PLYOMETRIC TRAINING
for dynamic performance

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*Sean Fyfe*
It just goes to show how important a training aspect plyometrics has become, for *Peak Performance* to dedicate an entire special report to the subject. The only other training aspects that can boast such an honour have been resistance training (which incorporates some plyometrics) and core stability training. Like core stability, plyometrics is essential for elite performance, but needs to be performed effectively to be useful.

Throughout these chapters there are reinforced explanations defining the concept and practicalities of plyometrics. I make no apologies for these repetitions; it is crucial that the reader is reminded as to why they are performing these exercises. There is also a reminder throughout that plyometrics must be performed by athletes who have a base level of strength training behind them, and performed with an emphasis on quality of technique, rather than quantity of reps or weight.

The opening two-part chapter introduces plyometrics and its merits. The second chapter moves into the gym where dynamic power can be developed through power-combination training. The third chapter focuses purely on the effect plyometrics has on jumping, which is of course a plyometric exercise in itself! Squat variations are then presented, followed by a look at the effectiveness of plyometrics for the upper body. Detailed plyometric programmes are provided for endurance runners who likely neglect its importance. Finally another two-part chapter presents advice on using plyometrics in rehabilitation.

I hope this special report helps you leap and bound your way to success!

Sam Bordiss
Editor
Depth jump

The depth jump is the archetypal plyometric exercise, mentioned in a number of chapters. Here’s how to perform the exercise effectively.

Basics
Main muscles involved: quadriceps (thigh), hamstrings, glutes (buttocks), calf muscles
Joint motion: ankle extension, knee extension, hip extension
Sports applicability: running (sprinting, middle and long distances), all running and jumping based sports such as tennis, football, basketball and high jump etc

Muscular action
Plyometric exercises work on the principle that a concentric muscular contraction is much stronger if it immediately follows an eccentric contraction of the same muscle. (Eccentric muscular action occurs when a muscle lengthens under load – eg the lowering phase of a biceps curl. Concentric muscular contraction occurs when a muscle shortens under load.)

The effect of a plyometric exercise is a bit like stretching out a coiled spring to its fullest extent (the eccentric contraction), then letting it go (the concentric contraction); large amounts of energy are released in a split second as the spring recoils.

Conditioning benefits
● General – The depth jump provides a great base of dynamic power for the majority of sports. This is because it closely matches the sport specific speeds of movement and muscular action. Most standard weight training lifts, even when performed as quickly as possible, take 0.5-0.7 seconds to complete, whereas during a depth jump your feet may only be in contact with the ground for between 0.2 and 0.3 seconds.
Sport specific – Although the basic depth jump is very sport specific in itself, it can be made even more so by adaptation and variation (more later).

Start position
Stand on top of a strong platform, 0.5-0.8m high (the greater the height, the greater the strength component, the lower the height the greater the speed component).

Action
1. Step slightly forward off the platform. Land toward your forefeet;
2. React as quickly as possible to the ground and spring immediately back up into the air;
3. Use your arms to add to your speed by drawing them back prior to stepping off the platform and swinging them vigorously upward as your feet hit the ground;
4. Keep your back in neutral alignment, ie not arched or rounded;
5. Focus your gaze straight ahead of you.

Training tips
- Maintain neutral posture and a balanced elevated chest position throughout the exercise. Do not attempt to absorb the landing on impact, rather react as quickly and as fast as you can, even if this sacrifices height gained;
- The faster a muscle is forced to perform an eccentric contraction, the greater the concentric force it can generate. To help your understanding: think of a rubber ball being thrown against a wall. What happens when the ball is thrown harder? It springs back even faster and further. This is the effect you are looking for when performing plyometric exercises, like the depth jump;
- Always warm up thoroughly before performing depth jumps;
- Don’t perform more than two workouts a week and allow at least five days before important competitions;
Monitor the number of jumps performed. Depth jump volume is measured in ground contacts; avoid more than 60 in a session. Start with 3 x 6 repetitions;
To allow your power-producing fast-twitch muscle fibres to be at their most effective, take 30 seconds recovery between exercises and two minutes between sets;
Perform depth jumps on a non-slip flat surface – a sprung gymnasium floor or an all-weather athletics track are ideal surfaces;
You need to be in ‘the right frame of mind’ to get the most out of depth jumping. Going through the motions will not turn on sufficient neuromuscular input to optimise their performance.

**Sport specific exercise progression**

**Single-leg depth jump (hop) for distance**
This variation will up your leg muscles’ power and is a great exercise for field and racket sports players, sprinters and jumpers (where all movements are performed with an independent leg action). Note the single-leg depth jump places greater potential strain on the legs and back, as such this exercise should only be performed by those with a high degree of prior plyometric training experience.
Assume the same starting position as for the first exercise, but this time drive forward to land about 1m in front of the platform, on the same leg. React as quickly as possible to the ground and hop forward as far as you can. Maintain an upright posture and cycle your hopping leg under your body whilst in the air. Coordinate your arms with your legs, *i.e.* in a running, ‘opposite arm to leg’ style. Try 3 x 5 repetitions, alternating left and right leg sets.

*John Shepherd*

**Warning** The author and PP take no responsibility for injuries caused by attempting this exercise. PP recommends that you always learn new exercises under the guidance of a professional.
This opening two-part chapter introduces the concept of plyometrics and explains how it should be implemented into training sessions. Part One clarifies the basics behind plyometrics, listing particular drills and training tips. Part Two focuses on making plyometrics sport-specific, using football as an example.

Part one:
Introduction to plyometrics

Want more hang time, more sprint speed, greater rotational power and greater stopping ability? Then plyometric training is your answer. Plyometric training was the brain child of Eastern Bloc sports scientists in the 1960’s – although jumping exercises have been involved in the training routines of athletes for many years previously.

Why are Plyometric moves such great sports conditioners?

Plyometric drills closely reflect both the movement pattern and the performance speed of numerous sports and sports skills. This is something that weight training cannot do.

An elite sprinter’s foot will only be in contact with the ground for a split-split second (0.084 seconds – to be exact) and even running at a moderate running pace can result in a foot strike time of 0.2 seconds. These are speeds that just cannot be replicated in the weights room - most standard weight training lifts, even when performed at their quickest, take around 0.5-0.7 seconds to complete.

What’s a plyometric exercise?

Basically any exercise that involves a dynamic shift from absorption of force to expression of force is a plyometric exercise. A typical example would be two consecutive bunny
(two-footed) jumps. On landing from the first jumps the muscles of the legs, calves and ankles would be put on stretch (this is technically known as an eccentric contraction), they then transfer power by way of a shortening muscular contraction (technically known as a concentric contraction). Research (and practice) shows that muscles are able to exert much more force when they perform plyometrically.

Still need convincing try this:
Stand next to a wall and using a double-footed action, jump as high as you can. Now – after a pause - take a step back and step into the double-footed jump, you will jump higher.

The eccentric contraction primes the concentric one for a greater power output- so you jump higher. It’s a bit like pulling out a spring to its fullest length and then letting it go immense amounts of energy will be released in the split second the spring recoils.

Improving your plyometric capability
Although the body naturally performs the plyometric action when required, this does not mean that the response cannot be improved. In fact the right training programme can significantly lift your power and speed. This is achieved by boosting muscle and tendon strength and improving the neuromuscular activation of the response (basically, your brain becomes better at coordinating what is required).

Table 1 ranks plyometric drills by their intensity. It is very important to realise that a low intensity drill is no less important than a higher intensity one. It’s just that the former places less strain on the body. It’s very important that familiarity is achieved with plyometric exercises gradually and progressively as they can place a lot of strain on the ankles, knees and back (and shoulders when upper body plyometrics, such as ‘clap press-ups’ are performed). Technique is therefore obviously important.

How to warm up for plyometrics
After 3-5 minutes of easy running, perform some dynamic movements, such as arms and leg swings and walking lunges.
You may also want to do some runs of gradually increasing speed over 30-40m. Active and passive (held) stretches have little relevance to plyometric (and other dynamic movement) and can actually impair performance. In fact some research has indicated that stretching this way can lead to injury.

### Plyometric training tips

1) Always warm up suitably
2) Wear well cushioned supportive shoes
3) Perform on dry flat grass, a running track or sprung sports hall floor
4) Remain focused and in the zone throughout your workout
5) In the majority of cases quality of performance is key – if your reactions start to slow then you’ll ‘pattern’ this slower
movement into your body’s neuro-muscular system. You need to make your ground contacts as quick as possible.

6) Don’t perform plyometrics close to important competitions – allow 3-4 days clear

7) Think about the needs of your sport and tailor make specific plyometric drills (see part 2—specific plyometrics)

**How much plyometric training should I do?**

This will obviously vary in regard to your sport, experience, the time in the training year and the intensity of the plyometrics being performed, but here are some guidelines:

For jumps on the spot or from standing measure the volume in terms of foot contacts. As a guide a beginner in pre-season training in a single workout could perform 60-100 foot contacts of low intensity exercises, for example, 5x5 tuck jumps and 5x5 hops on the spot (left and right) and 5x10 split jumps.

Intermediate trainers might be able to do 100 -150 foot contacts of low intensity exercises.

Advanced trainers might be capable of 150 -200 foot contacts of low-to-moderate intensity exercises. Intensity is the key, the more dynamic the move and the greater power generated, the greater the requirement to reduce the number of foot contacts.

Bounds and hops can also be measured by ground contacts but are made more intense by the distance they are performed.
over and whether a run up is used. A top class triple jumper might perform 10 x 10 bounds, with a 6 stride run-up and find this of moderate intensity, whereas a novice footballer would not be able to complete this workout. It is always best to underestimate what you think you can achieve - this will provide you with a starting point from which you can progress.

A note on muscle soreness
When starting a plyometric training programme some muscle soreness will be inevitable. You must warm up thoroughly and warm down after your workouts and progress slowly.

Weight training and plyometric training
Weight training will strengthen your soft tissue (ligaments, muscles and tendons) making them less prone to strain and should always be part of a training programme that incorporates plyometrics.

Part two:
Sport-specific plyometrics
Plyometric exercises are a great way to enhance sport specific power. In Part One we looked at why this was so and provided typical examples of plyometric drills (ranked by intensity). In Part Two we show you how with a bit of tweaking and specific thinking, you can make your plyometric drills even more specific to your sport.

A reminder on how plyometric exercises work
Plyometric drills work on improving the natural recoil of muscles and tendons. As indicated in Part One this is the result of an eccentric (muscle lengthening) contraction priming an immediate subsequent concentric (muscle shortening) one.

The action is akin to a pogo stick – which would no doubt be banned from children’s use under current health and safety regulations! On landing on a pogo stick a spring mechanism
compresses and ‘fires’ the child and stick higher into the air, as they bounce down the road. A similar reaction occurs naturally in our muscles if we were to jump, for example, up and down on the spot. Our muscles don’t have in-built springs like the pogo stick, but they are able to create greater ‘spring’ due to the eccentric/concentric response (which is also known as the stretch, shortening cycle).

**Making your plyometrics more specific**

Although a series of bounds or hops will improve the speed and power capacity of for example, a badminton player, they are not the most specific way to develop power for this sport. Similarly a set of 4 x 6 depth/drop jumps with a 2 minute recovery between sets will not develop optimum plyometric power for a basketball or football player.

**Get sport specific criteria**

To construct a ‘specific to your sport’ plyometric routine you need to consider:
1. The nature of the power required for your sport
2. The duration of your sport
3. The acceleration and deceleration required of your sport
4. The ratio of lateral to linear movements made
5. The effects fatigue can have on power generation

**Football a specific focus**

Let’s take a look at the plyometric needs of a football player. For ease of understanding we will focus on strikers (as it could be argued that every different playing position requires a specific plyometric (and general conditioning) routine.

**Nature of power** – our striker will not cover too much ground on the pitch compared to say a midfield player. They will operate in the front third of the pitch, often with their back to goal. They will need to be able to make quick cuts and turns to get away from their markers. They’ll need dynamic 5-10m linear, lateral and rotational (turning) ability – with and without the ball. And they will need to be able to jump from both
relatively stationary and moving positions to make headers.

**Duration of the sport** – seems an easy one to start with as a match lasts 90 minutes. But how much of this time is actually spent running, walking, jumping, turning and so on? The information provided in table 1 will make for interesting reading in the light of this – although it applies to all playing positions.

**Acceleration deceleration requirements** - our striker needs to be able to get away from his or her markers. Specific acceleration will be needed from standing and off of various running speeds. For example, the player may be jogging and then react and sprint at full speed into the box to make a run to get onto the end of a through pass. In terms of deceleration they may be sprinting toward the corner flag to get onto a pass and then have to halt rapidly in order to control the ball make a pass or attempt to beat their opponent.

**Ratio of lateral to linear movements** – Table 1 provides an indication of the ration of various movements to one another in football. But getting even more striker specific – our player will probably make more lateral and rotational movements than linear ones due to the nature of their position. They are

| Table 1: Football specific movements across the course of a match and season |
|---|---|---|---|
| | A match | A season | A training | A season | Total season |
| Action mode | Match (n) | Season (n) | Training (n) | Season (n) | Total (n) |
| Passes | 35 | 2100 | 100 | 22000 | 24000 |
| Runs with ball | 7 | 420 | 50 | 11000 | 11000 |
| Headers | 6 | 360 | 15 | 3300 | 3700 |
| Shots | 1 | 60 | 10 | 2200 | 2300 |
| Tackles | 7 | 420 | 15 | 3300 | 3700 |
| Jumps | 9 | 540 | 15 | 3300 | 3900 |
| Turns | 7 | 420 | 30 | 6600 | 7000 |

Source: Professor Pekka Luhtanen http://www.coachesinfo.com/article/86/#
not 100m sprinters who operates exclusively in a straight line, although they will need to develop a similar power capability. Most of their dynamic ability as noted involves twisting and turning movements.

**The effects of fatigue** – research indicates that most football injuries occur in the last quarter of a match when the players are fatigued. This has an obvious bearing on general conditioning as well as specific plyometric training. Coaches need to ensure that the striker (and all other players) is robust to withstand injury and that if they need to leap to head the winner in the 90th minute they can.

**Designing specific plyometric drills?**

Having analysed our sports requirements we then use our grey matter to design specific drills. We’ll continue with the football striker example, by providing examples of specific plyometric drills according to our ‘get specific criteria’ analysis (note these dovetail over one another – so the drills that follow have/may have an application to one or more of the criteria). The drills could be used during pre and in-season.

**Heading**

Jumps will need to be made off-balance, from a run and from double and single leg take-offs. A range of plyometric drills can be developed to reflect this:

**Sit, react, turn and jump drill** The player sits on floor with hands by hips and legs outstretched. To a command they get up turn and sprint 5 m to leap to head a ball that has been thrown with the right timing or simulate a header. The coach can tell the player which type of jump to perform to head the ball, for example, from a double or single foot take-off.

**Cutting**

Although a striker who is naturally quick will have an advantage on the pitch in terms of, for example, sprinting onto a through ball and escaping their marker. This may not make them the best lateral or rotational mover - these are separate skills that
must be practised. Plyometrics can assist this process. Here’s an example of a relevant drill:

**Cut and sprint drill** The player jogs 10m to a cone they then perform a short lateral cut (jump) to their right to land slightly forward and to the right of the cone. On landing on their right foot they immediately sprint 10m at a 45-degree angle to a cone placed in the relevant spot. This drill should be practised to the left and to the right. Reps and sets can be varied to reflect the fatiguing aspects of the game. This drill will provide a base of plyometric power for the less contrived (improvised) cuts and steps that a player will need to make in a game.

**Deceleration drill** Player runs at mid pace to a cone placed 10m away and then decelerates to a stop before reaching another cone placed 2m in advance of the first. How is this a plyometric drill? Without going into too much detail any activity that involves an immediate eccentric to concentric action is plyometric as it involves the stretch-shortening cycle (even walking). However, it’s really when the speed of the activity is increased that it becomes truly sports specific and plyometric training.

Deceleration requires plyometric power. Specifically the eccentric contraction is emphasised, before the concentric one - it’s the one that applies the brakes. The deceleration drill will develop greater eccentric ‘stopping’ power.

**Other ways to condition eccentric stopping power**

**Eccentric action depth jump**
It is possible to specifically condition eccentric power, by isolating the concentric reaction. A specific example is performing a depth jump to land and absorb the impact only without overly yielding at the knees. No attempt is made to perform a jump after landing - *ie* add a concentric contraction.

**Eccentric action weight training**
By concentrating on lowering the weight to a slow 5 count muscles can be trained to develop greater eccentric power.
Acceleration drills
Acceleration particularly from standing or other stationary position emphasises a concentric muscular contraction. This is because the performer will have not moved fast nor far enough to benefit from an enhanced concentric response from their muscles, from the preceding priming eccentric one. Plyometric drills can be developed to enhance acceleration.

Fan drill use the centre circle on a football pitch and place 8 cones randomly around one half of the circle – number each 1 – 8 from left to right.

The player stands ready on the centre spot. The coach calls out a number and the player speeds bounds to the relevant cone - a speed bound is performed by pushing the ground behind as dynamically as possible, whilst moving forward from left to right leg. It differs from the normal running action in that the legs do not fold up behind the performer to the same extent as they do when running.

The body should be inclined forward and the arms pumped vigorously backward and forward in a sprint action to achieve dynamic acceleration.

In the same way that weights and other drills can be used to develop greater eccentric strength for deceleration purposes so too can drills be designed to enhance acceleration with its concentric muscular action emphasis.

Jump squats with light to medium weight dumbbells held at arms’ length
The performer bends their knees to create a ‘thighs parallel to the ground’ position and then leaps into the air whilst holding the dumbbells. On landing they lower into the ‘ready’ position, hold for 2 seconds and perform another jump. The pause will ‘turn off’ the plyometric response and require the performer to utilise concentric leg strength to power them skyward.

Effects of fatigue
With thought it is possible to create a specific plyometric
endurance workout that will benefit the striker. This workout involves short recoveries and multiple repetition plyometric drills. The session is tough and should only be performed by the well-conditioned and they should also only be used sparingly in the player’s conditioning. An example:

- Place two cones 15m apart
- Player jogs to first cone, turns and hops back to first cone
- Player jogs to second cone and hops back on other leg
- Player jogs back to first cone and sprints to second cone
- Player jogs back and performs another sprint to second cone
- Player walks back and then performs double-footed bunny jumps to second cone
- Player walks back and performs simulated headers off both legs to second cone – jogs back to second cone and repeats
- Player walks back to first cone and speed bounds back to second cone
- The coach can add more or less drills.

Depending on the player’s conditioning and the time in the training year, the sequence (or any other) can be repeated any number of times. Body weight exercises, such as press-ups and sit-ups could also be included to break up the more intense plyometric work and add a further element of fatigue. To make the drill even more sport specific – dribbling a ball between the cones could be introduced at some point as could a series of 20 short distance passes made from the left and right foot to another player standing 5 metres on from the second cone. After the last pass the player jogs back to the first cone and continues with the plyometric exercises.

Plyometrics are a great way to develop specific sports power. From this article (and Part One) you’ll appreciate how they can be made even more relevant to sports and specific skill requirements. To achieve this it is crucial to analyse the movement patterns of the specific sport and develop drills that reflect these and other factors such as fatigue.
The gym or weights room is a familiar place for power athletes. However, unless the training is correct, those weights could turn a power athlete into a strength athlete, which would have disastrous consequences in competition. Part One looks at various research focusing on developing power over strength. Part Two is dedicated to power-combination training, incorporating plyometrics with traditional resistant training.

Part one:
Power training

Power and the glory – building power for winning performance!
Although power and strength are intimately connected, they’re not the same thing. Training for power in sports requires a significantly different approach to traditional conventional strength-training methods.

Despite strength being important for the majority of sports, it's invariably the most powerful athlete who is blessed with superior performance. Take rugby or American football as examples. The power of some of the tackles makes for a truly awesome spectacle. These athletes demonstrate incredible power – that is they are able to overcome resistance as quickly as possible.

And with a high power to weight ratio, they show that they can move themselves or an object (such as an opponent!) very quickly, in split seconds. This contrasts with gross strength, which is about developing the ability to lift as heavy a weight, or overcome as much resistance as possible regardless of the speed of the movement – but usually slowly!

Developing sports-specific power in the weights room
As noted, most coaches advocate fast movement lifting with
weights in the region of 70% of 1RM as a means of developing athletic power. Typical exercises would include squats, hang pulls and bench presses. Jumping/throwing weight exercises such as the jump squat and bench throw are also commonly performed, often with similar loadings. But are these the optimum loads?

Researchers from Connecticut looked precisely at this and whether the training response varied between men and women\(^1\). Their study involved National Collegiate Athletic Association Division I athletes. Each performed power testing at 30, 40, 50, 60, and 70% of individual 1RM in the squat jump, bench throw, and hang pull exercises.

The team discovered that there were differences between genders in maximal power output during the squat jump (30-40% of 1RM for men; 30-50% of 1RM for women) and bench throw (30% of 1RM for men; 30-50% of 1RM for women) exercises. The women were able to generate more power with heavier loads. There were no gender differences for the hang pull exercise, where maximal power output occurred at 30-60% of 1RM.

This led the researchers to conclude that about 30% of 1RM elicited peak power outputs for both genders and all exercises used in the study and also that this should be the starting point for developing power in these lifts in strength trained athletes. Thirty per cent may seem pretty light to many coaches and athletes and it could be reasoned that heavier loads could develop greater power. However, moving greater weights inevitably slows down the speed of the lift, jump or throw. And, as power is all about applying maximum force at the highest velocities, it is easy to understand how too heavy a weight could compromise the development of this vital sporting quality!

Other researchers have considered the validity of the ‘30% marker’ for developing power with dynamic weight exercises. For example, a team from Australia looked specifically at the jump squat\(^2\). Twenty-six athletic men with varying levels of resistance training experience performed sessions of jump squats. Heavy loads (80% of 1RM squat best) and light loads (30% of 1RM squat best) were used across an eight-week programme. EMG and other measures of performance were
used to determine the results.

It was discovered that the light-load jump squat group significantly improved their power and velocity. It also improved their squat 1RM. Although the heavy-load group also significantly increased power and their 1RM (ie absolute strength), they were significantly slower over a 20m-sprint test – a crucial marker of sports performance. This investigation again validates that jumping with 30% 1RM loads seems to produce the greatest power returns in terms of improved athletic ability.

Weight training protocols, strength type and muscle fibre adaptation

The theme of the previous research was reflected in another study performed by a team from Ohio\(^{(3)}\). They specifically considered the number of repetitions performed and the effect they had on muscle fibre adaptation, maximal strength (1RM), local muscular endurance (maximal number of repetitions performed with 60% of 1RM), and various cardio-respiratory measures (for example, maximum oxygen consumption, maximal aerobic power and time to exhaustion).

Thirty-two untrained men were involved in the study and were divided into four groups. The exercises used were the leg press, squat, and leg extension. They were performed two days a week for the first four weeks and three days a week for the final four weeks:

1) Low repetition group (Low Rep) who performed 3-5 RM for four sets of each exercise with 3 minutes’ rest between sets and exercises;
2) Intermediate repetition group (Int Rep) who performed 9-11 RM for three sets with 2 minutes’ rest;
3) High repetition group (High Rep) who performed 20-28 RM for two sets with 1 minute of rest;
4) A non-exercising control group (Con).

Crucially, in the light of the subject matter of this article, pre- and post-training muscle biopsy samples were analysed for fibre-type composition, cross-sectional area and capillarisation.
In particular, fibre-type changes would indicate what effects the training was having. An increase in fast-twitch fibre, for example, would indicate an increase in power and strength capability among the subjects.

Not surprisingly, it was discovered that maximal strength improved significantly in the Low Rep group compared to the other training groups. For the High Rep group the maximal number of repetitions at 60% 1RM improved the most. In addition, maximal aerobic power and time to exhaustion significantly increased at the end of the study for the High Rep group only – indicating a positive transference to endurance ability.

All three major fibre types (types I, IIA, and IIB) hypertrophied (increased in size) for the Low Rep and Int Rep groups, whereas no significant increases were demonstrated for either the High Rep or Con groups. More interestingly, the percentage of type IIB fibres decreased, with a concomitant increase in IIA fibres, in all three resistance-trained groups. This is significant for power training athletes; type IIB fibres are the big power providers and are the ones that will get you to the finish line the quickest in a 100m sprint.

In this instance, weight training seems to have blunted their power potential by changing them to type IIA fibres. Although fast-twitch, these ‘intermediate’ type IIA fibres are not as adept at producing out and out power as their IIB counterparts. Other researchers have discovered similar findings when it comes to the effect of weight training on fast-twitch fibres(4). There are ways of getting round this; for example eliminating or reducing the amount of medium/heavy weight, weight training performed as important competitions near, allowing for a reversion of IIA fibres back to IIB and also ‘power combination training’.

References
Part two:
Power combination training

The potentiation effect: can one training mode really enhance another?

As alluded to at the end of part one, the key to improving dynamic power could lie with the power combination workouts and the potentiation effect. Part two examines further.

Complex training describes a power-developing workout that combines weights and plyometric exercises. In the mid-nineties, these workouts were greeted with great acclaim as research indicated that they could significantly enhance fast-twitch muscle fibre power and, therefore, dynamic sports performance. However, more recent research has highlighted a number of questions about complex training as well as some new potential benefits.

The key physiological vindication for these workouts is the ‘potentiation’ effect – ie the enhancing effect one training mode can have on another. Initially, research focused on the potentiation of the plyometric exercises by the weights exercises (note that the exercises involved are ‘paired’ and work the same muscle groups). More recently, though, researchers have turned their attention to whether weightlifting power could be enhanced by the prior performance of a plyometric exercise.

Fast-twitch muscle fibre holds the key to increased dynamic sports performance, since these fibres can contract 2-3 times faster than their slow- twitch counterparts. Type IIb fast-twitch fibres are the turbochargers of the power athlete’s engine (as opposed to type IIa ‘transitional’ fast-twitch fibres, which can be modified for either power or endurance purposes). But these turbochargers are notoriously difficult to activate fully, since there can be as many as 1,000 of these fibres to every one motorneuron in their muscle motor unit.

A motorneuron acts as a sort of ignition key to its bundle of JARGON BUSTER

Capilliarisation
The process of increasing tiny muscle capillaries in muscle tissue; this increase in the number of ‘oxygen carrying highways’ to the muscle benefits aerobic muscular capacity and promotes endurance

Fast-twitch muscle fibre
Muscle fibres that contract very rapidly (three times faster than slow-twitch fibre) and which are crucial for increasing dynamic sporting ability

Potentiation
Increased stimulation of fast-twitch muscle fibre, thought to be the result of increased neural activity
power-producing fibres. Under normal training and competition situations, ‘turning the key’ requires a highly focused mental approach. Simply going through the motions will not excite type IIb fibres enough to achieve a PB weight lift or series of bounds.

In fact, it is argued that even when an athlete is ‘psyched’ – *i.e.* applying great mental pressure to unleash the might of their fast-twitch fibres, this may still not be enough. It is because of this that power combination workouts, with their seeming ability to fully potentiate fast-twitch fibre as if by magic, have become very appealing.

The way plyometric and weights exercises are ordered into a power combination workout can have a significant effect on training adaptation and potentiation. There are two basic approaches:

- **Complex training.** This involves performing sets of weight training exercises before sets of related plyometric exercises – *e.g.* three sets of 10 half squats, before three sets of 10 jump squats. Such combinations of sets are known as ‘complexes’;

- **Contrast training.** This involves alternating sets of first weights then plyometric exercises – *e.g.* one set of 10 half squats followed by one set of 10 jump squats, repeated over three sets.

**Complex training effects**

It is argued that the weights exercises for both complex and contrast training workouts should be in excess of 70% of 1 repetition maximum (1RM), since lighter loads are considered inadequate for activating type IIb fibres and setting off the potentiation effect.

Although a great deal of research points to the success of power combination workouts a number of questions have been raised – not least over the potentiation effect itself. Jones and associates, for example, looked at complex training and the effect heavy squats had on counter-movement jump (CMJ) and depth jump (DJ) height, and on muscle activity, as measured by electromyography (EMG), in the subsequent plyometric exercise(1).

Eight strength-trained men were involved in the research
under two conditions:
1. Complex training, performing five squats at 85% of 1RM, followed by the first set of jumps, with the second, third and fourth sets performed three, 10, and 20 minutes after squatting;
2. Control condition, involving only CMJ and DJ performance.

The team found no positive potentiation for any CMJ performance variable or EMG activity, regardless of muscle or phase of jump; nor were there any significant effects of the squats on DJ performance. However, EMG activity in the biceps femoris (hamstrings) during the propulsive phase of the DJ was found to be significantly higher after squatting (although this did not improve jump performance). The researchers concluded that complex training did not enhance plyometric muscular activity.

There are a number of potential explanations for these findings. First, it is possible that greater exposure to the complex training workout could have produced greater improvements in plyometric performance: the fact that higher EMG activity was discovered in the hamstring muscles during depth jumping indicates that more fast-twitch fibres were being recruited, which in time could have provided more propulsive power.

**Order of exercises**
Secondly, the order of the exercises could have affected the outcome, and the results might have been different if a contrast methodology had been used. (Research has suggested that the contrast method may be more effective at eliciting potentiation in those with little experience of power combination training or lower strength levels, of which more later).

Research by Duthie and associates examined jump squat power in complex, contrast and ‘traditional’ training workouts\(^2\). Eleven women with varying strength levels completed three randomly ordered testing sessions, as follows:
1. Traditional – completing sets of jump squats before sets of half squats;
2. Complex – sets of half squats before jump squats;
3. Contrast – alternating sets of half squats and jump squats.

The researchers found no significant enhancement of jump squat performance with any method in the subjects with lower strength levels. However, the stronger women demonstrated superior jump squat performances with contrast training, and the researchers concluded that this method was more effective for increasing power output in athletes with relatively high prior strength levels.

Other research, such as that by Gourgoulis et al, has also pointed to the importance of prior strength levels on power combination workout outcomes. They found that pre-squatting significantly enhanced the vertical jumping ability of stronger participants by 4.01%, but of weaker ones by just 0.45%.

In practical terms, this means that coaches must be mindful of individual strength levels, and be prepared to vary the ordering of power combination workout training elements accordingly in order to achieve the most significant adaptations. They should also be prepared to vary the loading of the weights exercises (between 70 and 90% of 1RM) and the number of repetitions. Recording the results will highlight which workouts produce the best results and the physical attributes performers may need to work on to produce the best potentiation gains.

Training maturity should also be taken into account as an important potential variable in the success of power combination workouts – particularly when it comes to the order of exercises. Research by the Soviet sports scientist Yuri Verkhoshansky (the so-called ‘father’ of plyometric training) showed that novice track and field athletes developed less explosive strength when they performed heavy weights exercises before their plyometrics (rather than vice versa) over a 12-week training period. This may simply be because the heavy squatting tired the athletes’ relatively untrained muscles to an extent that impaired subsequent explosive performance.
The length of rest periods between exercises is a further matter for debate in connection with power combination workouts. A complex training workout in its ‘purest’ form is designed to create an almost immediate potentiation effect. The rest between exercises and sets is normally kept to about two minutes – long enough to minimise fatigue but short enough to create and maintain potentiation, therefore optimising power output throughout the workout. (Note, though, that some power combination workouts are designed to deliberately develop power endurance and use shorter recoveries and greater numbers of exercises. These workouts, applicable to such sports as basketball and rugby, inevitably generate greater fatigue that can inhibit potentiation.)

Research by Fastouros considered the rest factor and the value of combined training methods in a study of 41 healthy men divided into three training groups, as follows:\(^4\):

1. Weight training exercises only;
2. Plyometrics only;
3. Plyometrics and weights exercises on the same day but, crucially, not during the same workout. This group performed the weights exercises first, followed by plyometrics some three hours later.

The team found that, although all training methods improved vertical jump and squat performance, the athletes combining plyometrics with weights experienced the greatest performance enhancement – a maximum squat improvement of 36kg, compared with 16.4kg for the weight training group and 28kg for the plyometric group.

This research has positive implications for those embarking on power combination training. Separating the two training elements on the same training day with a longer recovery time could avoid fatigue yet still maintain potentiation.

Most power combination training research has focused on the potentiation of plyometric exercises by weights work. However, research by Masamoto looked at the effects of plyometrics on weight training, particularly on 1RM squat
performance\(^{(5)}\). Twelve trained men participated in three 1RM testing sessions, separated by at least six days of rest. In the first session, they performed a series of weights sets with increasing loads until 1RM was determined; in the second and third sessions, they performed either three double-leg tuck jumps or two depth jumps 30 seconds before each of three 1RM attempts, interspersed by at least four minutes’ recovery.

The researchers discovered that performing a plyometric exercises before going for a 1RM best had a positive effect. Tuck jumps upped the average squat performance to 140.5kg, and depth jumping boosted it to 144.5kg, compared with 139.6kg with no prior plyometrics. This is obviously very encouraging news for power and weight lifters and anyone else looking to increase general muscular strength via weight training.

Can power combination workouts enhance competitive as well as training performance? Research by Matthews looked at the effect of pre-squatting on 20m sprint performance\(^{(6)}\). During the control condition, participants performed two 20m sprints separated by 10 minutes’ rest. During the experimental condition, the second sprint was preceded by five squat repetitions with a load equal to each participant’s five repetition maximum (5RM). While the researchers found no improvement between the first and second sprints in the control condition, there was a mean improvement of 0.098 seconds when the second sprint was preceded by the squats.

**Squats and sprint cycling**

Similar findings were made by Smith et al, who looked at the effect of squats on a very intense 10-second bout of sprint cycling\(^{(7)}\). In this study, involving nine men, the time between squatting and sprint performance was varied over three conditions, as follows:

1. Control – a 1RM squat attempt immediately before the 10-second cycle sprint;
2. 10 squats at 90% of 1RM five minutes before the sprint;
3. As for 2 but with a 20-minute rest before the sprint.
The researchers noted significant increases in average power and average power relative to body weight with the second condition and concluded that this protocol could be useful in enhancing sprint performance.

The implications of this research are obviously immense, although in practice it may be difficult to schedule in five minutes of squatting before a 100m sprint final! However, you may be able to get away with performing the following potentiating exercises to be completed five minutes before competition – as long as you experiment with them in training first:

- Sprinting/jumping/throwing – perform three single leg-squats on each leg;
- Sprinting/jumping/throwing – perform five squats with a willing training partner/team-mate on your back;
- Weightlifting – perform five throw-and-catch medicine ball chest passes against a wall as fast as possible and/or complete three tuck or depth jumps.

Power combination training, despite some of the reservations expressed earlier, seems to offer a great deal for those in search of increased fast-twitch muscle power. However, coaches need to take careful account of prior strength levels, training maturity and the types of power combination workouts most appropriate for their athletes, in order to get the most from them.

John Shepherd

References
Jump to it – why and how you should improve your jumping ability

Being able to jump well is crucial for performance in a number of sports, requiring good conditioning and technique. This chapter examines the theories and practical strategies, revolving around plyometrics that can help you maximise your vertical and horizontal jumping ability and so enhance your sporting prowess.

The standing long jump and sergeant jump measure the ability to jump for distance and for height respectively (from a standing two-footed position), and are often used as tests of sports ability. Table 1 (overleaf) displays relative standards for standing long jump (distance) ability. At first sight, this type of jump appears pretty straight forward; the athlete simply bends their knees, whilst swinging their arms back and forward, before making their leap into the pit. However, even this relatively simple jump can be improved technically in one training session, perhaps adding 10cm or more to the distance jumped.

A study by Australian researchers focused on the optimum take-off angle for standing long jumps (1). They discovered that jumping distance was strongly influenced by the jumper’s take-off speed and take-off angle. High take-off angles resulted in poor jump distances, as the athlete was unable to generate sufficient horizontal velocity to propel their bodies forward. The researchers discovered that take-off angles of 19-27 degrees optimised jumping distance and that this was actually lower than the jumper’s preferred angle of take-off (31-39 degrees).

Role of arms in jumping
The use of the arms and free leg (when jumping from one leg)
are, like angle of take-off, equally important determinants of jump distance. In an effort to discover exactly how much contribution the arms make to standing long jump distance, researchers from the University of Texas used computer modelling to investigate what effect free and restricted arm movements had (2). They found that simulated jump distances were 40cm longer when arm movements were free. Arm movement allowed for a 15% increase in jump velocity of the centre of gravity.

More specifically, this was attributed to an additional 80 joules of propulsive work done by the shoulder muscles. In order to benefit from this extra energy during sports activity, you need to vigorously swing your arms back and forward as they rise and fall with your thigh movements, timing the arm swing past your legs to coincide with the leg drive into your take-off. This will maximise jump speed (provided of course you aim for a take-off angle of between 19-27 degrees). Arm action is crucial to optimum performance, whatever the jump.

The high jump is the ultimate test of vertical jumping ability. The men’s world record stands at an incredible 2.45m and was set by Cuba’s Javier Sotomayor in 1993. Researchers from John

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<th>% Rank</th>
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<tr>
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<td>2.94 – 3.15 metres</td>
<td>3.40 – 3.75 metres</td>
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<td>1–10</td>
<td>1.60 – 1.74 metres</td>
<td>1.90 – 2.04 metres</td>
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Source: Chu DA, Explosive Power and Strength Human Kinetics 1996
Moores University in the UK, have looked specifically at how the free limbs are used by elite high jumpers in generating vertical velocity\(^3\).

Six elite male high jumpers were subject to tests that enabled the researchers to determine the power and speed of the jumper’s joint motions at take-off. It was discovered that the arms had a greater influence on take-off performance than the free leg. This seemed to be as a result of the limited ability of the free leg to drive further ‘into’ the jump once the take-off foot was grounded and extending into the jump, and was in contrast with the ability of the arms to drive more forcibly ‘through’ into the jump.

In all it was estimated that the free limbs contributed 7.1% of whole-body momentum at take-off. The researchers concluded that in order to maximise the contribution the free limbs can make to performance, the arms should have a vigorous downward motion at touch-down (take-off) to make the most use of the high (but little changing) relative momentum of the free leg.

**Foot contact**

Such detail can even be extended to foot contact when jumping. Researchers looked at the relevance of foot positioning, and in particular foot-landing positions, when athletes performed depth jumps drills\(^4\). These exercises develop plyometric leg power and require the performer to step off of a suitable platform and on landing, spring immediately upward, sideways or forwards. Specifically, the researchers addressed the force generated from flat-footed versus forefoot ground contacts.

Ten healthy male university students performed two types of depth jump from a 0.4m high box placed 1m from the centre of a force plate. They performed jumps down onto either the balls of their feet (without the heels touching the ground during the subsequent vertical jump), or onto their heels (flat-footed). The researchers discovered that the first (landing) and second (subsequent jump) peaks in force generation were 3.4 times greater and 1.4 times lower respectively for flat-footed landings
The most effective warm-ups for enhanced jumping

An increasing amount of research has indicated that the way an athlete warms up before jumping can have a significant effect on performance. Australian researchers considered the effects of four different warm-up types on depth jump and standing jump performance:

1) Four-minute run only;  
2) Run and static (held) stretch;  
3) Run, stretch and practice jumps;  
4) Static stretch only.

Unsurprisingly, the static stretching warm-up produced the lowest jump scores (much research indicates that static stretches performed before exercise impair the ability of muscles subsequently to contract forcibly and quickly). Again perhaps unsurprisingly, the run plus stretch plus practice jumps consistently provided the highest scores. Interestingly, the run-only warm-up proved to be superior to the run and stretch warm-up on a number of measures; for example, depth jump height was 3.2% better and rate of force development a highly significant 15.4% better.

The research adds weight to the current belief that static stretching impairs jump performance and that the body needs to be warmed up dynamically but safely to provide the heightened neuromuscular condition needed to optimise jump performance.

Note: had the stretches in the warm-ups involving running been dynamic, for example, leg swings and leg cycling, the effects of this method on jump performance could have been even more significant.

As opposed to forefoot landings.

For athlete and coach this type of research has some important implications. Specifically, the nature of jumping foot-strike (ground contact) should be carefully analysed for particular sports and the most appropriate jumping exercises performed that have the greatest sports match. For example, while a flat-footed landing depth jump will develop some jumping power, it may not optimally transfer into the specific performance requirements of an athlete in a specific sport. To give some examples:

- A sprinter may benefit more from forefoot, single-leg-landing depth jumps, as the sprint action is performed from a similar foot-strike position;
- A basketball or volleyball player may derive greater vertical spring (a key requirement of their games) by using flat-footed, single- and double-leg-landing depth jumps.
As the previous research indicates, the free-limb actions also have to be carefully considered and training drills designed to replicate these. Thus high jumpers, when performing depth jumps, should employ a double-arm shift action (where both arms are driven back and forward and ‘up’ into the jump at take-off) to mimic the specifics of their event. They should also emphasise single-leg landing jumps. Doing this will maximise the transference of the conditioning drill into actual event performance.

**Leg stiffness**

The long jump is ultimate test of horizontal jumping and long jump research provides equally prescriptive and detailed findings. For example, researchers from Germany looked at the athlete’s centre of gravity during the take-off phase\(^5\). The researchers focused on a number of contributory factors, one of which was the ‘leg stiffness’ of the jumpers’ muscles.

Leg stiffness refers to the tensile properties of muscle. Using an analogy, suppose that a long jumper’s legs were made of plasticine. Even if the athlete could make it down the runway, the take-off leg would instantly buckle under the forces required to launch the athlete off the runway.

However, now suppose our athlete’s legs were made of carbon fibre; there would now be little if any yielding and the jumper would very efficiently transfer their horizontal velocity into the jump. Obviously, long jump athletes (and other jumpers) do not want plasticine legs, but would they benefit from carbon fibre-like stiffness? The German researchers concluded that while there is a minimum standard of leg stiffness required for maximum long jump performance, further increases in stiffness do not lead to longer jumps.

Leg stiffness can be enhanced by weight training and plyometric drills, power combination training and jumping itself. However, from a more technical perspective, researchers have advocated increasing the touch down velocity of the take-off leg to improve jumping distance. This is something that is also recommended, by George Dintimen\(^6\), one of the world’s leading speed coaches. He argues that the faster a plyometric drill is performed (the long
jump take-off is a plyometric movement) the greater, everything else being equal, will be the power transference into the jump. Using another analogy, the harder a ball is thrown against a wall the further and quicker it will fly back.

Thus, the faster the foot makes contact with the ground during jumping and running movements, the quicker the reaction will be. However, despite this, athlete and coach need to realise that certain jumping movements require more ground contact time than others (see table 2, above). If a high jumper attempted to use the same amount of approach speed as a long jumper, then optimum vertical lift would be sacrificed, as there would not be enough ground contact time to generate vertical lift. It is important that these take-off times are replicated in training, as well as the foot-strike position, and that free limb movements are optimised (as outlined above) for maximum jumping power.

**Training to improve jumping ability**

How can athletes utilise these findings to enhance their own training performance? As indicated, plyometric drills are the main weapon in the training armoury when it comes to enhancing jump ability. Here’s how to get the most out of them:

- Plyometric exercises must replicate the movement patterns and

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<th>Sport</th>
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<tr>
<td>Sprinting</td>
<td>.090</td>
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<tr>
<td>Bounding</td>
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<td>Hop</td>
<td>.180</td>
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<tr>
<td>Depth jump 40cm drop</td>
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<td>Depth jump 100cm drop</td>
<td>.300</td>
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<td>Hopping</td>
<td>.180</td>
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speed of movement of the jumping activity as closely as possible. 
- Athletes should be fresh and rested when performing plyometric exercises, especially if they perform in immediate anaerobic pathway activities such as long and high jump and the gymnastic vault.
- For sports involving fatigue, where jumping is required, such as football and rugby, quality jumping power should be developed, in ways similar to immediate anaerobic pathway athletes, but also in separate workouts, under conditions of fatigue. Exercises should also be performed on the surface that the player will normally encounter, *ie* in the case of a field sports player, soft to hard turf.
- For field sports (as for immediate anaerobic activities) the mechanics of the jumping skill must be optimised. For example, footballers must be made aware of the importance of using their free limbs to aid height and distance. However, due to the nature of these sports, perfect technique will not always be possible. To this end practices should be employed that work on balance, kinaesthetic awareness and proprioception. These will maximise jumping potential and reduce the chances of injury, as the player is able to better control the position of their body in space, their proximity to other players and their landing.
- Power combination training that combines weights and plyometrics in the same workouts should be utilised throughout the training period. Research indicates that both exercise modes affect the other in a way that enhances the power generation of fast-twitch muscle fibre.

**References**

Squats – new research on an old favourite

Squats are not only technically demanding, they’re also one of the most exhausting strength exercises in the gym. However recent research suggests that squats and their variations have much to offer power athletes seeking a competitive edge.

Speed, acceleration and jumping ability are used in many track and field events, as well as field sports, gymnastics, weightlifting and martial arts to name just a few other activities. Developing lower-limb strength and then power helps improve speed, acceleration and jumping\(^1\). In particular, developing maximal strength in the lower body is an essential prerequisite of developing power.

Strength training develops the muscles’ ability to exert force, for example pushing a heavy object. Power training develops the ability to exert this force in less time – *ie* to make the movement quicker, for example throwing a ball.

Sprinters can generate forces of up to three and half times their body weight when racing, so having sufficient leg strength to generate this force without injury is necessary\(^2\). This explains the commonly quoted guideline that a power athlete needs to be able to squat a weight equivalent to twice their body weight – *eg* an 80kg male rugby player should be able to squat 160kg.

The squat and squat jump are two exercises that have a major role in developing leg strength and power. This article will look at recent research on squat variations and the squat jump and give some guidelines on what loads should be lifted in order to gain the greatest benefit.

**Strength before power**

The squat exercise uses most of the major muscle groups in the
lower body, overlapping with those used in running and jumping, so it is very suited to most sports. The squat can increase the ability to produce power in the long term, but it has also been shown to improve power production in the shorter term through the post activation potentiation (PAP) effect in trained individuals\(^3,4\).

Post activation potentiation has not been fully explained yet, but the effects are the basis behind the theory of complex training, which combines strength and power exercises into small sets, where the muscles’ ability to produce a more powerful contraction is improved by performing strength exercises shortly beforehand.

However, this does not appear to happen in untrained individuals, who are simply fatigued from the preceding strength exercises. The assumption, therefore, in the rest of this article is that the athlete has already established a strength base (the ability to squat a load equivalent to their own body weight).

**Chain squats**

Although most squatting is performed using a simple barbell and weight arrangement, there are variations on this theme. A popular variation of the squat in the USA is to add chains to either end of the barbell.

The chain is attached to the top of the barbell, with some portion of it on the floor. As the squatter descends, more of the chain is on the floor, decreasing the overall load. As the squatter ascends, less of the chain is on the floor, increasing the overall load. This arrangement requires greater force production at the top end of the squat (because more of the chain is off the floor and thus suspended from the barbell) when the legs are in a more mechanically advantageous position to produce greater force. This mechanical advantage arises from the fact that the length of the quadriceps is shortened, allowing more opportunity for cross-bridge contractile activity.

At the bottom of the squat, when the quadriceps muscles are lengthened, there is less cross-bridge activation and the legs are

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**JARGONBUSTER**

**Post activation potentiation (PAP) effect**
The increase in the ability of a muscle to contract after a previous series of contractions; a short-term effect due to acute mechanical, chemical and neuromuscular changes in the muscle.

**Cross-bridge contractile activity**
The ability of the contractile filaments in muscle fibres to slide over one another using special protein molecules (cross-bridges) to pull the filaments together and produce a muscle contraction. With a shorter muscle length, more of these protein cross-bridges are able to attach, producing a stronger contraction.
at a mechanical disadvantage. So, although the external resistance is constant (the barbell), the force produced by the muscles isn’t constant due to mechanical changes.

The theory behind the use of chains is that it overcomes mechanical changes and produces a constant force throughout the movement. This may be of use in movements such as a lock forward scrummaging in rugby union, where more force may have to be produced with the legs nearly straightened in order to assist the prop’s push forward against the opposition.

An alternative method is to use elastic bands or tubing, with one end fixed to the floor and the other to the barbell. Again, as the squatter descends less resistance is produced because the tension in the elastic is reduced, but more resistance is produced on the ascent due to the elastic lengthening and tensing.

How big a chain? Well, it depends on the strength of the athlete! Chains can normally be bought in inches (width) and feet (length), with half-inch chains being a good size for strong athletes when squatting. Smaller chains can be used for
intermediate athletes and also for the bench press.

A half-inch chain weighs around 7.5kg per foot. If the barbell rests on a typical athlete’s shoulder at 5ft off the ground, two half-inch chains would provide an additional 75kg of load. Descending 2ft would reduce this load by 30kg (2ft length of chain that was previously suspended would now be on the floor at each end of the barbell). So an athlete with these chains could have a barbell weighing 60kg, and be squatting 135kg at the top of the movement but only 105kg at the bottom.

Another proposed benefit of chain squats is that the athlete does not have to slow down their movement near the top of the squat; instead they still have to keep trying to move quickly to overcome the added resistance. This type of training movement is probably more appropriate for sporting situations where contact is involved, and the player has to drive into the opponent with maximum extension of the legs, rather than slowing down just before impact.

**Chain squat research**

Two studies have been conducted to test the efficacy of this training method. In the first, US researchers from Marquette University in Wisconsin looked at 11 college athletes and measured electromyographical activity during a squat with barbells, with barbells and chains, and with barbells and elastic bands (5).

No difference was found in force production between the three conditions. However, the authors commented on the fact that all the athletes ‘felt’ the squats were different to perform. They also commented on the fact that part of the study design was to reduce the load of the barbell by 10% to accommodate either the chains or elastic bands. However, in normal training conditions, one of the advantages of using chains and bands is that additional loads can be lifted. This additional load may result in greater force production and therefore strength gains.

In the second study, researchers looked at 10 resistance trained adults and the effects of altering resistance at around 60% and 85% 1RM (maximum weight that can be lifted for one rep) of the squat (6). They used bands to provide an extra 20%
or 35% of the total resistance and compared this to a control group who were just doing the squat.

No differences were found in the rate of force development between the squat with bands and the squat without. However, both peak power and peak force were found to be greater when using bands. The difference was even more significant when performing the 85% 1RM, heavier load. The optimal condition appeared to be the heavier 1RM load, with 20% of the resistance coming from the bands. More research is warranted in this area, but the use of chains or bands in squats could be a worthwhile addition to athletes’ strength training routines.

**Squat jumps**

One method of developing power in the legs is through the use of weightlifting exercises such as the clean and the snatch. This is currently in vogue; with many national governing bodies (NGBs) issuing guidelines that all their funded athletes become proficient in these lifts.

However, the time and effort that it would be necessary to
Description of exercises

A brief description of the squat and squat jump follows, but care should be taken when performing these exercises with load. Learning these exercises under qualified supervision is recommended.

Squat – The common form of this exercise is performed with a barbell placed across the back of the shoulders:

- Place the bar on the squat rack at a height that is 3-5 inches lower than your shoulders;
- Stand under the bar and position yourself so that it rests on the upper part of your shoulder blades (or traps). The bar should NOT be resting on the vertebrae of the neck area;
- Place your hands on the bar, palms facing forward, at a distance that is comfortably wider than shoulder width;
- Drawing your shoulders back and keeping the back straight, stand fully erect and step forward, lifting the bar clear of the supports;
- Standing with feet shoulder-width apart, toes pointing slightly out, inhale and contract the abdominals;
- Draw the shoulder blades backwards, squeeze and tighten your lower back muscles in order to ‘lock’ your spine into a straight position;
- Keeping the back straight, start the descent by leading with the hips rather than the knees. In practice, this means drawing the hips backwards before the lowering begins. Bending the knees before shifting the hips backwards tends to throw the knees forward and makes it harder for the powerful buttock muscles to contract;
- Ensure that the first few inches of the lowering movement are slow and controlled. Don’t allow the bar to build up its own momentum;
- Continue to lower smoothly until your thighs are parallel with the floor. Don’t let your thighs drop below parallel. Check that your torso is not angled too far forward – as you reach the bottom of the movement, the angles at the hip and knee joints should be roughly equal;
- Check that your heels remain flat on the ground during the entire lowering phase. Raising

Invest in developing the technical proficiency in these lifts to allow the athlete to lift loads that develop power, may be better spent in performing other exercises that have similar benefits, but require less coaching – the squat jump being one such exercise.

How much load should be placed on the athlete? Well, the assumption made here is that they have already established a strength base (non-strength trained subjects respond differently to the squat jump than trained individuals, with loads as little as
the heels increases the risk of injury to the knees by shifting the centre of gravity forward, in turn placing extra stress on the lower back;

● When the thighs are parallel with the floor, contract the thighs, buttocks and lower back, then begin the lift. Keep the upward movement smooth, but try and develop some ‘drive’ through the movement remembering to follow the same path as that through which you descended. The torso and back should remain erect and the hips remain under the bar throughout the ascent.

Squat jumps – This exercise is commonly performed with a barbell across the shoulders and with a much lighter weight than the squat.

● Stand with feet shoulder-width apart, descend until thighs are parallel to the floor as described above and then jump up with feet leaving the floor;

● Don’t pause at the bottom part of the squat jump. Land on both feet and cushion the landing with a small bend of the knees, then return to standing position;

● Try not to make a noise when landing; this will help remind you to land with a cushioned knee, rather than a jolt.

Safety precautions – The squat is a very common exercise (every time you lower yourself into and raise yourself out of a chair without using your hands you are performing the squat action); however, care must be taken when loading the spine.

● If you have any lower back problems, or knee, hip or ankle joint problems, then you should get these treated before squatting unsupervised;

● If you cannot perform 10 squats with just your own body weight, then no load should be added across your shoulders;

● Squat jumps are more dynamic and can cause a jarring effect on the back and neck if not performed correctly. Do not perform loaded squat jumps if you cannot squat with a load equal to your body weight on the barbell.

5kg creating a decrease in peak instantaneous power)\(^{(7)}\). However, too heavy a load will slow the jump down. The velocity of the jump has to be enough to allow maximal power output to be achieved.

Fortunately, measuring power output, or looking at changes in performance such as 20-metre sprint times, can identify the optimal load for squat jumps. One study looked at using either 30% or 80% loads of the subjects’ 1RM squat to perform squat jumps and then measure the changes in performance \(^{(8)}\).
The 26 subjects followed an eight-week, twice-weekly training programme performing four sets of five jumps after warming up, with three minutes rest between sets. Both groups improved their 1RM and their peak power. The 30% group increased their peak velocity and decreased their 20m sprint times. The 80% group increased their 20m sprint times. So while both training modes were effective in increasing peak power and 1RM strength, the lighter loads had a much better impact on speed of movement, matching the findings of the second chapter of this special report.

This is obviously of importance to most coaches and athletes. However, it’s worth adding that the training history of this group of subjects was quite varied, and so this may be partly why they benefited from the lighter loads.

Another study looked at rugby league players who were strength and power trained and found that squat jumps with loads varying between 47 and 63% of 1RM were effective in improving power output (9). These players were strong athletes; the loads showing the highest power output were between 85 and 95kg, and one group of the players in the study had average 1RM for normal squats of 161kg.

The researchers found that using a load less than 47% 1RM did not result in enough resistance for peak power to be generated. But a load heavier than 63% 1RM resulted in too slow a movement. More generally, trained players may need higher loads to generate peak power because of their neural adaptations to strength and power training; they can simply recruit more of their muscle fibres to act in synchronisation quickly than non-trained individuals.

If you are intending to start using squat jumps, try sequencing them into your current strength-training programme. Having a minimum strength base of squatting 1RM equivalent to your own body weight is essential. A four-week, twice-weekly programme of four sets of five jumps at 30% of 1RM with three minutes rest between sets is a good start. As you become stronger you can alternate fortnightly between strength sessions and sessions incorporating squat jumps. When you can
squat equivalent to twice your body weight for 1RM, then you can progress towards the jump squat load of 50% 1RM.

James Marshall

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1. JSCR 2005; 19(2):349-357
3. JSCR 2005; 19(4):893-897
4. JSCR 2006; 20(1):162-166
5. JSCR 2002; 16(4):547-550
8. JSCR 2002; 16(1):75-82
Plyometric training is now a common element of elite sports training programmes. But, while its beneficial effects on the lower body are well documented, there is some doubt over how useful it is for upper body force development.

First documented as an effective training method by Soviet coaches in the middle of the last century, the main purpose of ‘plyometrics’ is to increase the rate of force development, the key ingredient of power. By contrast, the main purpose of heavy weight training is to increase total force production – ie maximum strength.

It is logical for athletes to seek to increase the rate of force development, because most sports involve fast movements for which forces must be generated quickly. The foot-to-ground contact time in the high jump, for example, is less than 100 milliseconds, yet it will take around 500 msec to generate maximum force. For elite performance, an athlete’s rate of force development is often more important than the maximum force he or she is able to generate.

The other advantage of plyometric training is that it comprises jumping and throwing movement patterns that involve a stretch-shortening cycle (SSC). The muscle and tendons are first lengthened with an eccentric load – eg pulling back your arm to throw a ball – which may increase the subsequent concentric force production and/or allow release of elastic energy – eg as the arm accelerates forwards to release the ball. Since most sporting movements involve sprinting, jumping and throwing SSC movements, plyometric training can be viewed as highly sport specific.

Plyometric training for the lower body nearly always takes
the form of various jumping movements, such as hopping, bounding and drop jumps, while upper body plyometrics often uses medicine ball throwing movements. Both of these types of movements have been well documented\(^{(1)}\). However, research into the effectiveness of plyometric training is less readily available than coaching manuals for the relevant exercises.

One study that raises some questions about the effectiveness of medicine ball training comes from Australia’s Southern Cross University\(^{(2)}\). Researchers allocated 24 junior baseball athletes into three groups, one performing upper body heavy weight training, the second using upper body medicine ball exercises and the third acting as non-exercising controls.

They found that while the plyometric training – in the form of medicine ball exercises – improved strength but not baseball throw velocity, heavy weight training improved both parameters. This suggests that upper body plyometrics is not effective at boosting rate of force development. However, these junior baseball athletes had not previously used strength training and the findings might have been different for strength-trained athletes.

Further investigation at the same institution\(^{(3)}\) compared the different effects of upper and lower body plyometrics, this time using 41 previously trained subjects, who were assigned to weight training or plyometric training or a control condition for eight weeks.

The researchers tested their subjects’ lower and upper body strength, rate of force development and power before and after the training programme. They found that plyometric training increased leg muscle power but not the rate of force development and power in the upper body.

The effectiveness of plyometric exercises for increased leg power was established by a previous study from the same researchers\(^{(4)}\). They found that 10 weeks of drop jump training improved counter-movement jump (CMJ) performance by 10\% in previously strength-trained subjects, implying that their rate of force production, or power, had increased.
In summary, the research mentioned so far confirms the beneficial effects of jumping plyometrics for the lower body but not the effectiveness of medicine ball exercises for the upper body.

One explanation for this distinction could be that the relative loading on the legs of a jump is greater than that of a medicine ball throw on the arms. During a jump exercise the whole mass of the athlete – say 75kg – is moved. The force required to produce this movement comes from the leg muscles, mostly the quadriceps (thighs), gastroc-soleus (calf) and gluteus maximus (buttocks).

During a medicine ball throw the mass of the ball is moved – a 5kg ball being the weight most commonly used by athletes. The force required to produce this movement comes from the arm muscles, mostly the pectorals, deltoids, triceps and latissimus dorsi.

The difference in load between jumping and throwing in this example is 15-fold. This does not mean that the leg muscles are 15 times stronger than the arm muscles. Leg press repetition maximum scores in well trained male athletes are usually 2.5-3.5 times body weight, while bench press rep max scores are 1.25-1.75 times body weight, suggesting that the legs are about twice as strong as the arms. However, in medicine ball exercises the arms are moving significantly less than half the mass moved.

Table 1: recommended plyometric exercise for the upper body

<table>
<thead>
<tr>
<th>Exercise</th>
<th>Weight</th>
<th>Sets x Reps</th>
<th>Rest</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overhead med ball throw</td>
<td>Female 10-15kg ball Male 15-20kg ball</td>
<td>3-4 x 6-8</td>
<td>2 min</td>
</tr>
<tr>
<td>Plyo press-up</td>
<td>(body weight)</td>
<td>3-5 x 5</td>
<td>2-3 min</td>
</tr>
<tr>
<td>Chest pass</td>
<td>Female 10-15kg powerbag Male 20-25kg powerbag</td>
<td>3-4 x 6-8</td>
<td>2 min</td>
</tr>
</tbody>
</table>
by the legs in jumping exercises. Thus, the relative load on the arms is less than that on the legs. Theoretically, then, if you use a typical weight of medicine ball, you will not be training the upper body as hard as you train the lower body with jumping.

This conclusion is supported by recent research(5). Subjects were tested for shoulder external rotator and elbow extension power before and after a six-week medicine ball throwing programme, using one specific exercise involving both sets of muscles. They had to stand, catch a 1kg ball in one hand with the arm horizontally abducted and extended, adduct and flex the arm across the body (eccentric phase) and then rapidly abduct and extend the arm releasing the ball. This throwing movement involves the external shoulder rotators (the posterior shoulder muscles) and the arm extensors (the triceps).

Retesting revealed a significant increase in elbow extensor power, but not in external rotator power. The researchers suggested that the greater muscle mass of the posterior shoulder by comparison with the triceps meant that the training was more effective for the latter than the former.

Evidence that a heavier load upper body plyometric exercise can be effective has come from Canadian research(6). The

![The plyometric press-up](image)
Researchers tested female subjects on a medicine ball for chest pass distance (the distance the ball can be thrown forward, measured from the athlete) and on a chest press for strength.

They then performed either a normal press-up exercise (from the knees) or a plyometric version of the press-up, as illustrated below.

With plyometric press-ups, you start by kneeling upright, then fall forward onto the hands, absorbing the weight using the press-up lowering movement (eccentric phase), then rapidly propel yourself upwards and back to the start position (concentric phase) with a ballistic movement.

On retesting, the researchers found that both chest press strength and chest pass distance increased for the plyo press-up group. The fact that they improved their performance on the throwing test implies that they had improved the rate of force development in their upper bodies.

During the plyometric press-up a significant percentage of bodyweight – about 40% – is moved. The force for this movement comes from the pectorals, anterior deltoid and triceps muscles. For an adult weighing 75kg, this means that the upper body musculature is working against about 30kg of weight – significantly more than with commonly used medicine ball weights.

The implication of this research is that, if plyometric exercise is to be effective for the upper body, a load greater than a medicine ball must be used.

The plyometric press-up has been shown to provide such an effect for the common forward horizontal throwing movement (the chest pass). For the overhead throwing movement, which is specific to many sports, it may be worth using very heavy medicine balls or ‘powerbags’ (cylindrical sand-filled sacks with handles to hold onto).

I would suggest 15-20kg as a good (male) training load for the overhead throw movement. With this movement, you stand up, take the weight up and behind the head (eccentric phase), then rapidly pull the arms down and forward, releasing the ball or bag.
When performing such upper body plyometric exercises as the plyo press-up and overhead throw, I recommend 3-5 sets of 5-10 repetitions. To promote a high rate of force development, it is important to take 2-3 minutes rest between sets. This ensures that you do not exhaust the fast-twitch muscle fibres that are crucial to force development.

In summary, plyometrics are effective for increasing power. However, the load of the movement must be proportional to the strength of the muscles involved in the movement. Using heavy throwing objects or plyometric press-ups allows the upper body to be trained effectively.

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References

1. Donald Chu, Jumping into Plyometrics, Human Kinetics
As a middle or long distance runner (or coach) do you include strength sessions in your weekly training programme? In my experience, as a strength and conditioning coach working with elite athletes, those who don’t have either had negative experiences of weight training or hold certain prejudices – eg that strength training will lead to increased weight or interfere in some way with running training.

Given my position, it should come as no surprise to learn that I believe strength training is important for middle and long distance runners. However, its beneficial effects, backed up by research, will be experienced only if it is performed in the right amounts, using the correct choices of exercises.

Athletes and coaches should always have an open-minded approach to tweaking and improving their training programmes. At the same time, they should also question the benefits of any new or additional training method. Why is this kind of training good for my event? What is the exact benefit that I will gain from it? How can I successfully fit it into my routine?

For endurance runners, high volume mixed with high intensity running training is essential for success. Recovery between sessions is equally important to avoid staleness; and consequently any additional training will not necessarily be beneficial if it adds to fatigue rather than enhancing fitness.
If endurance runners wish to add strength sessions to their training programmes, they need to prioritise, ensuring each exercise in the routine is beneficial. Big weight lifting sessions, involving lots of exercises, taking more than an hour to complete, may be useful for a rugby player but won't help an endurance runner.

There are two key principles for endurance runners to bear in mind when including strength training into their programmes:
1. Strength training should be introduced cautiously and progressed very gradually;
2. Programmes must be time efficient and fit into the weekly running programme.

I will describe the kind of strength programmes incorporated into the weekly training routines of two elite middle and long distance athletes throughout a training year: one an 800m runner and the other a 5000m specialist, both competing at senior international level and carrying out the kind of high mileage training you would expect.

For each programme, I will describe not just the content and volume of the exercises but the overall physiological goals of the programme, so that the purpose of each exercise is clear. And let me assure you from the outset that gaining muscle mass is not the main aim.

The 800m strength programme
The aims of strength training for this particular male 800m runner were:
1) to increase the power of the leg muscles;
2) to develop general strength to help prevent soft tissue injuries in the leg muscles.

It is probably fair to say that these will be the two most important goals for all 800m runners. Leg power is important to help promote the high maximum speed required for the event; and general strength in the hamstrings, calf and core
help to increase the resistance of soft tissue to fatigue and strain. These were problems to which this athlete was particularly prone, in common with many other runners.

The exercises included in the programme were selected only if they served one of the above goals. Thus, there were no upper body strength exercises as the athlete did not feel he had anything to gain from increased upper body strength and did not want to risk gaining any upper body muscle mass. The programme was split into three distinct phases: off-season preparation; pre-competition peaking and competition maintenance.

**Off-season preparation phase**
The main aim of this off-season preparation phase, described in the table below, was to increase maximum leg strength in the powerful gluteal and quadriceps muscles. The front squat and one leg squat were used for this purpose and you can see that increasing the weight lifted was the goal for these exercises. This development of maximum strength lays the foundation for power to be developed later on in the training cycle.

<table>
<thead>
<tr>
<th><strong>Strength session: twice a week</strong></th>
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<tbody>
<tr>
<td><strong>Front squat</strong></td>
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<tr>
<td><strong>One leg squats</strong></td>
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<tr>
<td><strong>Swiss ball hamstrings hip lift</strong></td>
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<tr>
<td><strong>One leg barbell calf raise</strong></td>
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<tr>
<td><strong>Gluteal bridge (single leg)</strong></td>
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<tr>
<td><strong>Side plank</strong></td>
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<tr>
<td><strong>Reverse crunch</strong></td>
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<tr>
<td><strong>The plank</strong></td>
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<table>
<thead>
<tr>
<th><strong>Plyometric session: once a week</strong></th>
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<tbody>
<tr>
<td><strong>30cm drop and catch</strong></td>
</tr>
<tr>
<td><strong>Power skips</strong></td>
</tr>
<tr>
<td><strong>Ankle hops</strong></td>
</tr>
<tr>
<td><strong>Double hurdle hops</strong></td>
</tr>
<tr>
<td><strong>Total foot contacts</strong></td>
</tr>
</tbody>
</table>
In addition, hamstring, calf and core exercises were included for the purpose of injury prevention. You can see that progress was made in the strength endurance of these muscles with the increased reps performed. The one leg squat and one leg calf raise, both performed with barbell on the back, have the additional benefit of developing lateral pelvic stability and gluteus medius strength.

The strength session, completed twice a week, would be unlikely to lead to any significant muscle hypertrophy (increased mass) for two reasons:

- It is a very low volume routine, involving just four main leg exercises, with low repetitions of the two main barbell exercises;
- An endurance runner does so much running that the leg muscles will probably have little spare energy for building additional muscle. Body builders avoid endurance training at all costs so that all their spare energy can go into building muscle.

Plyometric exercises were performed once a week, introduced with light volume initially (75 foot contacts) and progressed very gradually in order to avoid injury. Plyometrics are very valuable exercises for runners as they are specific to the running action in terms of both movement and velocity. Their benefits include increased recruitment of the fast twitch fibres and greater elastic energy return from the tendons.

It is worth noting here that strength training strengthens tendons as well as muscles. I like to think of weights and plyometrics as enhancing the whole ‘muscle tendon unit’, which explains how this kind of training can play the dual role of improving performance and reducing injury risks in endurance runners.

The whole of the soft tissue adapts to the training and becomes more able to deal with strain and repetitive eccentric contractions, so reducing the risk of injury. In addition, the tendon is able to store and release more elastic energy so that the Achilles and knee tendons can contribute greater mechanical power to running speed.
Pre-competition peaking phase
The main aim of this phase was to develop maximum power of the leg extensor muscles and maintain the strength endurance developed in the hamstrings, calf and core. The sessions described above were each performed once a week, with the core exercises from the previous phase also maintained on a twice-weekly basis.

These two sessions combine plyometrics and weights exercises into a single workout, mostly because of the athlete’s desire to maximise recovery of the leg muscles. The benefits of the workouts were enhanced by using ‘complexes’ of weights and plyometrics exercises (eg front squat and hurdle hop in session 1 and one leg squat and speed bounds in session 2). Explosive strength exercises, like dynamic lunge drives and barbell squat jumps, were included to increase power, while the hamstring and calf exercises were retained from the previous phase for purposes of injury prevention.

Again, this kind of high quality, low volume explosive strength programme poses no risk of hypertrophy, given its low levels of repetitions. The main goal is to develop power with minimal fatigue.

Competition maintenance phase
During the competitive season, when the athlete began racing seriously, his training volume and frequency changed again.
The aim of this phase was to simply to maintain the level of power and general strength developed in the previous phases.

During this time, the athlete performed either session 1 or session 2 from the pre-competition phase (see table on previous page) once a week, with no sessions performed within 5-6 days of a race. The weights were reduced slightly during this phase to minimise fatigue while maintaining quality and the core exercises were carried on as before.

The outcome of this programme was considered successful by the athlete in question, who increased his leg power (as measured by counter movement jump and drop jump performance) by 15% and suffered no significant soft tissue injuries during the training year, thus fulfilling both his training goals.

In addition, by focusing on a limited selection of exercises, using high quality and low volume training, he was able to complete all his running sessions and experienced no gains in muscle mass.

The 5k strength programme

The aims of strength training for this long-distance female runner were also to increase leg muscle/tendon power and reduce injury risk. But the training programme differed because she does not need – and probably can’t manage to produce – very high levels of leg power.

Long distance runners need to be very powerful in relation to their own body weight, but not as powerful as sprinters, who are heavier and stronger. In addition, this athlete had a limited strength training history and so needed a lighter programme than the 800m runner to ensure there were no adverse consequences to strength training. Her programme was structured as follows:

The strength session (see table above right) was used to develop general strength in the leg muscles and tendons to help reduce injury risks and increase resistance to fatigue. The barbell step-up, involving the quadriceps and gluteals, was considered the main plank of this routine, and two hamstring exercises were selected as the athlete was particularly weak in
Upper body exercises were also included as she has very little upper body strength and felt that some gains in this area might help promote a more efficient arm action.

Overall, this programme, performed only once a week, is unlikely to result in hypertrophy for the same reasons stated above. An elite long distance runner, training twice a day, probably has very few spare calories available to build muscle. In addition, this low volume session, involving only six exercises once a week, was not enough to promote muscle mass and the athlete did not gain weight.

The plyometric session (see table overleaf) was used to promote leg power. Research has demonstrated that when a similar explosive strength/plyometric programme was added to a 5k runner’s weekly programme, maximum speed and 5k performance improved by comparison with a control group who maintained a running-only programme (1).

This performance improvement was independent of any change in VO₂max or lactate threshold, and the researchers concluded that the plyometric exercises had improved the stiffness and/or energy return of the leg tendons so that the runner was more economical as well as more powerful. This study also shows how the neuromuscular system contributes to endurance performance and must not be ignored in the training programme, which supports my previous arguments in favour of weights and plyometrics for the whole muscle tendon unit of endurance runners.

Some of you may be surprised to see sprint drills and 30m

<table>
<thead>
<tr>
<th>Strength session – once weekly</th>
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<tbody>
<tr>
<td>Barbell step-up (40cm box)</td>
</tr>
<tr>
<td>Swiss ball hamstring hip lift</td>
</tr>
<tr>
<td>Calf raise (machine)</td>
</tr>
<tr>
<td>Standing hamstring hip extension (band)</td>
</tr>
<tr>
<td>Dumbbell press</td>
</tr>
<tr>
<td>Dumbbell row</td>
</tr>
<tr>
<td>+ Core exercises eg side plank, bridge etc</td>
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</table>
sprints included in the plyometrics routine. For this athlete, the drills were there to promote sprint technique and served as a useful low impact warm-up before the plyometrics session.

**Sprinting is a plyometric action**
In fact, the 30m sprint was considered a plyometric exercise in its own right, as sprinting is essentially a plyometric action. The athlete aimed to accelerate as hard as she could during these sprints – a demanding exercise for long distance runners, who have limited acceleration.

The drills and sprints were seen, more specifically, as a means of boosting pace at the end of a race, which is crucial to success at international level. It is known that all members of the Ethiopian distance squad carry out drills and sprints on a weekly basis, and they have proven their ability to produce winning sprint finishes in international competition.

The strength session was usually performed on an easy running day, often the day after – but never the day before – an interval session. The plyometrics were usually performed immediately after a steady morning run, when the athlete was feeling warm but not too fatigued. Again, plyometrics were never performed on the day of – or day before – an interval session.

These timing provisions were there to ensure that the training was performed in a time-efficient manner, to maximise recovery, without compromising the quality of running training. For similar reasons, no strength or plyometrics session was performed within 5-7 days of a race, unless the race was not considered important and was being used only as a measure of fitness. The athlete ceased

<table>
<thead>
<tr>
<th>Plyometric session – once week</th>
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<tbody>
<tr>
<td>1. High knee skip drill, 2 x 20 m</td>
</tr>
<tr>
<td>2. Knee pick up drill (using mini hurdles) 2 x 10 hurdles</td>
</tr>
<tr>
<td>3. Fast knees-up drill, 2 x 20 m</td>
</tr>
<tr>
<td>4. Power skips, 3 x 10</td>
</tr>
<tr>
<td>5. Mini hurdle hops, 3 x 8</td>
</tr>
<tr>
<td>6. Vertical jumps, 3 x 8</td>
</tr>
<tr>
<td>7. 4 x 30m sprints</td>
</tr>
</tbody>
</table>
strength training two weeks before the major competition of the summer to ensure freshness for racing.

No changes in volume during the season were required for this particular athlete, but an athlete with a long strength training history would probably have been able to perform more work during a training session, reducing the volume as the season progressed.

The results of the programme were positive for the athlete, who succeeded in improving her jump power by around 15%.

The purpose of these two long-ish case histories is to show how strength training can most appropriately be added to an endurance runner’s weekly routine.

The aim of strength training – which includes both weights and plyometrics – is not to increase maximum strength or muscle mass but rather to boost leg muscle power (power being a different quality to strength), enhance elastic energy release from the tendons and promote general strength in the muscle tendon units and a stable core, with a view to preventing injuries.

A sensible approach, taking account of the volume of running training, is needed to ensure that the programme can be maintained on a long-term basis without compromising the running. I hope the examples above have illustrated how this can be achieved.

Remember, though, that these are individualised programmes for particular athletes I have been working with and that all athletes need their own customised programmes. Feel free to base your weights or plyometrics programmes on these examples, but make sure that any exercises you include are tailored to suit your particular needs and event.

Use these examples as a guide to the kind of training that is effective, not as a definitive strength training guide for endurance runners.

Raphael Brandon

References

Considering the preceding chapters have emphasized the importance of technique and training maturity when dealing with plyometrics, it would seem sensible to conclude that they should be off-limits to athletes returning from injury. However this final two-part chapter explains that this is not quite the case, as long as guidelines are strictly adhered to. Part One covers general plyometric rehabilitation rules. Part Two focuses on how to use plyo-rehab for throwing athletes.

Part one:

Introduction to plyometrics

There is a role for explosive power training in therapy programmes.

Plyometric drills have been used in training programmes for decades to enhance athletic performance. This training modality is seen as the link between strength and sport-specific speed. Increasingly plyometrics is also being used in rehabilitation, and my own practical experience leads me to believe that it is an essential therapeutic tool when steering athletic clients back to a safe and successful return to sport after injury.

The literature to date is mostly anecdotal. Chmielewski et al in their 2006 literature review(1), called for research to examine whether plyometric exercise is useful in the prevention of reinjury and to validate the assumption that plyometrics promote a return to sport for injured athletes. It would also be very useful to have research on whether the body’s response to plyometric training is altered by injury. Finally, what research there is looks only at lower limb training, although the modality is starting to be used more for upper body training, too.

The lack of evidence in support of plyometrics within rehabilitation is no reason not to use them. But we need to start from a thorough understanding of what this training modality
is about: what type of fitness gains are possible, and what
cautions are necessary. We can then apply this knowledge to
the rehabilitation setting.

The science of plyometrics
Plyometrics train the neuromuscular system to operate more
powerfully, so that the muscles are able to perform more work
in less time (7), exploiting the elastic properties of the muscle-
tendon unit to increase explosive power. One research
definition puts it this way:

Plyometric exercise is an activity that involves and capitalises
on the mechanisms of the stretch-shortening cycle to increase
the efficiency of force production at a joint or increase
performance(1).

Plyometric movements occur throughout sport, in running,
jumping and throwing. But what differentiates plyometric
exercise from normal strength training is its focus on developing
the efficiency of the stretch-shortening cycle.

A plyometric movement can be broken down into
three phases:

The loading phase
If we look at a simple plyometric movement such as a ‘tuck
jump’ (jump and pull both knees into the chest while in the air),
the ‘loading’ phase is the instant of landing prior to repeating
the jump. This landing results in a stretch to the muscle-tendon
complexes that do the work of slowing the body down against
the pull of gravity (ie, those that are working eccentrically as
feet hit the ground from the jump), which in this instance
means:

- quadriceps
- gluteus maximus
- hamstrings
- gastrocnemius and soleus.

Under training, this stretch-upon-impact can result in the
muscle developing greater elastic force in response to the
stretch. The training effect arises from physiological adaptations at the micro-fibre level within the muscles and tendons: First, there is ‘muscle potentiation’: an increase in the proportion of cross-bridges attached to the actin protein filaments (2) and a decrease in the cross-bridge detachment rate (3); second, the stretch prompts the local motor unit to produce excitatory neural feedback to the muscle (4); and thirdly, the stretch causes a storage of potential energy in the elastic components of the muscle-tendon complex, which allows for greater recoil of the muscle during the shortening cycle.

It is actually the tendon complex that undergoes the most length change during the loading phase. This stimulates the Golgi tendon organ (sensory nerve receptor in the tendon), which results in greater force being generated in the subsequent contraction.

As well as capitalising on the properties of the stretch-shortening cycle, plyometric exercises also tap into two other reflex mechanisms: length feedback and force feedback. In both cases, local neural feedback/feed-forward loops provide information to the muscle, its synergists and antagonists, either to ratchet up or to damp down their response to the stretch. The main purpose of length feedback is to help increase joint stiffness, while force feedback regulates the coupling between joints (1, 5, 6), resulting in enhanced neuro-motor control and joint stability.

**The coupling phase**
This is the brief moment of transition between the loading and unloading phases, when joint angles and ground reaction forces are about to change direction. During this time, the muscle-tendon complex length is constant and the muscle is in a state of isometric activation.

**The unloading phase**
This is the period from when the muscle-tendon unit begins to shorten (concentric contraction) through to when the foot
leaves the ground (lower limb) or when a resistance object such as medicine ball is released (upper limb).

According to Chmielewski et al\(^{(1)}\), the value of plyometrics lies not in isolating a single mechanism that can improve explosive power, but in its ability to train the combination of mechanisms outlined above in the interests of performance gains.

Researchers have established a direct correlation between plyometric training and the following improvements in athletic performance:

- increase in vertical jump height\(^{(10,11,9,12,7,13)}\)
- decreased sprint times\(^{(14)}\)
- increase in golf club speed and driving distance\(^{(15)}\)
- running economy\(^{(16)}\).

Plyometrics in isolation can also improve isolated muscular strength, but better results are achieved when used in combination with traditional strength training\(^{(8,9)}\).

**How to use plyo techniques**

There is no agreement on what exactly constitutes plyometric training. But broadly speaking there are two types of plyometrics: low intensity and high intensity.

Low intensity drills are conducted at a submaximal effort level, with an emphasis on good technique or body position. These exercises are used to train dynamic balance and proprioception.

High intensity drills are about achieving rapid force development and maximal output. Athletes should already be able to perform low intensity drills and should gradually progress towards the more complex and high intensity work.

Thus, a lower limb plyometric exercise programme should start on the ground only, and on two feet. As the athlete gains in competence, they move on to single leg activities, the use of boxes (to jump up to or down from) and weights.

The aim of progressions is to increase load and speed of movement. If the progressions are too advanced, the athlete
will struggle to make gains. Take, for instance, the ‘drop jump’, in which you jump from a height to the ground and immediately make a maximal jump. If the box height is increased too early, the athlete will be forced to increase their ground contact time, undermining the point of the exercise (gains in both reaction speed and force).

Progressions can also be made to challenge the athlete’s stability at speed, through, for instance, single leg exercises, exercises from a lunge position or adding a rotational movement or change of direction upon landing.

Get the fundamentals right
No athlete should attempt plyometric work, high or low intensity, until they can competently perform key functional movements such as double and single-leg squats. If someone can’t squat properly, they certainly won’t be able to do squat jumps. And if they can’t squat on one leg with good form, then all single-leg plyo training should be out of bounds.

This is particularly important advice for young, developing athletes. If they fail to achieve physical competencies in functional movements before attempting more complex exercises, they will set themselves up for early and possibly career-threatening injury.

The role of plyometrics in rehab
We know that plyometrics improve neuromuscular function, including joint position sense (proprioception) and postural control. In a series of studies conducted from 2004 to 2006, Myer et al\(^{(17,18,19)}\) showed that plyo work improved postural stability in single-leg stance; trunk stability when landing from a jump; and biomechanical measures relevant to lower limb injury risk. In 2002, Swanik et al found that upper limb plyo training improved joint position sense\(^{(20)}\).

However, these studies were performed on uninjured athletes, so it is unclear whether injury and its effects on the neuromuscular system would alter the outcomes. As mentioned above, the sports therapy profession really needs some research
into this question in order to have confidence in adding this training tool to our rehab repertoire.

In the meantime, we must draw on what knowledge we do have and apply it as best we can. The key training principle of specificity dictates that training for a sport should replicate the movement patterns and energy systems required for that sport. Since the aim of rehabilitation is to regain the pre-injury level of function of the injured site – or in many cases to improve on the pre-existing level of function – and also to return the athlete to their pre-injury state of fitness, specificity would seem to argue in favour of using plyometrics as a rehab tool. If an athlete has to run, jump, change direction and so on in their sport, then their rehabilitation should prepare them specifically for those actions. The crucial judgement for therapists lies in what level of activity to introduce at what point in the rehab process.

Low intensity plyometrics is a very useful tool to retrain dynamic balance and proprioception after injury, and once functional stability is regained, such exercises can be gradually introduced. In late stage rehabilitation, when the injury site is strong and close to fully repaired, higher level plyometric drills that mimic the sporting environment may be included. It is essential that recovering athletes perform explosive type movements in a closed environment before returning to any field or court sport.

**Proceed with caution**

Therapists should be aware that there is a risk of aggravating injury with plyometric exercises during rehabilitation. However, I believe if the athlete returns to play an explosive sport without having performed plyometric exercises at a high level, they will be at greater risk of re-injury.

Always err on the side of caution when introducing progressions, making sure only ever to progress one element at a time: repetitions, or drop height, or stability challenge etc. Delay progressions by an additional week if there is any doubt about the athlete’s readiness to cope with them.
How much and when
Low intensity plyometric rehab can be done daily as long as the exercises don’t provoke soreness to the injured area. This kind of plyo work does not cause high levels of stress to the muscle-tendon complexes, unlike high intensity plyo drills, which should be reserved for late-stage rehab. Although this is anecdotal, I recommend that high intensity exercises should only ever be done every second day at the very most. If an athlete is able to perform high level exercises, they are by definition likely to be a week or two away from competing, and then they can resume their normal training regime.

It is very important to specify the number of ground contacts (repetitions) the athlete is to perform. Progression should follow the general strength training pattern, in which early stage exercises will be done using low resistances and higher numbers of repetitions. As loading increases, the number of reps will decrease.

Thus, low intensity plyometric exercises, where maximal muscular output is not demanded, can have a larger number of repetitions/ground contacts, but this number reduces as intensity rises. Increasing the number of ground contacts is a progression in itself. You might set for your athlete a low intensity drill such as single leg hops, 3-4 sets of 20 hops. By the time they are doing single leg squat jumps, you might be asking them to perform 3-4 sets of 6-8 repetitions.

Case Study: The rugby player
Take the rugby player as an illustration. His injury is an isolated Grade 2 strain of the medial collateral ligament (inner side knee ligament), managed conservatively with a brace. As pain and ligament recovery allow, the player should first return to squatting, lunging, single leg squats and proprioception exercises on the ground. Once he has mastered the full range of movement and strength in these exercises, he can progress to proprioception work on an unstable surface such as a wobble board or mini-trampoline. He may also now add in some low intensity plyometric drills on two legs. These can be progressed
to the injured leg alone, building up to high-intensity single leg work. At the same time, he will be progressing his running, cutting moves, direction changes, skill drills and fitness level.

Conclusion
In the past, plyometrics, particularly high intensity exercises, have not been seen as an important part of rehabilitation, probably because of the associated risk and decreased emphasis on exercise based therapy. However, I believe this modality is sound in principle and essential in practice to the success of late stage rehabilitation. As long as the exercise is mimicking the sporting activity and you are confident the athlete’s injury can withstand it physiologically, embrace it.

References


Part two: Plyometrics for throwing athletes

In part one we looked at the role that plyometric training can play in rehabilitating athletes with lower-limb injuries. Arguably the same approach could be used for upper-limb training and rehab, so we now take a look at what research evidence there is for plyometric-type training related to the upper limb, and whether it holds any useful pointers for rehab work.

One of the most important upper-limb sporting movements is the throw; indeed, in many sports the balance of a game can hang on the speed and accuracy of a single throw. According to the definition of Chmielewski and colleagues, throwing is an obvious example of a plyometric movement:

‘Plyometric exercise is an activity that involves and capitalises on the mechanisms of the stretch-shortening cycle to increase the efficiency of force production at a joint or increase performance(1).’

Baseball pitchers throw at speeds of up to 160 km/hr and professional tennis players serve balls that cross the court at up to 250km/hr. This equates to a rotation speed at the shoulder joint (‘shoulder angular velocity’) of more than 7,000 degrees per second, made possible by the arm moving through a series of stretch-shortening cycles to produce a rapid development of force.

If the sports therapist is going to fully rehabilitate clients with upper-limb injuries who are involved in throwing sports, they need to understand the type of upper-limb plyometric or explosive type training that these athletes undertake. Keeping in mind that the medical and therapeutic staff share the job of returning the athlete to pre-injury performance levels, the research we report on here should help determine what, if any, upper-limb plyometric exercises might usefully be included in late stage rehabilitation.
The research
In a 2001 literature review of studies examining the effectiveness of various training methods for improving throwing performance, DeRenne et al\(^{(2)}\) looked at 26 articles across the three training categories widely used in periodised training programmes (see box overleaf). Of these studies, 22 reported increases in throwing velocity, one found a decrease and three found no change after the training period.

But the lack of consistency across the studies in terms of their training periods, weekly volumes, exercises used or percentage changes achieved in throwing velocity meant that the reviewers’ conclusions are rather limited.

Overall, the three categories of exercises (general, special and specific) target different training effects and all three types are successful in improving throwing velocity. It is safe to assume that a training programme should include elements of all three categories. Traditionally, this would have been done sequentially, the athlete moving from general to specific exercises over time. These days the prevailing thinking is towards a more integrated approach, ensuring that some sport- and movement-specific training takes place all year round.

Despite the limited conclusions of the review, there are still some useful findings worth noting from some of the research studies that it examined.

Strength training
Within the category of general strength training, many of the earlier studies such as Toyoshima et al\(^{(3)}\) concentrated purely on upper-body work. These studies show that even such basic training methods can produce gains in throwing velocity. More recent studies included lower body and trunk exercises to make better use of ground reaction forces for the throwing action. While this makes good sense in theory, there is little in the literature to confirm its added value.

Another recent trend favours a preferential use of certain upper-body exercises such as bench press, lat pulldown and barbell pullover, all of which strengthen the powerful adductors and
internal rotators of the shoulder. This approach seems to correlate with greater improvements than just using free weight shoulder exercises. My own tendency would be to include both types of exercise, to avoid muscular imbalances and hence injury.

**Special training**

‘Special’ exercises need to be performed explosively. So in this phase of training straightforward strength exercises are performed explosively (at speed) alongside more complicated movements that target power and the linking of lower and upper body, such as the clean and jerk.

The only study in the literature (Lachowetz et al(4)) to use traditional strength training explosively does not help much, because the training is combined with cable pulley work and other specific throwing action exercises.

Newton and McEvoy(5) compared traditional isotonic resistance exercises with medicine ball upper-limb plyometric drills in baseball players with no previous experience of weight training. Both groups benefited from strength gains, but only the isotonic training group showed enhanced throwing velocity. This suggests that in untrained populations it is probably necessary to train for basic strength before training for throwing velocity.

The same team (McEvoy and Newton 1998(6)) used squat jumps and bench throws (Smith machine bench press, using light weights, in which you throw the bar up and catch it) of weights at 30-50% 1RM and achieved a ‘significant increase’ in throwing velocity in the treatment group.

**Specific training**

The third training category – throwing-speed specific – concentrates on the athlete generating excess force (by using weighted throwing implements or resistance tubing) or excess speed (by minimising weight and/or drag). The literature review suggests that ‘overspeed’ training works better than ‘over-force’ training, but that either modality will improve on results obtained from just practising throwing (DeRenne et al, 1990(7)).

In 1994 DeRenne looked at the effect of a combined
A standard programme would divide training into three categories. Traditionally these follow sequentially, but recent thinking suggests the components need to be mixed up a bit.

For throwing performance the programme might include:

**Category 1: general**

**Aim:** to improve the overall contractile properties of the muscle or the ability of the muscle to produce force (in this case, throwing strength and speed).

Exercises would include:
- bench press
- lat pulldown
- pull-over
- chin-ups
- shoulder press
- shoulder dumbbell drills such as lateral raises, internal and external rotation, bicep curls and tricep extensions.

Because throwing uses the whole body to produce velocity, the general programme should also include trunk and lower-limb exercises such as sit-ups, squats, deadlifts and back extensions.

**Category 2: special**

**Aim:** to turn strength into explosiveness or power which is the ability of the muscle to produce high force over a short period of time. The exercises can include any of those listed in category 1, adapted to develop explosive force by using lighter weights, fewer repetitions and faster movements.

Other suitable exercises include:
- bench throws
- squat jumps
- push press
- clean and jerk
- cable exercises that replicate components of the throwing motion.

**Category 3: specific**

**Aim:** to replicate the throwing motion in such a way as to overload the neuromuscular system to recruit the high threshold motor units.

Exercises are normally one of two types: force overload (eg, throwing a weighted baseball) or speed overload (eg, throwing an underweight ball). Cables, pulleys or tubing are all useful for increasing resistance, set up in the closest way possible to the sport-specific throwing action and then resistance-adapted for the required overload effect.

For tennis players I add weight to the end of the racquet to train force overload, and I use a racket without strings (which reduces the weight and minimises air resistance) for velocity overload training.

programme of over-speed and over-force training in baseball pitchers\(^8\). The researchers tested two five-week programmes with different combinations of force and speed, and found that both groups showed a significant increase in throwing velocity.

Another interesting study, only recently published (Carter
et al 2007(9)), compared an eight-week baseball training programme of high volume upper-limb plyometrics with a regular strength and conditioning regime (no upper-limb plyometrics). This study found no difference in isokinetic strength between the two groups, but the plyometrics group demonstrated a 2mph increase in throwing velocity. The exercises for this study included rotation against tubing resistance, medicine ball overhead football throws and weighted baseball throws.

**What it all means**

Overall, the research is deficient in two main respects. First, we need more work done on an integrated training approach that mixes up the different components, to tell us whether this is a more effective regime for increasing throwing velocity than the traditional separation of elements. And second, we need to know whether the results obtained using baseball hold good for other throwing sports, as the research literature is heavily dominated by this one sport.

So what can we learn from the studies we do have? We know that plyometric training has a positive impact on the function of the neuromuscular system, resulting in improved postural control and joint position sense. Swanik et al in 2002(10) found that upper-limb plyometrics improved upper-limb joint position sense. It seems clear to me, therefore, that the sports therapist charged with returning a throwing athlete to pre-injury levels of performance will want to use plyometric training as part of the late-stage rehabilitation work.

**References**


Further reading

