RSI REVISITED PART 3

A Comprehensive Manual By:

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PUSH

THE REACTIVE STRENGTH INDEX REVISITED

PART 3

by Eamonn Flanagan, PhD.

Welcome to the 3rd and final chapter of the series. I hope this final installment can develop our understanding of the practical implementation of reactive strength training and RSI testing. Hopefully by the end of this chapter we'll have provided clear, practical guidelines for the development of reactive strength qualities in athletes.

In parts 1 and 2, we “hinted” at a possible relationship between reactive strength and maximal strength. Many coaches and professional organizations recommend a high level of maximal strength before undertaking plyometric training programs. For example, the NSCA has advised that “*for lower body plyometrics, the athlete’s 1RM squat should be at least 1.5 times his or her bodyweight*”.

But the research in this area is a little light… do you really need a certain level of lower body strength before starting plyometrics? Will low strength levels expose athletes to injury risk if you start plyometric training? Let’s start part 3 by exploring the relationship between plyometric reactive strength and maximal strength as developed by traditional strength training exercises.

REACTIVE STRENGTH VS MAXIMAL STRENGTH

A number of research studies have shown that reactive strength has a relationship to maximal strength and that stronger athletes often produce higher RSI scores compared to weaker counterparts. We examined the relationship between reactive strength and maximal strength in 20 academy and sub-academy rugby players in a research study in 2011.[1]

We ran the incremental DJ-RSI protocol across different drop heights and compared reactive strength performance against the players’ maximal strength in a back squat exercise. We observed a strong positive relationship between reactive strength and traditional maximal strength ($r = 0.63$). Stronger athletes tended to demonstrate higher reactive strength. However, while the relationship was “statistically strong”, we must think of this from a coaching perspective. The “variance explained” statistic (r^2) showed that just 40% of the variance in one measure (reactive strength) was explained by the other measure (maximal strength). So this means there is 60% of reactive strength performance which is not explained by, or associated with, maximal strength qualities!

Practically, this makes a lot of sense. Any coach routinely measuring RSI will tell you of many athletes with freakish RSI scores but who can’t do much in the weightroom. A reminder from part 1: reactive strength tasks are highly ankle dominant but most traditional strength training relies on greater contribution from the knee and the hip in exercises such as squatting and deadlifting. A reminder from part 2: both are important in the physical preparation of athletes.

In the same research study, we also divided our group into those with lower strength levels (1.5 x BW back squat) and those with higher strength levels (1.9 x BW back squat). The stronger athletes produced moderately higher reactive strength indices at all drop heights with a statistically significant difference at the highest drop height (50cm / 20 inches).

Researchers, Barr and Nolte, ran a similar study with female rugby players using drop jump drop heights from 24 cm all the way up to 84 cm (10-33 inches) and showed similar results.[2]

They found some notable correlations between strength and reactive strength ability and observed that the athletes with bigger front squats hit higher RSI scores across all drop heights with the largest differences being seen at the highest drop height (84cm / 33 inches). The authors concluded that "*it is likely beneficial for female athletes to achieve high levels of maximal leg strength if they are to use high drop heights when performing drop jumps*".[3]

We should remind ourselves here that correlation doesn't mean causality. We don't yet know, with certainty, whether strength training directly positively improves reactive strength or vice versa. For example, perhaps the reason the "stronger" athletes express greater reactive strength is simply because they have been in structured training programs for longer and have been training both maximal strength and reactive strength longer than the weaker athletes. However, logic dictates that athletes with established levels of strength are more likely to tolerate the loadings involved in high-intensity plyometrics. An extensive body of scientific research shows that traditional strength training increases the mechanical strength of connective tissues such as tendons and ligaments. Strength training has positive effects on tendon strength, integrity and stiffness. Increases in tendon strength and integrity will help athletes tolerate the high eccentric loadings involved in high-intensity plyometric training. Stronger athletes will be more resistant to injury and will be less likely to suffer muscle soreness following plyometric training with high eccentric loads (such as drop jumping). Increases in tendon stiffness also allows athletes to utilise the fast

SSC more effectively to get larger expressions of force from each rep in their plyometric training.

A number of research studies have also looked at the combined effects of plyometric and strength training methods. Typically, the findings show that a combined approach of strength training and plyometric training together results in as good, if not better, training effects on plyometric and jumping performance. This is particularly true for novice athletes with lower levels of maximal strength. These athletes will be benefitting from the specific effects of ankle-dominant reactive strength training but they will also be benefitting from the positive effects on knee and hip strength and power from traditional strength training.

My interpretation is that general strength should be developed alongside reactive strength qualities for optimal physical development. However, I doubt there is a magic "strength threshold" below which athletes should not complete plyometric training. For athletes with low maximal strength (1-1.5 x BW squat), strength work should be a key training focus and I would avoid high-intensity plyometric exercises. But I would still include low to moderate level fast SSC plyometric work to develop the reactive strength qualities we know are so important to performance in sport.

So what plyometric exercises are low, moderate or high intensity? This is a key consideration when developing a plyometric training program.

PLYOMETRIC INTENSITY

In 2009 I had the privilege (and challenge!) of having Dr. Bill Ebben as my external examiner as I defended my PhD. Dr. Ebben was a pioneer in developing our understanding of the demands and intensity of plyometric training. In 2007 he outlined clear, practical recommendations on plyometric exercise intensity for the NSCA.

Plyometric intensity can be defined as the amount of stress the plyometric drill places on the muscle, connective tissue and joints involved. The intensity will typically be determined by the eccentric loads involved and the time period in which the eccentric loads are applied. The plyometric intensity must be considered in the jumping action of the plyometric exercise (force production) AND also in the landing portion of the exercise (force absorption). Both phases impart stress on the muscle, connective tissue and joints and both phases impact on the exercise intensity experienced by the athlete. In any exercise intervention, intensity is a key variable which must be understood and considered in the formulation of an optimal plan.

Here are the guidelines on plyometric intensity from Dr. Ebben with some additions and amendments that I have added:

- Any single leg plyometric exercise is more intense than the same exercise performed bilaterally (with both legs). A single leg drop jump from 30cm drop height will result in much greater knee joint reaction forces than a bilateral drop jump from the same height.

- Fast SSC exercises will typically result in greater intensities than slow SSC exercises due to the much shorter time period of force application resulting in greater loading rates.

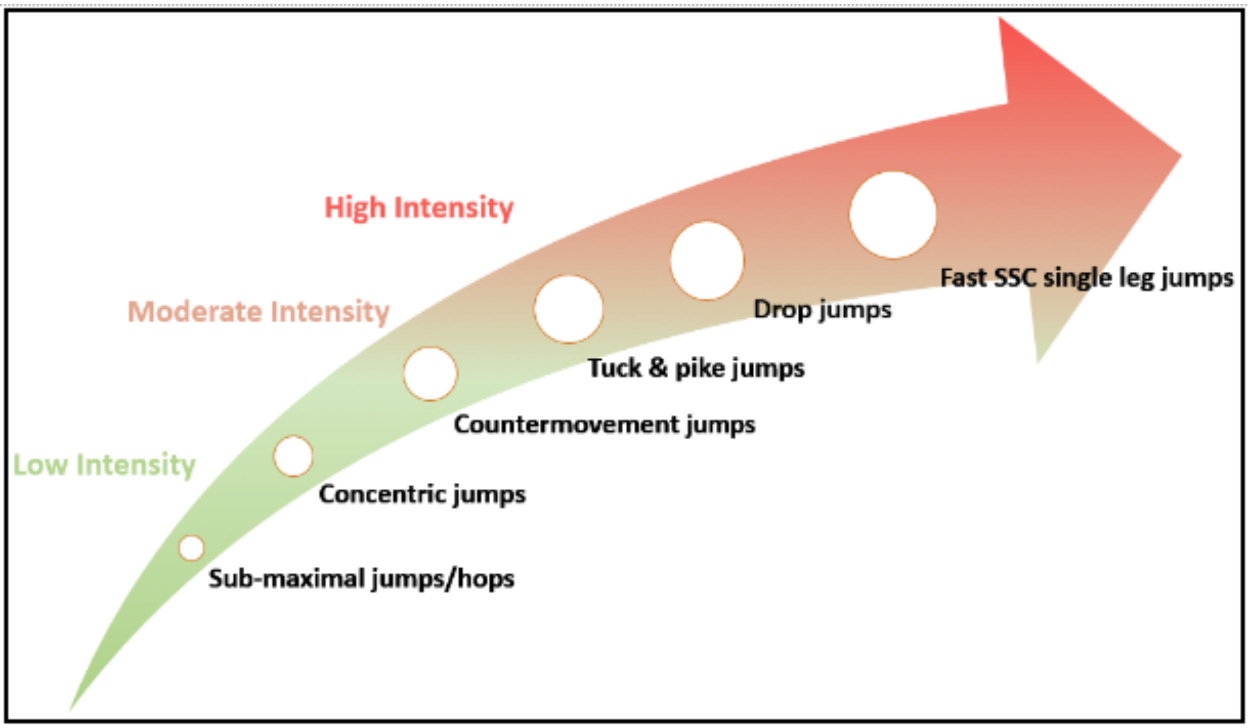
- Despite sometimes being considered a low intensity category, some "jumps in place" such as pike jumps and tuck jumps have high knee joint reaction forces. This may be due to the forceful extension of the legs just prior to landing in these exercises.

- Performing any exercise in a "repeat" fashion will be have higher total stress than performing individual reps. For example performing 5 countermovement jumps with full landings and a pause between each rep will have lower total landing stress than 5 reps performed immediately after each other.

- The height that athletes jump up to or down from (as in depth jumps) is one of the most potent predictors of plyometric intensity. For example, a person who performs a countermovement jump to 60cm will experience greater ground reaction force and stress on landing, than an athlete jumping to 45cm.

- Jump variations performed with maximal arm contribution, reaching the arms overhead, result in higher jump heights and as a result greater landing stress.

We can use these guidelines and Dr. Ebben's work to develop a simple intensity scale for plyometric exercises.



At the lowest point on this scale are sub-maximal jumps and hops. These could be slow or fast SSC exercises. Sub-maximal options are great tools to begin to develop plyometric technique and to develop athlete's condition to tolerate the demands of plyometric training. Before starting plyometric training, it is essential that athletes have robust jumping and landing technique in both slow and fast SSC actions. This classification on the scale would include sub-maximal options such as vertical and horizontal jumps with a strong focus for athletes to "stick" landings in strong body positions. Also included would be low-intensity, fast SSC options, such as ankle-dominant pogo hopping (vertically or horizontally), with a focus on short contact times over any emphasis on jump height. Box jumps could also be included in this first classification stage. Box jumps limit the ground reaction forces involved in the landing phases of jumps as we jump up to the box rather than landing down to the ground with higher eccentric velocities. I'm not too keen on box jumps for maximal slow SSC development as they can result in more "tucking" than actual jumping but I think they can work well to teach good jumping and landing mechanics without imparting too much stress on a novice plyometric trainer – just use a box height that allows for good landing mechanics with the hips higher than the knees in a quarter squat type position.

Concentric jumps such as the squat jump do not utilize the stretch shortening cycle and as a consequence result in slower contraction times and lower jump heights than countermovement jumps. With contraction times elongated and jump height limited, the rates of jumping and landing forces experienced are reduced in comparison to countermovement jumps.

As previously discussed, jumps with additional knee and hip flexion/extension after the jump, such as tuck jumps or pike jumps have higher knee joint reaction forces compared to squat jumps and countermovement jumps. This is likely due to the forceful extension of the legs toward the ground right before landing. This gives a little less time for athletes to get the feet and legs into an optimal position for force absorption on landing and the forceful extension also probably adds (limb) velocity on landing. Tuck jumps and pike jumps can probably be considered high intensity exercises, especially when they are performed in a “repeat method” fashion. When performed in a repeat method, they may also represent a higher intensity stimulus than single effort drop jumps.

Drop jumps are unquestionably a high intensity plyometric exercise, especially when “drop heights” are equal or greater than the athlete’s vertical jump height. Single leg variations of fast SSC exercises are likely to be the most intense plyometric exercises due to the high eccentric loads involved being isolated to a single limb coupled with the short time periods in which the landing and jumping forces are absorbed and applied.

> ***“Maximizing plyometric program effectiveness and preventing injuries depends on the logical progression of exercise intensity.”***
> - Dr William Ebben

Once we have a clear understanding of plyometric exercise intensity we can begin the process of constructing plyometric training programs in a safe, effective, and considered manner. In this programming process, as we consider plyometrics on a scale of intensity, we can also consider them on a scale of specificity. Are exercises general or specific? Will they result in general mechanisms of adaptation or more specific transfer of training effects?

GENERALITY VS SPECIFICITY - THE SPECIFICITY OF PLYOMETRIC TRAINING

Any exercise can be considered to have general and specific training effects depending on the context within which it is used. For example, a football lineman may use the bench press exercise as a general method to improve upper body strength which he can later learn to apply in specific sporting skills on the football field. However, for a powerlifter, the bench press is pure specificity. It is the competition exercise.

In their excellent review paper on resisted sled sprinting in *Sports Medicine*, [5] Petrakos, Morin, and Egan describe two broad strategies to enhance sporting performance:

- Increase physical output (force production)
- Increase efficiency of physical output (force application)

To illustrate this, the authors use the example of training for improving sprinting speed. Typically more "specific" sprint technique drills such as ankling, skipping, bounding or high knee exercises are used to enhance the efficiency of physical output. Methods for increasing the pure physical output are traditional S&C strategies such as strength training and general plyometric exercises.

General training methods can be considered as methods which are focused on increasing physical output. They aim to increase the amount or the rate of our force production. Specific methods are training methods which more closely target the efficiency of our output. They aim to optimize the application of the force we produce. Both are important qualities for sport performance. Athletes of an equal sports performance standard could have vastly different levels of force production or force application ability.

So any exercises can be classified in a hierarchy from general to specific. This depends on how similar the biomechanical properties of the training exercise are to the sporting action we are trying to improve.

Legendary Soviet hammer coach Anatoliy Bondarchuk would term this “dynamic correspondence” between training exercises and competition activities. [6]

I would consider the dynamic correspondence of plyometrics to sporting activities in four areas:

- How close are the contact times to the contact times of the sporting activity?
- Does the plyometric exercise generate force vertically or horizontally in a similar fashion to the sporting activity?
- Is the plyometric exercise bilateral or unilateral?
- Is the plyometric a “single effort” or “repeated effort” method? And how does this relate to the sporting activity?

In his classic text, “Transfer of Training in Sport”, Bondarchuk outlines the relationship between different jumping exercises and sprint performance. See the graphic below. The “correlation coefficient” is a representation of how closely performance in the training exercise (jump types) is to the competition event (100m sprint). A value closer to 1, represents a stronger relationship. A value closer to 0 represents a weaker relationship. Looking at Bondarchuk’s data (this is just a sample of his extensive body of work) we can see that specific methods (such as repeat jumps) have a stronger relationship to 100m performance than more general methods (such as the vertical jump).

Correlation of Training Exercises to Sport Result (100m)

Exercise	100m time 10.2 – 10.5s	100m time 10.5 – 10.8s	100m time 10.8 – 11.1s
Vertical Jump	-0.22	0.27	0.37
Standing Triple Jump	-0.20	0.27	0.39
10 Repeat Jumps	0.35	0.43	0.56
50m Alternating Hops	0.41	0.50	0.56

Adapted from Bondarchuk's Transfer of Training in Sports, Vol. 1

Let's presume our ultimate goal is to improve sprinting performance. An exercise such as the drop jump has low dynamic correspondence to sprinting. It is bilateral, while sprinting is unilateral. It has longer contact times that those observed in top speed sprinting. It is purely a vertical action while sprinting involves a subtle combination of both vertical and horizontal force application. However, this does not mean that drop jumps do not have a place in the physical development of those trying to improve sprinting performance.

"General" plyometric exercises such as drop jumps allow a unique opportunity produce very high forces against the ground with short contact times. Appropriate general exercises can provide a powerful overload stimulus of the fast stretch shortening cycle and stimulate a base level of general neuromuscular adaption. This adaptation, in turn, will allow athletes to express high force and high rates of force development in more specific exercises and activities.

Specific methods should have a much greater "dynamic correspondence" to the sporting activity we are attempting to improve. Let's return to our example of training to improve sprinting speed. Leading sprint mechanics researcher James Wild describes how a more general exercise such as the drop jump could be modified to increase its specificity for sprinting.[7] The drop jump could be performed in a single leg fashion with an appropriate box height and short ground contact times. A forward bounding action could be added to enhance the horizontal force application. Such a manipulation of a general exercise may be a more appropriate method of training to assist maximum velocity development for advanced athletes.

Both the general and the specific have a place in the training plan. The general methods tend to be best for increasing the absolute physical output, but more specific methods are needed to increase the efficiency of the force application and the transfer to sports performance. Both are required and the timing and dosage of these exercise types should be informed by the usual principles of training.

THE TRAINING PLAN - PUTTING IT ALL TOGETHER

So how do we put this all together in a coherent training plan for reactive strength development? It's impossible to outline a single "one size fits all" approach but based on our knowledge of plyometric intensity and plyometric specificity we can develop a simple framework within which coaches can develop individualized plans.

Initially, the goal should be to introduce athletes to the correct technique in jumping, landing, and hopping activities. While the ultimate goal may be to develop fast SSC reactive strength, slow SSC exercises can still be useful in this phase. Slow SSC exercises provide the opportunity to work on appropriate jumping mechanics and joint alignment. They also allow athletes to work on appropriate landing mechanics and to develop eccentric strength. In this phase athletes can also be introduced to "reactivity" with the use of short series of low-intensity fast SSC options such as pogo hopping (vertically or horizontally). Series of 10-15 hops per set should be appropriate. In these exercises, the key focus is on short contact times over maximal jump height. Skipping or low intensity bounding could also be included here.

In the second "development" phase, we can begin to introduce more moderate intensity fast SSC exercises such as repeated hops over very low hurdles. Here the height of the hurdle is used to limit the jump height, not to encourage it. The focus remains on short, sharp ground contact times and tall, strong posture throughout the hopping action. We do not want to use a hurdle height which encourages a focus on jump height (to the detriment of contact times) or encourages "tucking" in the jumping action to the detriment of posture. If the equipment is available, in this phase the coach can monitor ground contact times to encourage the development of the fast SSC. As ground contact times reduce toward 0.13-0.16 seconds, the hurdle height could be raised conservatively. But the coach must constantly consider ground contact times and postural control in the quest to develop reactive strength that will positively transfer to sport. At some point, increasing hurdle height will elongate contact times and athletes may be "tucking" more than they are hopping.

For field sports athletes with an eye on knee-injury prevention and/or improving change of direction ability, this phase may also include low-to-moderate intensity multi-directional activities. These could include series of multi-directional hops over low hurdles or lateral/diagonal movements incorporated into pogo hop series. Coaches must remember that multi-directional plyometric activities will apply shearing forces to the ankle, hips and particularly the knee so they must be introduced conservatively. Proper attention must be paid to alignment and control and it makes sense to being multi-directional work in more of a slow SSC fashion with full landings and longer contact times.

In this second phase, longer, more "extensive" series of low-to-moderate intensity pogo hops could also be used to develop reactive strength endurance. In this phase we may want to build up the athlete's specific work capacity for high level plyometric training. French sport scientist J.B. Morin has advised that various types of "extensive" work is essential to condition the ankle stabilizing musculature. From a reactive strength perspective, longer series of 30-50 repeated, sub-maximal hops could be used here.

when you stand, every day they work… you have to do long series… they recover fast. If you do small series only, you will never work on these muscles.

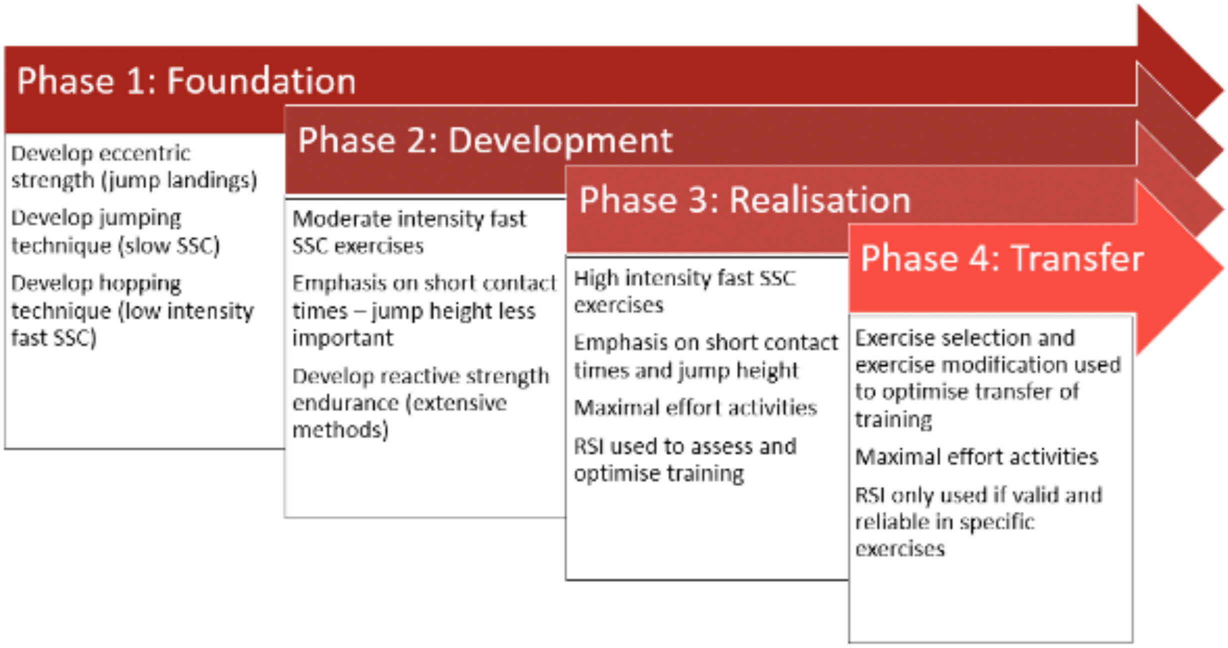
J.B. Morin[8]

"These muscles (at the ankle) are used to fatigue… they are balance muscles. When you walk, when you stand, every day they work… you have to do long series… they recover fast. If you do small series only, you will never work on these muscles."
- J.B. Morin

In the third phase, we have built to "realization". Here the focus is now on high-output, maximal-effort reactive strength training. General, fast SSC plyometric exercises such as the drop jump or maximal effort repeat hops are ideal here. We want to apply a powerful overload stimulus to improve the mechanisms of the fast SSC. In this phase, measurement of ground contact times and the reactive strength index are ideal to help optimize exercise intensity, motivate the athlete and to track progress.

Finally, and most importantly, we need to find methods to assist with the transfer of the physical qualities we have developed to the sport itself. The methods used will depend entirely on the sporting action we are seeking to improve. As previously discussed, for sprinters this may mean plyometric exercises with a greater horizontal and unilateral focus. It may mean using exercises such as horizontal drop jumps, single leg drop jumps or repeated bounding. For a field sport athlete attempting to improve change of direction ability, this may mean high effort, multi-directional fast SSC exercises. There is no limit to the possibilities here. The coach needs to be creative and consider "dynamic correspondence" of the training exercises to the sporting demands. A cautionary note: the sporting action itself is the most appropriate form of "specificity" and in most cases must be the predominant training method. But highly specialized plyometric exercises can be included in the training plan to overload specific aspects of performance and to enhance overall training transfer.

In this final phase, the use of the reactive strength index may or may not be appropriate. The manner in which "jump height" in the RSI is calculated means it may not be valid in some horizontal or multi-directional activities. But just because we can't measure a specific training type, doesn't mean we shouldn't train it. Some work is needed to develop valid and reliable reactive strength testing techniques in unilateral and horizontally focused exercises. But unilateral, horizontal or multi-directional plyometrics may be key in ensuring effective transfer of training.



These phases may not be totally separate, distinct phases. There will be overlap. Some elements of the "foundation" phase may remain throughout the program depending on an athlete's needs. Some athletes may progress quickly from phase to phase, others may need longer to acquire the physical competencies and qualities to safely progress to more advanced methods.

Within each phase the coach must carefully consider the training volume required to stimulate adaptation. There are no hard and fast rules here. Again, individual considerations must be made. But the existing body of sport science research can offer some clues in terms of training frequency and training volume:

- Two plyometric sessions per week appear to be as effective (and more efficient) at improving jump performance and sprinting ability than 4 sessions per week[9]

- Training durations of at least 10 weeks and more than 20 total sessions will be necessary to maximize performance improvement[10]

- High-intensity programs (phases 3 & 4) should have at least 50-60 jumps per session to maximize performance improvement[9]

The outlined progression from phase 1 to 4 is simply a framework within which coaches can apply their own coaching principles and judgement. Consider the guidelines. Assess the athlete's needs. Formulate an individual plan and most importantly, adapt and tweak the program as required.

If you've made it this far, thanks for sticking with this article series. Over the course of 3 parts and 10,000 words we've covered everything from the stretch shortening cycle to plyometric programming and have referenced the work and opinions of some top quality researchers and practitioners along the way. I hope the material we've covered helps inform your training and coaching practice, but in many areas the research is light. Please be critical, question and challenge it all!

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