric exercises. In isolation, ground contact times can be used to improve plyometric exercise specificity and ensure the exercises being performed are within the ground contact guidelines for fast SSC (<250ms) data-preserve-html-node="true" data-preserve-html-node="true" utilization. In addition, RSI provides practitioners with more involved ways in which they can monitor, assess, and influence plyometric training and performance.

The RSI can be used to optimize the height for plyometric depth jumps from both a performance and injury-risk management perspective. This optimization process involves athletes performing 2-3 drop jumps across a range of "drop" heights (for example: 15, 30, 45, 60 cm) with the jump height, contact time, and RSI calculated for each jump at each height. This develops a plyometric profile for each athlete. When RSI is maintained or improves with an increase in drop jump drop height, and contact times are maintained below the 250ms threshold, we can assume the athlete's reactive strength capabilities are sufficient for that intensity of depth jump. If decreases in RSI or an elongation of ground contact times of >250ms are observed, this likely indicates a drop height involving sub-optimal training stimulus or excessive stress on the muscle-tendon system. The figure below outlines two "real data" RSI profiles for elite junior rugby players. Athlete 1 is a lean, physically well-developed player, with impressive lower body maximal strength (205kg back squat at 94kg body weight) and good maximal speed ability (40m of 5.01). Athlete 2 has a much younger training age and poor body composition profile. While he also has good maximal speed ability (40m of 4.98), his strength levels are still developing (150kg back squat at 94kg body weight).



This simple assessment immediately benchmarks athletes' reactive strength capabilities against each other. We quickly see that Athlete 1 has the more developed reactive strength qualities at each of the drop heights tested. It also helps the coach individualize the intensity of fast SSC plyometrics for both players. Athlete 1 could use a typical drop height of around 50cm, while athlete 2's drop heights would range from 12 to 36cm. With such a low projected "optimal" drop height for Athlete 2, the coach may consider using simpler, lower intensity fast SSC plyometric exercises such as "pogo" hops or repeated low hurdle hops. We'll explore the intensity of fast SSC plyometric exercises and reactive strength exercise progressions later in this series.

Research by Byrne et al (2010)[12] has shown that plyometric training guided by such an optimization process is highly effective in improving reactive strength ability. One group of participants in the study had their optimal drop jump drop height identified through RSI. They trained only at that drop height for 2 sessions per week over an 8 week period. The participants performed between 3 and 5 sets of drop jumps at their optimal drop height and improved reactive strength significantly across the full range of tested drop heights.

Hopefully I've built a case highlighting the importance of fast SSC plyometrics and the value of the RSI to assess and inform plyometric performance and training. Reactive strength is a key part of the athlete performance profile. Many traditional jumping exercises do not have the required movement characteristics to stimulate the fast SSC.

And I have really just scratched the surface. As this series continues I will outline a number of additional tests within which RSI can be used to assess fast SSC function and inform training. We'll also take a look at its use as a monitoring tool to assess and manage athlete fatigue and "readiness to train." We'll dig deeper into the specificity of plyometric training and hopefully provide you with some guidelines on managing plyometric training intensity.

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