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RESISTANCE TRAINING

the next level

A SPECIAL REPORT FROM

PEAK PERFORMANCE

The research newsletter on stamina, strength and fitness

RESISTANCE TRAINING

the next level

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A CIP catalogue record for this book is available from the British Library.

Printed by: Baskerville Press Ltd
6-8 Newton Road, Salisbury, Wiltshire SP2 7QB

Published by Peak Performance Publishing

Peak Performance Publishing is a trading name of Electric Word plc
Registered office: 33-41 Dallington, London, EC1V 0BB
Tel: 0845 450 6402
Registered number: 3934419

ISBN: 1-905096-21-6

Publisher Jonathan A. Pye
Editor Sam Bordiss
Designer The Flying Fish Studios Ltd

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CONTENTS

From the editor

As the old saying goes, you learn something new every day. I can't think of anything that that applies to more than resistance training. As sport science develops in terms of principles and application, there is no end to what you can improve in your sessions in the gym, no matter what sport you play. Even if you don't play sport, resistance training has health benefits that largely go unheard of.

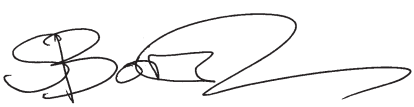
On the flip side there is nothing more damaging for an athlete than getting their resistance training sessions wrong. Not can only it lead to dramatic deterioration in performance, it can also make an athlete more susceptible to injury. Worth making sure you get it right then!

This Peak Performance publication is a compilation of articles that will assist athletes and coaches in their resistance training programmes. It is aimed at people who are already competent in the gym and want to take their training to the next level. The first four chapters are articles highlighting different approaches and types of training that can benefit certain athletes. Periodisation, plyometrics, the potentiation effect; they're all in there.

The middle chapter is a strength and conditioning programme for the Triathlon. Now I know there are only so many triathletes in the world but any sport that involves swimming, running and cycling can apply to everyone in some sense or another.

In the second half of the book we look at why women and youths should work out with weights. There's a chapter on diets and creatine. The chapter on shoulder injury prehab and rehab will apply to many athletes; I hope it helps prevent future nasty injuries. The final chapter also has a rehab theme, looking at how you can complete resistance training out of the gym.

I hope this special report becomes as much a part of your resistance training regime as your dumbbells, sets and reps.



Sam Bordiss
Editor

For that extra edge all you need is variety

Most athletes in search of that elusive extra edge in strength and power look to resistance training in one form or another. Often they think they need a new exercise to sharpen them up. But what they may not realise is that considerable improvements in training outcomes can be achieved without changing the content of their routines but simply by altering the sequence of exercises and varying the rest times between exercises.

In this article I want to provide of how different sessions can be devised with specific outcomes in mind by changing the sequence and rest times between sets. All the sessions I will describe are based on just five exercises: bench press, bench throw, bench pull, the squat and the squat jump.

Technical guidance

All the exercises described in this article should be performed with care and not without prior coaching.

- ***Bench press*** Lie face up on an exercise bench, lower the exercise bar to your chest and then push up;
- ***Bench pulls*** Lie face down on a higher-than-normal exercise bench, pull the exercise bar up to your chest from the floor, then lower it;
- ***Bench throws*** Using a smith machine or other guided tracking device for safety, lie face up on the exercise bench, lower the exercise bar to your chest, then throw it up as quickly as possible, catching it as it comes back down;
- ***Squat*** Standing up, place the exercise bar across the back of your neck on your shoulders, bend your knees until your thighs are parallel with the floor, then return to start position;
- ***Squat jump*** As for the squat, but instead of returning to a standing position, jump up as high as possible and land safely.

How much rest is enough?

So far research has not come up with a definitive answer to this question. This is partly due to the varied training levels of subjects used in the studies. In a study of untrained college students, rest periods of 30 and 90 seconds between sets were compared to determine which was most effective at increasing strength or muscle mass [1]. After 12 weeks of training, both groups were found to have increased strength and muscle mass by comparison with non- training 'controls', but the improvements in strength were most marked in those who rested for just 30seconds.

By contrast, a study on trained subjects found that five minutes rest was better than one or two minutes for increasing the amount of total weight that could be lifted over 4 sets of the squat and bench press at an **8RM** load [2].

Of course, an increase in strength is desirable, but another study found that the downside of short rest intervals (one minute compared with three minutes) when doing heavy training sessions (10 sets of 10 reps at 65%1RM) may lead to greater muscle damage, affecting the athletes' ability to perform on the following day and may also increase affect the immune system in such a way as to increase susceptibility to illness [3].

Yet another group of researchers compared the effects of rest intervals of one, two, three, four and five minutes on three sets of bench press performance at 90% 1RM and 60% 1RM, and also of one, two, five, seven, 12 and 15 minutes at 85% 1RM [4,5,6]. They considered not just the objective impact of the rest intervals on performance but also the athletes' subjective preferences.

The rest intervals of one and two minutes led to a significant reduction in performance by comparison with the longer intervals. And, interestingly, the intervals of 3-6 minutes, which resulted in most improved performance, were also those most preferred by the athletes. The researchers concluded that trained subjects might be best placed to identify the optimal amount of recovery needed for the work they perform.

However, while a longer rest interval seems best for trained subjects, performing high volume, strength based workouts, a shorter rest may be appropriate when performing complex training sets, where an explosive exercise like the squat jump is performed after a strength exercise like the squat. No significant differences in jump performance were found after intervals of one, two and four minutes in a study of 21 US College athletes who performed sets of 5RM squats followed by five countermovement jumps [7]. This has practical implications in terms of fitting sets into training sessions. If too much rest is taken between exercises, then less overall work can be performed within the time available.

Another study also found that one-minute rest intervals were best for trained subjects performing two sets of 1RM squats in trained subjects [7]. So it appears that briefer rest intervals may be appropriate for some power sessions using lighter loads, such as body weight, or when performing very low-volume, but high-intensity lifts.

‘Shorter rest intervals are more appropriate when performing complex training sets’

Does sequencing matter?

How important is the order in which the exercises are performed? Very – if you are trying to achieve the most effective workout with the least amount of work.

For example, performing squat jumps after squats makes for effective training in experienced athletes, but not their recreational counterparts [8]. This is because recreational athletes find the squats tiring and are less able than trained athletes to activate the potentiation response, whereby one exercise enhances the impact of the next one.

That same effect has been demonstrated, again for trained subjects, with upper body exercises using the bench press and bench throws [9]. This study, involving already strong rugby players, used six reps of 65%1RM bench press, followed by three minutes rest, then five bench throws of 50kg. Power output was shown to have increased after the bench press, by comparison with a control group who just performed the bench throws.

But what happens if you put **plyometric exercises** (*eg* jumps) before strength exercises (*eg* squats)? That's what a team of US researchers set out to consider with 12 experienced subjects who performed 1RM squats after a warm-up of five sub maximal sets of squats [10]. The study compared the effects of three different sessions: in the first, the subjects performed the normal warm up, and in the second and third they performed either two depth jumps or two countermovement jumps after the warm-up and 30 seconds before attempting their 1RM.

The researchers found that performing the depth jumps increased the 1RM by an average of 3.5% by comparison with the countermovement jump or no jump at all. The explan-ations for this improvement is speculative (because no measurements of neuromuscular activity were made), but it is likely that the prime muscles involved in the squat exercise were prepared for maximal effort by the depth jump. This enhancement is likely to have taken the form of increased muscle fibre recruitment and rehearsal of movement patterns. The fact that only two jumps were performed ensured that fatigue was not a factor. It is important to notes that no similar research has been carried out with untrained subjects, and care should be taken before extrapolating these results to them.

Interestingly, further research has shown that power may be enhanced by working the **antagonist** muscles before the **agonist** muscles. The researchers found that performing the bench pull immediately before the bench throw lent more power to the latter movement [11]. It seems that when a power exercise is preceded by an opposite movement, the antagonist muscles can be educated into relaxing more during the subsequent exercise. Again, however, this effect has been observed in only one study, and this was on trained subjects.

One further factor to consider when deciding the order of exercises in a session is the impact of overall fatigue. The order of exercises may be carefully designed to promote power or strength and you may have planned in rest periods at the optimum times, but if the session lasts as long as 45-60 minutes the quality of work at the end is likely to be lower than at the beginning.

In a study looking at a sequence of six different exercises, using three sets to failure, with a 10RM load, with two minutes' rest between sets, the researchers found that the last two exercises produced significantly fewer reps, an effect which persisted when the sequence of exercises was reversed [12]. In other words, of the six exercises performed, only four were performed with sufficient load; the last two had fewer reps, so less work was done and less strength gained as a result.

'When designing your sequence of work, it is important to put the most important movements at the beginning of the session'

One implication of this finding is that, when designing your sequence of work, it is important to put the most important movements at the beginning of the session. If all the movements are considered important, it is probably better to split them into different sessions, allowing for adequate recovery and adaptation between sessions.

So, a power training session for experienced trainers might look something like Table 1, below, with one set of squats followed by one set of squat jumps, repeated twice more, then the bench pull, bench press and bench throw performed as a sequence, then repeated twice more.

Table 1: power training session for experienced trainers

Exercise	Load	Reps	Sets	Recovery
Squat	60% 1RM	5	3	1 min
Squat jumps	30% 1RM	5	3	4 mins
Bench pull	85% 1RM	3	3	3 mins
Bench press	60%	5	3	1 min
Bench throw	10%	5	3	3 min3

And a strength training session for experienced trainers might look like Table 2, overleaf, with the squat jumps and squat performed in sequence, then the bench pull, bench throw and bench press as the final sequence.

Table 2: strength training session for experienced trainers

Exercise	Load	Reps	Sets	Recovery
Squat jumps	30% 1RM	5	4	1min
Squat	80% 1RM	5	4	3 mins
Bench Pull	80% 1RM	5	4	3mins
Bench Throw	10%	5	4	30secs
Bench Press	80%	5	4	3mins

Less experienced trainers would benefit from establishing a strength base before performing explosive exercises with weights. A good rule of thumb is that you should be able to squat your own body weight before considering progression to more advanced leg exercises. Failure to establish a strength base could not only put you at risk of injury but also hinder long term gains in power.

As a starting point, you could use the strength session set out in Table 2, but leaving out the squat jumps and the bench throw.

In conclusion

Research has yet to come up with definitive answers on the amount of rest required within a session and the ideal sequence of exercises.

- What is known is that experienced strength trained subjects are better able to produce power than untrained subjects.
- Therefore coaches should ensure that their athletes have a solid strength base before introducing more varied and complex training methods.
- If time permits, the athletes themselves may be the best judges of how much rest they need within a session.
- Sequencing strength exercises before plyometric exercises, and vice versa will provide an added training stimulus that will ultimately produce stronger, more powerful athletes.

James Marshall

Jargon buster

RM (repetition maximum) The maximal amount of work that can be performed for a given number of repetitions. For example, 1RM is the most weight that can be lifted once. 8RM is the most weight that can be lifted 8 times consecutively.

Plyometric exercise An explosive form of exercise, often involving jumping movements, that utilises the muscle's ability to stretch then contract rapidly to produce more force.

Antagonist/agonist muscles An agonist is the muscle that contracts to allow movement, and the antagonist is the opposite muscle that normally relaxes to allow this movement

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Does it work for the upper body ?

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 sporting movements 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 milliseconds 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 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 on both parameters. This suggests that upper body plyometrics is not effective at boosting rate of force production. 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 production 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 5 kg 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 as strong as 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 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 on an **isokinetic dynamometer** 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 researchers tested female subjects throwing 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. (The mechanics of this study are explained in greater detail in the box below.)

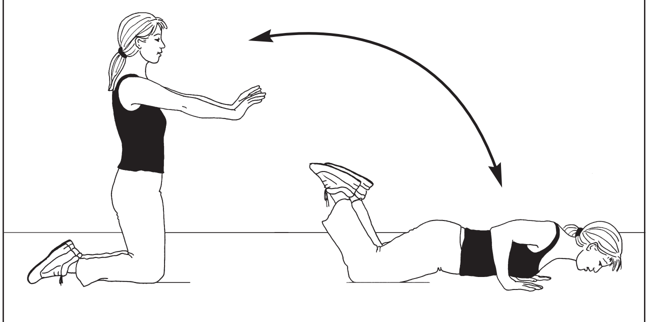
With plyometric press-ups, you start by kneeling upright, then fall forward onto the hands, absorbing the weight using the press-up lowering movement (eccentric phase), then rapidly propel yourself upwards and back to the start position (concentric phase) with a ballistic movement.

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 production in their upper bodies.

Table 1: recommended plyometric exercise for the upper body

Exercise	Weight	Sets x Reps	Rest
Overhead med ball throw	Female 10-15kg ball Male 15-20kg ball	3-4 x 6-8	2 min
Plyo press-up	(body weight)	3-5 x 5	2-3 min
Chest pass	Female 10-15kg powerbag Male 20-25kg powerbag	3-4 x 6-8	2 min

The plyometric press-up



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 30 kg 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 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, then, 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.

Raphael Brandon

Jargon buster

Stretch-shortening cycle (SSC) A movement that involves an eccentric muscle contraction immediately followed by a concentric contraction.

Eccentric A muscle exerting force when lengthening.

Concentric A muscle exerting force when shortening.

Elastic energy Energy stored in the connective tissue.

Medicine ball A weighted ball that can be thrown and caught for training purposes.

Counter-movement jump An example of an SSC in which you squat and them jump up as high as possible.

Abducted A limb moving away from the centre of the body.

Adducted A limb moving towards the centre of the body.

Fast twitch muscle fibres Muscle fibres that are able to contract at high forces and speeds but that fatigue easily.

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The potentiation effect: can one training mode really enhance the other?

Designing a periodised training programme to enhance speed and power can be mentally taxing – so much so that those on the hunt for these prized attributes may even develop a 'complex'!

Complex training describes a power-developing workout that combines weights and plyometric exercises. About 10 years ago, 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 complications 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 weight lifting power could be enhanced by the prior performance of a plyometric exercise – of which, more later.

Complex training effects

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 motor neuron in their muscle motor unit.

A motor neuron acts as a type of ignition key to its bundle of 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. And it is argued that weight training alone may recruit relatively low numbers of type IIb fibre motor units, preferring to target type IIa fibres and even convert IIbs to IIas, with the overall counterproductive effect of slowing the athlete down.

However, plyometric training, which can generate huge amounts of force in a split second, is much better at hitting type IIb fibres and, therefore, at increasing speed and force production. The way plyometric and weights exercises are ordered into a power combination workout can have a significant effect on training adaptation. There are two basic approaches:

- ***Complex training*** This involves performing sets of weight training exercises before sets of related plyometric exercises – *eg* 3 sets of 10 half squats, before 3 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 – *eg* 1 set of 10 half squats followed by 1 set of 10 jump squats, repeated over 3 sets.

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 question marks 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 electromyograpy (EMG) in the subsequent plyometric exercise [1].

Eight strength-trained men were involved in the research under two conditions:

1. Complex training, performing 5 squats at 85% of 1RM, followed by the first set of jumps, with the second, third and fourth sets performed 3, 10, and 20 minutes after squatting;
2. Control condition, involving only CMJ and DJ performance.

‘A number of question marks have been raised over the power combination workouts’

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.

Order of exercises

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 to 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.

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.)

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 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(3). 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 of performers that may need to worked 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 the other way round, 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.

Rest periods and recovery

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 are applicable to such sports as basketball and rugby.)

'Training maturity is an important potential variable in the success of power combination workouts'

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 focussed on the potentiation of plyometric exercise by weights work. However, research by Masamoto [5] looked at the effects of plyometrics on weight training, particularly on 1RM squat performance. 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 either3 double-leg tuck jumps (TJ) or 2 depth jumps (DJ) 30 seconds before each of three 1RM attempts, interspersed by at least four minutes' recovery.

'Can power combination workouts enhance competitive as well as training performance?'

The researchers discovered that performing a plyometric exercises before going for a 1RM best hade a positive effect. Tuck jumps upped the average squat performance to 140.5kg, and depth jumping 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.

Squats and sprint cycling

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.

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 sprint cycle;
2. 10 squats at 90% of 1RM 5 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 the 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 3 single leg squats on each leg;
- Sprinting/jumping/throwing – perform 5 squats with a willing training partner/team mate on your back;
- Weight lifting – perform 5 throw-and-catch medicine ball chest passes against a wall as fast as possible and/or complete 3 tuck or depth jumps.

Power combination training, despite some of the reservations expressed earlier, seem 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

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Power without mass – how strength and plyometric training can boost endurance running performance

As a middle or long distance runner (or running 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, maybe useful for a rugby player but wont 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.

In this article 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

Strength session: twice a week		
Front squat	4 x 5	Progressed to heavier weights (60-90kg)
One leg squats	3 x 5	Progressed to heavier weights (40-70kg)
Swiss ball hamstrings hip lift	3 x 10	Progressed to single leg, then increased reps
One leg barbell calf raise	3 x 10	Progressed to increased seps
Gluteal bridge (single leg)	3 x 30s	Progressed to 3 x 60s
Side plank	3 x 30s	Progressed to 3 x 60s
Reverse crunch	3 x 20	Progressed to adding weight to legs
The plank	3 x 30s	Progressed to 3 x 60s
Plyometric session: once a week		
30cm drop and catch	3 x 5	Progressed to 30cm drop jump 4 x 5
Power skips	3 x 10	No progression
Ankle hops	3 x 10	No progression
Double hurdle hops	3 x 5	Progressed to 4 x 5
Total foot contacts	**75**	**85**

The main aim of this off-season preparation phase 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.

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 using 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 become 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 following sessions were each performed once per week, with the core exercises from the previous phase also maintained on a twice-weekly basis:

Session 1	
Drop jumps 40cm	4 x 5
Front squat + hurdle hop	3 x 5 + 5
Swiss ball hamstrings hip lift	3 x 20 each leg
One leg barbell calf raise	3 x 15
Session 2	
Dynamic lunge drives	4 x 5
Barbell squat jumps	3 x 3
One leg squat + speed bounds	3 x 5 + 5
Swiss ball hamstrings hip lift	3 x 20 each leg

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, with 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

'Long distance runners need to be very powerful in relation to their body weight, but not as powerful as sprinters'

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 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 muscles mass.

The 5km strength programme

The aims of strength training for this 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 bodyweight, 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. His programme was structured as follows:

Strength session – once weekly	
Barbell step-up (40cm box)	3 x 8, progressing weight lifted
Swiss ball hamstring hip lift	3 x 10, progressing to 3 x 20
Calf raise (machine)	3 x 8, progressing to 3 x 15
Standing hamstring hip extension (band)	3 x 10 each leg
Dumbbell press	3 x 10, progressing weight lifted
Dumbbell row	3 x 10, progressing weight lifted
+ Core exercises *eg* side plank, bridge *etc*	

Plyometric session – once weekly
1. High knee skip drill, 2 x 20 m
2. Knee pick up drill (using mini hurdles) 2 x 10 hurdles
3. Fast knees-up drill, 2 x 20 m
4. Power skips, 3 x 10
5. Mini hurdle hops, 3 x 8
6. Vertical jumps, 3 x 8
7. 4 x 30m sprints

The strength session 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 this muscle group.

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 was used to promote leg power. Research has demonstrated that when a similar explosive strength/plyometric programme was added to a 5km runner's weekly programme maximum speed and 5km performance improved by comparison with a control group who maintained a running-only programme [1].

This performance improvement was independent of any change in VO_2max 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 (see PP 186, September 2003).

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

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TRIATHLON

Your complete strength and conditioning programme

Triathlon is a demanding multi-discipline sport, calling for high levels of endurance in the water, on a bike and on the road. And, while triathletes spend most of their time swimming, cycling and running, they also need a supplementary resistance-based conditioning programme to enhance overall performance. In this article, a programme of strength and conditioning exercises suitable for serious competitive triathletes is presented.

When adding a strength programme to your training routine it is important to consider the following questions:

1. What kind of strength development can deliver a performance improvement? The answer depends on two factors – the strengths and weaknesses of the individual athlete and the nature of his/her sport. Obviously an article like this can only address the second factor, so the programme set out is generic rather than specific. However, it is comprehensive enough to provide a reasonable starting point for a more individualised programme.
2. How will the strength workouts enhance rather than detract from your weekly training schedule? Any serious endurance-trained athlete finds it difficult to commit to – and recover from – extra training time, so a strength programme for triathletes has to yield the maximum results with the minimum expenditure of time and energy.

Strength training can improve performance via two main effects: first, the resultant increase in strength can enhance the skill, power or efficiency of the sporting movement;

secondly, it will reduce the risk of injury. When designing a triathlon strength programme, you have to consider whether a performance and/or injury benefit is possible for each of the three disciplines. Once you have done this, you have a rational basis for choosing the best exercises. Based on research and my own experience, I recommend that you target performance for running, and injury prevention for running and swimming (see boxes).

The tables that follow set out four routines that make up the whole strength and conditioning programme. When you put all the routines together, you will find at least one exercise targeting each performance or injury prevention benefit for triathlon. Each routine includes no more than six exercises that should be completed once a week. Strength routines 1 and 2 take about 45 minutes, while the core and jumping routines should take around 20 minutes. This level of time investment is realistic for athletes and allows for a beneficial rather than a tiring effect.

How strength and conditioning training reduces triathlon injury risks

It is hard to prove that following a strength programme will result in fewer injuries for elite runners, swimmers and cyclists. However, experience and clinical research supports the use of preventive strengthening exercises in specific muscle groups. For example, strength in the calf and anterior tibialis (the muscles at the front and back of the lower leg) has been linked inversely with Achilles tendon overuse injuries.

Core strength exercises are recommended for both running and swimming injury prevention. Balance between the strength of the quadriceps and the hamstrings is recommended specifically for running injury prevention, while good rotator cuff and scapula muscle function is recommended for swimming injury prevention.

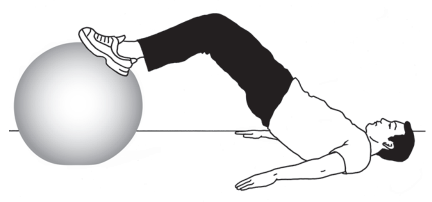
Therefore, triathletes should include in their routines exercises for all the trunk and core muscles, rotator cuff and scapula muscles, together with isolated exercises for the calf and hamstrings.

Strength routine 1

Squat

Squat *Strengthens the quadriceps, gluteals and trunk muscles and helps strengthen the legs for running, enabling better control of vertical landing forces. Good squat strength may also help prevent knee injury.* This is performed with a barbell placed across the back of the shoulders. Start with feet shoulder width apart, toes pointing out slightly. Take a deep breath and squat down, taking the hips backwards and feeling the weight pressing down through both heels. Lower yourself to a knee bend of at least 90° (see picture below, right), ideally with the thigh parallel to the ground to ensure optimal gluteal activation. Return to start position while breathing out – this helps support the spine. Start by mastering the technique with 3-4 sets of 8 repetitions with a light bar. Progress to 4 sets of 5 reps with 2-3 minutes' recovery between sets. Aim to increase the weight you can lift for 5 reps.

Swiss ball hammy



Swiss ball hammy *Strengthens the hamstrings specific to the running action – with the foot in contact with a surface and the hamstrings acting to extend the hip. Also strengthens the trunk and hip muscles.* Perform this exercise with the soles of your feet on a Swiss ball and your back on the floor. Start with the whole back on the floor, knees slightly bent, with legs up on the ball. Push down through the feet into the ball, pushing the hips up at the same time. Lift hips until there is a straight line through the knee, hip and shoulder, keeping upper back and neck on the floor. Lower down slowly until hips just touch the floor, then repeat. Start with 3 sets of 10 reps with two feet on the ball. Increase to 3 sets of 20 reps. Progress to 3 sets of 5 reps with one foot on the ball. Increase to 3 sets of 15 reps as you get stronger.

Rear sling *Strengthens the shoulder and rear rotator cuff muscles and so helps prevent swimming injury. It can also be performed standing on one leg to challenge core stability.* Perform with a pulley machine, using a handle attached below hip height. Stand with good posture, holding the pulley handle across the body, palm facing back, a slight bend fixed in the elbow. Using only the shoulder, and keeping the elbow stiff, pull the arm up, across and out. The finish position is with the hand above the head out from the body, palm facing forwards. Retain good posture, without using the trunk or rotating the body during the movement, and finish with shoulders wide and relaxed. Use 2-3 sets of 8-10 reps, aiming to increase the weight lifted for 8 reps.

Front sling *Strengthens shoulder and front rotator cuff muscles and so helps prevent swimming injury. It can also be performed standing on one leg to challenge core stability.* This is the opposite of the rear sling. Start with the pulley handle attached above head height, holding the handle, arm away from the body, palm facing forward. Pull the arm down and across the body, finishing with the hand by the opposite hip and palm facing back. The same coaching points apply as for rear sling. Use 2-3 sets of 8-10 reps of this exercise. Aim to increase the weight lifted for 8 reps.

Trunk twist standing *Specifically recommended for swimming trunk rotation strength, as it is performed with the body in an extended position, similar to that used in swimming.* Stand with broomstick or barbell attached to a long resistance band at one end, feet shoulder width apart, knees soft, with good back posture. Then rotate shoulders, pulling on the band. Focus on the trunk muscles to rotate rather than pushing the bar around with your arms. Keep hips facing forwards throughout. Complete 2-3 sets of 8-10 reps to each side. Increase the strength of the band as you gain strength.

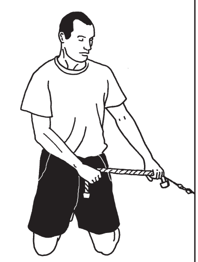
Single-leg calf raise *Specifically strengthens calf muscles to help prevent lower leg running injuries. It can also be performed barefoot to target the foot muscles as well.* Stand on one leg, with the ball of the foot on a small step. Start by lowering the heel until you feel a little stretch in the calf, then push up onto the ball of the foot. You may need to hold onto something for balance, but do not push yourself up with your hands. Complete 3 sets of 10 reps. Increase to 20 reps,then begin to add weight. Use a barbell or a calf raise machine.

Strength routine 2

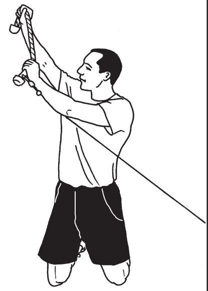
Step-up *Strengthens the quadriceps, gluteals and hip muscles and is excellent for running, increasing both leg strength and stability.* Start with a barbell across your back, with one foot on a step, high enough to ensure your knees and hips are bent at an angle of around 900. Push down through the heel of the foot upon the step and extend the leg, rising up onto the step. Then lower down, taking all the weight back onto the same leg, leaving the foot on the step. When the support leg touches down behind the step, begin to push up again. In this way most of the work is done with the leg on the step.Start by mastering the technique with 3-4 sets of 8 reps, progressing to 4 sets of 5 reps with 2-3 minutes' recovery between sets. Aim to increase the weight you can lift for 5 reps.

Russian hamstring curl *Develops excellent hamstring strength, which specifically helps the running in terms of injury prevention and increased propulsion forces.* Start in the kneeling position with a partner pressing down firmly onto your calf muscles from behind, aiming to keep the hip extended and the back in neutral. Slowly lean forward from the knees, using the gluteals to keep the hips straight. The hamstrings will be working very hard to control the movement, using an eccentric contraction. Lean forward as far as your hamstring strength will allow, ultimately aiming for an angle of 45°. If you can, pull yourself back upwards; otherwise fall onto the floor, catching yourself in the press-up position, then push back upwards to the start position. Start by mastering the technique with 2-3 sets of 5 reps. Do not progress until you can control the movement out and back, keeping the back straight. Slowly progress up to 3 sets of 8 reps, going out to 45° and coming back up, holding perfect posture and hip extension.

Up-chop kneel 1



Up-chop kneel 2

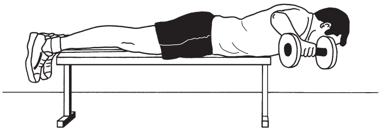


Up-chop kneel *Develops excellent core stability and trunk rotation strength and is therefore useful for both running and swimming.* Kneel next to a pulley machine with a handle attached below hip height. Grasp the handle in both hands to the side of the hip nearest the pulley machine. Lift the arms up and at the same time rotate the shoulders away from the pulley machine, keeping hips facing forwards and arms straight (see pictures above right). Complete 2-3 sets of 8-10 reps both sides. Aim to increase the weight lifted for 8 reps.

Down-chop kneel *Develops excellent core stability and trunk rotation strength and is therefore useful for both running and swimming. This is the opposite of the up-chop.* Begin with the handle attached above head height, grasping the handle in both hands above the head to the side of the pulley machine. Keeping the hips facing front and the arms straight, pull the hands down and turn the shoulders away from the pulley machine. Complete 2-3 sets of 8-10 reps both sides. Aim to increase the weight lifted for 8 reps.

Reverse flies *Develops upper back and rear shoulder musculature and helps stabilise the scapula. It is included as a swimming injury prevention exercise.* Lie face down on a bench with head and neck just off the edge of the bench, holding a dumbbell in each hand, arms straight out to the side. Lift the dumbbells off the floor until the hands are level with the body, arms remaining straight out to the side. Complete 2-3 sets of 8-10 reps both sides. Aim to increase the weight lifted for 8 reps.

Reverse flies



How strength and conditioning training improves triathlon performance

Strength training of the major leg muscles has been shown to improve long distance running performance – specifically running economy – independent of changes in the cardiovascular system. In particular, explosive strength training and plyometric (jumping) training have been proven to be beneficial[1]. The most likely reason for this is that increased strength and recruitment of the major leg muscles boosts the efficiency of the running action. The strengthening of the tendon due to the ability to create a better 'leg spring' may also play a part. Therefore triathletes should include strength and jumping exercises for the major leg muscles in their programmes.

Elite swimmers do perform strength training, but the leg strength exercises that boost power during the dive start and push off the wall in the turns for events in the pool are irrelevant for triathletes, who swim in open water. Core strength, particularly trunk rotation, is recommended for swimming performance, as is upper body strength work to increase the power of the arm pull[2]. However, it could be argued that increased upper body force may not improve the efficiency of the swimming stroke in long-distance swimming. Some swim coaches are concerned that 'muscling' the stroke will create extra drag around the swimmer, which is counter-productive. Therefore, triathletes should include core strength and trunk rotation exercises in their programmes, focusing only on the exercises that are most likely to benefit swim performance.

Elite road cyclists perform little strength training. In fact, it has been shown that elite cyclists have quite high maximal strength of the quadriceps compared with untrained adults of a similar age[3]. This suggests either that they are naturally strong in the legs, or that cycling training produces a strength training effect in the legs. This may be because of the high-force activities that occur naturally in cycle training and racing, including pedalling in high gears, pedalling up hills and intermittent sprinting. The inference is that leg strength training is unlikely to have any performance benefit for road cyclists. Upper body strength training will be detrimental if it increases muscle mass, as this will slow you down. In summary, triathletes don't need to perform any strength exercises specifically for cycling. Any leg strength training gains will occur as a side benefit of the leg exercises chosen for distance running.

Jumping routine

All these exercises are chosen to benefit running efficiency. These explosive jumping movements train both the major leg muscles and the tendons, helping you become more 'spring-like' and therefore more economical. These exercises require a warm-up and can be performed after the end of a steady run without much difficulty, ideally on a soft flat surface such as a soft running track or cricket pitch. Jumping exercises need to be introduced gradually, which is why I advise controlling the number of contacts for each exercise until you are used to performing them every week.

Vertical jumps Stand feet hip- to shoulder-width apart. Squat down slightly, swinging your arms back, and then rapidly jump up as high as you can, driving your arms upwards. Make sure you fully extend your hips, knees and ankles at take-off. Land softly on the balls of your feet and absorb your landing with a squat. Perform 3 x 5 reps, building up to 3 x 10 reps. Take 1-2 minutes' rest between sets.

Mini hurdle hops Set out 5 x 30cm mini-hurdles with about 1 metre space between each. Hop with both feet together over each hurdle with one 'bouncy' contact between each hurdle. Aim to make quick and light contacts with the floor on the balls of your feet, with a small knee-bend. You can pick your knees up into a tuck position over each hurdle if you like, to increase your jump height. Perform 3 x 5 hurdles, building up to 3 x 10, with 1 minute's rest between sets.

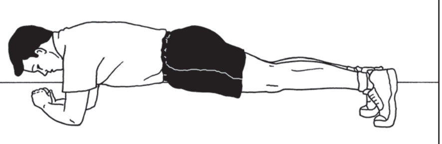
Power skips This is a simple skip, performed very dynamically. The aim is to drive up as high as possible with each skip, then land softly and step onto the other foot to drive up again. Perform 3 sets of 10 skips (5 each leg) and increase to 3 sets of 20 skips.

Core routine

The exercises in this routine are geared to developing good core stability for running and swimming. The routine targets the strength endurance of the abdominal, oblique, low back and gluteal muscles.

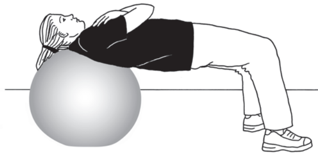
Plank Facing the floor, make a bridge with your body by supporting yourself on elbows and toes, forming a straight line with your body, like a 'plank'. Make sure your low back is in a neutral position, bracing your stomach to maintain it. Complete 3 sets of 30 seconds, progressing to 3 x 60 seconds.

Plank



Side plank On your side, form a bridge with your body by supporting yourself on one elbow and the side of one foot. Lift your hips so your body is in a straight line, like a 'plank'. Make sure your top hip and shoulder are directly above the bottom hip and shoulder. Hold the straight line position. Complete 3 sets of 30 seconds each side, progressing to 3 x 60 seconds.

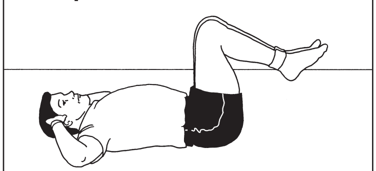
Gluteal bridge



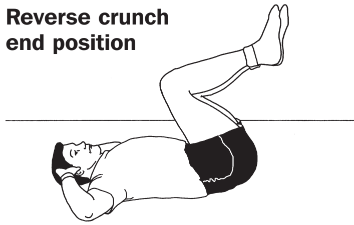
Gluteal bridge Place your feet on the floor and your neck and head on a Swiss ball. Squeezing your gluteal (buttocks) muscles, push your hips up until your back, hips and knees are in a straight line. Make sure your back is in neutral and focus on your gluteals to hold the position. Complete 3 sets of 30 seconds, double leg. Progress to one leg 3 x 30 seconds.

Reverse crunch Lie on your back with arms out to the side, then lift your legs off the floor with knees bent. Focusing on your abs, curl your pelvis and low back off the floor, crunching up. Don't kick or swing your legs to gain momentum – the slower you do the movement the more effective it is. Complete 3 sets of 20 reps. Progress by adding a dumbbell between the ankles to increase the load lifted by the abs.

Reverse crunch start position



Reverse crunch end position



Raphael Brandon

Raphael Brandon MSc is a sports conditioning and fitness specialist. He is also London region strength and conditioning coach for the English Institute of Sport

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Resistance training for women and youths

Walk into your average public gym and you are likely to see a mixture of male and female, young and old. However you will also notice that over in the weights area (in particular free weights); there is a distinct lack of young athletes and especially female athletes. Women shy away from weight training due to psychological and physiological perception. Young athletes don't so much shy away but are often told they have to wait until they are 18 until they can use free weights.

In the first part of this article we will look at the advantages women can gain from resistance training. In the second part we will explain why youngsters should be encouraged to us weights and how it should be applied.

Part 1: Why women avoid weight training at their peril – and how coaches can change their minds

Female athletes are less likely to perceive weight training as beneficial to their sport as their male counterparts, according to a recent study. This may not seem like much of a problem, but weight training is a significant aid to female athletes not just because it helps improve sporting performance but also because it helps ward off osteoporosis by enhancing bone mineral density (BMD).

Coaches and athletes need to be aware of these benefits as well as the social/cultural barriers that may discourage women from participating in weight training. This article will begin to address these issues as well as offering practical advice on training.

The study referred to above involved 139 male and 165 female student athletes from four US colleges [1]. The students, who participated in a total of 11 different sports, including soccer, athletics, lacrosse and basketball, completed two questionnaires:

- The Training Information Survey (TIS), including questions on weight training practice and perception, as well as other sports training and conditioning;
- The Sport Orientation Questionnaire (SOQ) that measures competitiveness, win orientation and goal orientation [2].

The authors were seeking to identify gender differences in weight training perception as well as differences between more competitive and less competitive athletes.

The key findings were as follows:

- Female athletes perceived weight training to be less important than their male counterparts, while their coaches considered weight training to be less essential for women than for men;
- The athletes who participated most in weight training activities were those who considered it essential to their sport. Participation was not linked with competitiveness, goal or win orientation;
- Female athletes were less confident about weight training than male athletes;
- The SOQ confirmed previous research that male athletes were more competitive and win orientated than women while female athletes were more goal orientated than men;
- In both groups of athletes, those who were goal orientated and competitive considered weight training equally important for male and female athletes, while those who were win orientated thought weight training was a masculine activity, important only for male athletes.

Leaving aside for the moment the differences between competitive, goal and win orientated athletes, the three main issues highlighted by this study were: the perception of weight training as a masculine activity; the finding that participation in weight training is linked to the perception of sport specific relevance; the fact that female athletes are less confident about weight training than males.

Unfortunately, coaches did not appear to be helping matters. And the researchers conclude that coaches need specific education and support in order to promote weight training appropriately to female athletes.

Sportswomen seem to have an adverse perception of weight training, perhaps because they link it in their minds with the image of muscle-bound, testosterone-fuelled bodybuilders. Coaches need to help them overcome this cultural barrier. But in order to do so, they will also have to overcome their own barriers to seeing weight training as essential for female athletes. As is apparent from this US study, women will weight train if they see it as essential to their sport. So what research supports the sport specific relevance of weight training?

‘Sportswomen seem to have an adverse perception of weight training’

Football training and gender

Let’s take soccer as an example. The physiological requirements of the game are similar for men and women: speed, power and the ability to perform repeated high-intensity sprints, with limited recovery time, over a period of 90 minutes [3]. It follows, then, that training should be similar for both sexes, varying only in accordance with training age and fitness level and the demands of competition.

A recent US study of female high school soccer players sought to evaluate the impact of strength training on various parameters of fitness [4]. One group incorporated a 10-week in-season programme of twice-weekly training sessions, including 30 minutes of strength training and 15 minutes of plyometrics, while a control group simply carried on with soccer-related activities.

By comparison with controls, the strength training students showed significant increases in their anaerobic power (as demonstrated in an abridged version of the multi–stage fitness test) and fat free body mass, together with reductions in body fat. These improvements may have been influenced by the untrained status of the players, but the study does demonstrate that a relatively limited intervention, involving 90 minutes of additional training per week, can lead to real improvements.

Gymnastics provides another useful example of the relevance of weight training to women. This is a challenging and difficult sport, since participants need power to tumble and strength to hold positions, but are also marked on form and grace, which call for a suitable body shape.

Runners and gymnasts

In a three-year longitudinal study, 20 US college-level gymnasts were tracked as they worked through a periodised resistance training programme. The programme initially worked on baseline strength levels and introduction of techniques, but then progressed to high velocity movements with the goal of boosting power without increasing body mass. The movements included in the strength training sessions were designed to be as sport specific as possible as well as linking in with the participants' skill training and competition cycle.

Analysis of the results showed year-on-year increases in power and fat-free mass, with a simultaneous reduction in body fat, keeping overall weight constant. Unfortunately, because the authors did not use a non-weight training control group, it is impossible to determine how much of these improvements were down to the strength training programme as opposed to normal gymnastic training. However, it would be difficult to find a control group of similar elite level athletes who did not perform some sort of supplementary training for three years.

The observation that strength training increases fat-free mass while reducing fat mass has particularly significant implications for female athletes in terms of their risk of the bone thinning disease osteoporosis.

Osteoporosis affects as many as 25 million people in the USA alone, and of these 80% are women [5]. The condition has been linked with a lack of load-bearing physical activity in youth [6] as well as other risk factors, including calcium insufficiency, smoking and use of oral contraceptives.

Sporting participation at high school level as well as current activity levels and percentage of lean body tissue have been shown to be predictors of low bone mineral density (BMD), an independent risk factor for Osteoporosis, in a study of 18-39 year old women [7]. In fact, women who did not participate in high school sports were seven times more likely to have low BMD than their sportier counterparts.

That study was concerned with general sports participation, but others have been more specific in their attention. In a study comparing the BMD of female cross country runners and gymnasts, the latter were found to have significantly higher BMD [8]. The researchers surmised that this was due to the greater levels of mechanical loading involved in gymnastics, as compared with running.

As well as being affected by particular sports, BMD is influenced by particular types of resistance training. In a study of young women, Overloading eccentric contractions performed at 125% of 1 Repetition Maximum (1RM) was shown to be less effective in boosting BMD than submaximal eccentric resistance training at 75% of 1RM [9]. The overload group performed three sets of six repetitions of their load, while the submaximal group performed three sets of 10 of theirs.

'The observation that strength training increases fat-free mass while reducing fat mass is paticularly significant for women in terms of osteoporosis'

The researchers were surprised by their results because they had assumed that the higher mechanical loading of the overload group would be most conducive to improving BMD. However, because of the high loading, they avoided load-bearing exercises like the squat in favour of machine-based exercises, which may have affected the response. They concluded that the greater number of reps performed by the submaximal group was the key factor in their enhanced response. This study shows that significant results can be gained without excessive training, allowing for continued sports training and competition.

So, if we accept that strength training leads to improved fitness parameters that help sporting performance, an increase in fat-free mass, a decrease in fat mass and an increase in BMD that will help prevent osteoporosis, what can coaches do to promote participation by female athletes?

Remember the findings of the first study mentioned in this article – that female athletes need to understand the benefits of strength training for health and sporting purposes that they tend to be goal orientated and are likely to lack confidence when performing weight training activities? Coaches can use this information to educate their athletes, provide them with short-, medium- and long-term goals, and create a positive, supportive atmosphere in the weight training facility that helps build confidence.

How can this be achieved? Goal setting has been covered in depth in the sporting literature, including *Peak Performance (see PP 195, April 2004)*, but coaches need to be aware that this key tool should be applied to conditioning, as well as sport specific training and lifestyle.

How coaches could help

Role models have been shown to be important in increasing participation by women in sport [10]. And if coaches can involve other female athletes, even from different sports, in implementing and demonstrating weight-training techniques, their own athletes may be more likely to respond.

Coaching in small groups of up to six athletes is also beneficial in that it allows for more individual tuition and creates a less intimidating atmosphere in which to facilitate learning. In my experience, groups of more than six beginners are difficult to coach in the gym, in terms of health and safety as well as technique. People are left either lifting unsupervised or with too much recovery between exercises so that they get cold or bored.

It may be wise to book out the gym for a women-only hour (or even afternoon) for the first five or six sessions, as this will reduce distractions and allow the athletes to lift weights without an audience.

A balance needs to be struck between repetition (to promote familiarity and confidence) and variety (to stimulate minds and bodies). One way to do this is by varying the training environment. For example, aqua-based plyometrics can be used as an alternative to land-based exercises. This will provide a fresh physical and mental stimulus, may be perceived as fun, and is less likely to result in muscle soreness than land-based training [11]. Follow this up with 10 minutes of water polo or water sprints and you will have created a session that your athletes really look forward to!

I would suggest developing a core set of 4- 6 exercises that you consider essential for your sport, then varying supplementary exercises around the core in each session. This will provide both the familiarity and the variety that your athletes need.

Within your core group of exercises, you can then introduce minor variations every 2-3 weeks. For example, in Rugby Union you could use two cycles over a two- month period, with the four core exercises changing slightly, as shown in table 1, below. Within each cycle you may have 10-12 individual sessions in which the supplementary exercises would change each time. Within that overall structure, you would then periodise the load, sets and reps, allowing for delivery of 20-24 different sessions.

Table 1: two monthly weight training cycles for Rugby Union

Type of exercise	Cycle 1	Cycle 2
Core	Clean and jerk	Clean and push press
Core	Snatch	Dumbbell snatch
Core	Squat	Front squat
Core	Bench press	Dumbbell press
Supplementary	Lunge	1 leg squats
Supplementary	Russian boxers	Tomahawks
Supplementary	Cheat rows	Pullovers

In summary, by educating themselves and then their athletes, coaches can start to communicate the benefits of weight training for female athletes. By means of goal setting, individual coaching and good session planning, coach can encourage, help and stimulate their athletes and then look forward to corresponding improvements in both fitness parameters and sporting performance.

James Marshall

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Part 2: Why young athletes should be encouraged to work out with weights

Parents and coaches continue to express concern about the suitability of strength training for children and adolescents despite mounting evidence that it is both safe and beneficial. Paul Gamble homes in on the advantages for youngsters.

Through my work as strength and conditioning coach to the London Irish Rugby Football Club and involvement with our regional academy and Elite Player Development Group, I have become aware of concerns expressed by young players and their parents about whether it is appropriate for adolescent athletes (aged 12-16) to train with weights.

The benefits of youth resistance training are well documented and almost universally accepted among health professionals, particularly in the United States (1, 2). However, public recognition of these benefits has tended to lag behind and misunderstanding and misconceptions abound.

Historically, concerns about youth resistance training stem from a perceived risk of potential damage to growth plates and consequent interference with normal growth. In fact, such damage has never been documented in connection with youth strength training programmes administered and supervised by qualified professionals, while studies using appropriate youth resistance training report a very low incidence of any type of injuries [1].

The most frequent causes of injuries to young people working out with weights include incorrect lifting technique, attempts to lift excessive loads, inappropriate use of equipment and absence of qualified supervision. But these factors should not apply with properly administered training.

Naturally, young players, like any inexperienced lifters, should only take part in strength training programmes prepared by qualified coaches, using safe equipment and supervised by qualified instructors. If these conditions are met, there are no grounds at all to restrict their participation.

The reality is that children are exposed to far greater forces (and for longer periods of time) during sports and recreational physical activity than with strength training – even if that training were to include a maximum lift!

Of all resistance training exercises, the Olympic lifts probably impose the greatest forces on the growing musculoskeletal system. Even so, research suggests that competitive weightlifting is one of the safer activities engaged in by young athletes.

Benefits of strength training

It is now becoming recognised that young people can derive the same benefits from strength training as adults. Previously, the presumption had been that strength training before puberty was not viable or effective. But now it is known that prepubescents exhibit scope for strength gains far beyond those attributable to normal growth and maturation [1].

Relative strength gains from resistance training in prepubescent subjects are of similar magnitude to those seen in adolescents, although the latter seem to exhibit greater

'For young contact sport players who aspire to play at the highest level participation in strength training is no longer optional'

absolute strength gains. Improvements in various motor performance have been observed following resistance training in children. These include vertical jump, standing long jump, sprint times and agility run times.

Resistance training has also been recommended as a preconditioning aid for youngsters. Habitual levels of physical activity in children are declining, reflecting changes in modern lifestyles. As a result, the physical condition of many children leaves them ill prepared for competitive sport. Resistance training offers a means to prepare them for participation in other sports and recreational activities, thereby also preventing overuse injuries[2].

This injury prevention aspect of youth resistance training is an important consideration for young athletes – particularly rugby players. Strengthening muscles via resistance training will increase the forces they are capable of sustaining, making them more resistant to injury, while improved motor control and coordination will also improve balance and joint stability.
For adolescent athletes in particular, structural adaptations to resistance training are key to injury prevention. These effects include increased strength of supporting connective tissues and passive joint stability, as well as increased bone density and tensile strength, which are particularly useful in collision sports like rugby football.

As well as protecting against injury, youth resistance training also seems to accelerate rehabilitation after injury, with evidence that resistance-trained young athletes recover more rapidly and return to training sooner than those who do not use this kind of training.

And, far from stunting growth, it now appears that resistance training, in combination with proper nutrition, has the potential to enhance growth within genetic bounds at all stages of development.

Participation in resistance training at an early age also carries health-related benefits similar to those observed in adults. These include a reduction in risk factors for cardiovascular disease and diabetes, both of which are becoming increasingly common in young people. In addition, initiating good health-promoting behaviours during childhood and adolescence increases the likelihood that these good habits will carry over into adulthood.

In view of the increasing prevalence of childhood obesity, the potential of resistance training to favourably alter body composition should also be taken into account. At any age, appropriate resistance training, in conjunction with aerobic exercise, appears to be the best strategy for losing body fat and maintaining weight.

Finally, psychosocial benefits associated with resistance training have been identified in youngsters as well as adults, particularly enhanced self-esteem and improved self-image.

Mechanisms for strength gains in young athletes

Before puberty, low levels of circulating anabolic hormones limit the contribution of hypertrophy (lean tissue growth) to strength gains, and the changes to muscles that do occur appear to be qualitative rather than quantitative. Neural effects thus appear to underlie the benefits of resistance training in these younger boys and girls.

Such neural adaptations are thought to include improved recruitment and activation of the muscles mobilised during the relevant training movements. Enhanced motor coordination, both within and between muscle groups, is also thought to contribute to strength gains following training.

By their very nature, such training adaptations would appear impermanent. And, indeed, prepubescent athletes do seem particularly susceptible to detraining effects if resistance training is discontinued. However, modest maintenance programmes (1-2 days per week) should be sufficient to sustain strength gains.

The greater hormonal response to resistance training in adolescents leads to structural changes to the muscles and associated connective tissues. As a result, marked changes in terms of muscle hypertrophy and gains in fat free mass are seen in this older age group.

Strength training recommendations for young male athletes

Guidelines vary according to chronological age and, more importantly, biological age. Any resistance training programme should be geared to the physical and emotional maturity of individuals in the group.

In general, if a child is ready for participation in organised sports, he or she is probably ready to undergo instruction in resistance training. However, for children with known or suspected medical conditions, medical clearance should be sought in advance.

When young athletes are first introduced to resistance training, light loads and high repetition schemes (12-15 reps) are most appropriate. At early stages of training, progression should be achieved by increasing the number of sets performed and the number of exercises in the workout. The number of training days can then be increased at a later stage.

Adequate rest and recovery is a key component of successful youth resistance training. And because young athletes may need more recovery time between sessions in order to maximise the effectiveness of training and reduce the risk of injury, training on non-consecutive days is recommended for younger individuals.

It has been suggested that before puberty the focus of the programme should be on improving motor control and coordination and developing proprioception (awareness of limb position and orientation of the body). However, at this stage developing strength is still seen as a primary programme goal.

Given that many of the benefits of strength training in this population stem from improved coordination, balance and proprioception, exercise modes that favour the development of these qualities should be emphasised. Thus calisthenic exercises and free weights may be better than resistance machines, although users are likely to require closer supervision.

In this context, it is worth noting that resistance machines need to be tailored to the dimensions of their users, and that some apparatus cannot be adjusted sufficiently for use by children.

With advances in training experience, exercises like structural multi-joint lifts (bench press, variations of the barbell squat and deadlift) can be introduced, although the focus throughout should be on proper lifting form, with loading limited until the athlete has mastered the appropriate technique.

Experienced young lifters can integrate Olympic-style lifts into their strength training programmes. These should be taught initially using a broomstick or empty barbell. For prepubescent athletes, in particular, the loads used for these lifts should be kept light, with the emphasis on the quality of the lifting movement.

As with adults, exercise specificity influences young athletes' responses to strength training, with greatest transfer of training effects observed with performance measures that are similar to the movements featured in training. Exercises should therefore be selected with their sport specific benefits in mind, taking account of the skill levels and training experience of the young athletes concerned.

Periodisation can be incorporated into youth resistance training programmes by means of systematic variations throughout the training year, taking account of the timing and duration of the playing season as well as the players' concurrent training and practice schedules.

Paul Gamble

What strength training does for youngsters

The documented benefits of resistance training for youngsters include:

- Significant strength gains, particularly in adolescents
- Improved motor performance
- Injury protection
- Preconditioning preparation for sports participation
- Beneficial structural adaptations, including increased bone density
- Accelerated rehabilitation after injury
- Potential to enhance growth
- Health benefits, including reduced risk of heats disease and diabetes
- Favourable effects on body composition
- Enhanced self-esteem

Jargonbuster

Resistance training Any form of training that involves an action performed against resistance.

Growth plates The area of growing tissue near the ends of the long bones in children and adolescents. These plates determine the future length and shape of the mature bone.

Strength training Resistance training specifically geared to developing muscle function and/or growth; typically involves free weights or resistance machines.

Preconditioning Training designed to build a base level of conditioning to prepare the body for participation in sport or physical training.

Hypertrophy Growth of lean tissue (particularly muscle) in response to training.

Neural adaptations Developments in the ability of the central nervous system to recruit and activate muscles for movement.

Lean body mass Body mass excluding fat.

Proprioception Awareness of the position of your limbs and body in three-dimensional space.

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Sample strength training workouts for youngsters

Beginners **15 reps, 1-3 sets**	**Intermediate** **12 reps, 3 sets**	**Experienced** **8 reps, 3 sets**
Unloaded squat Hands on head, squat until thighs parallel with floor	**Dumbbell squat** Dumbbells held at side, descend until thighs parallel with floor	**Clean pull with empty barbell** Start with barbell hanging down at arm's length, then propel explosively upwards by pushing through floor in a jumping action, pulling barbell to chest height, keeping elbows over bar
Modified push-up Performed resting on knees	**Decline push-up** Standard push-up position, with feet raised up on bench	**Incline dumbbell bench press** Sit back on an incline bench, dumbbells resting by chest below shoulder level, then press until arms extended with dumbbells finishing directly above face
		The following exercises require a spotter
Unloaded walking lunge Hands on head	**Seated cable row** Feet resting against blocks, torso upright, pull cable handles to chest level	**Barbell back squat** Standard back squat with barbell resting across shoulders, descending until thighs parallel with floor
Unloaded step-up Step up onto bench or box, alternating lead leg	**Dumbbell step-up** Light dumbbell or hand weights held at sides, step up onto bench or box, alternating lead leg	**One-arm dumbbell row** Left knee and hand supported on a bench, right foot planted next to bench, dumbbell hanging in right hand, pull DB upwards to finish next to rib cage. After 1 set repeat with other arm
	Standing dumbbell shoulder press Light dumbbells or hand weights on shoulders, then pressed until arms extended directly over crown of head	**Assisted chin-up** Standard chin-up on suspended bar, with manual assistance from spotter
		Dumbbell lunge Dumbbells held up at shoulders, lunge forward with right or left leg, then return to start by pushing off lead leg. Alternate lead leg with each rep.

NUTRITION

Two articles questioning high protein diets and the use of creatine

Diets, nutrition and supplements are synonymous with resistance training and athletes looking to take their strength training to an extra level. However speculation is common among scientists, coaches and athletes alike over how best to approach this topic, and more importantly how to apply it. These two articles highlight how tricky it is to gauge, and what the best stance to take is.

Part 1: Why low fat/high protein diets might not be best after all!

Years of careful research and scientific studies seem to point to the unavoidable conclusion that a low fat diet containing ample protein provides the best nutritional environment for strength athlete. But now some surprising new research suggests that this view may be over-simplified writes Andrew Hamilton.

Scan the ingredients list of any tub of 'weight gain' powder and it's easy to see the current thinking on nutrition and strength building. While the brands may differ, the contents are strikingly similar; all are invariably high in protein, low in fat, with varying amounts of carbohydrate. The reasoning is simple. Dietary protein provides the source of amino acid building blocks needed by your body to synthesise new muscle tissue, as well as to replace and repair tissue broken down during exercise itself.

Although the exact protein requirement for athletes remains the subject of debate, the consensus among sports nutritionists is that athletes do need more protein for optimum performance

At a glance

- Low-fat, high protein nutrition has long been considered as 'de rigour' for strength athletes
- But a new study indicates that higher fat and lower protein intake is associated with increased levels of muscle-building anabolic hormones in strength athletes
- Some research also indicates that dietary fat may help the body's anabolic hormones to work more efficiently
- These potential benefits may be associated with meat consumption, but more research is needed

and recovery than their sedentary counterparts. In fact the research suggests that athletes engaged in intense training actually need to ingest about 1.5 – 2 times the normal RDA for protein in order to maintain a positive protein balance [1-5]. This equates to 105-140g of protein per day for a 70kg athlete.

Fifty years ago, high protein steak and egg diets were the order of today. The thinking was simple: 'Muscles are made of protein; therefore to develop muscular strength requires a large intake of protein'. However, as the understanding of carbohydrate metabolism and sports performance grew, scientists began to realise that this approach was grossly oversimplified. That's because we now know that the uptake of amino acids into muscle cells is strongly regulated by hormones.

One of the most anabolic (*ie* muscle building) hormones in the body is insulin, which is released whenever carbohydrates are eaten The primary job of insulin is to regulate the amount of glucose in the blood that results from eating carbohydrate, by stimulating cells to take up glucose.

However, this release of insulin also has a potent anabolic effect, helping to drive amino acids into muscle cells, thereby stimulating muscle protein synthesis. In fact research has demonstrated that feeding protein plus carbohydrate to promote an insulin release results in 50% greater muscle protein synthesis than feeding protein alone [6]!

But carbohydrates also play another valuable role in muscle metabolism – that of helping to conserve hard earned muscle tissue. While a high-protein diet provides plenty of amino acid building blocks to build muscle protein, unless there's sufficient carbohydrate present to support training (remember, carbohydrate is the body's 'premium grade' fuel for exercise), these amino acids are simply used to supplement the fuel supply.

A low-carbohydrate diet combined with vigorous exercise therefore results in protein oxidation for energy, and since muscles are the major store of amino acids, this can result in muscle tissue loss, especially when training volumes are high.

Moreover, research has clearly demonstrated the importance of ample dietary carbohydrate in reducing the amount of catabolic stress hormones, such as cortisol and adrenaline, which are released during and after exercise and which stimulate the breakdown of muscle tissue [7,8,9]. In short, carbohydrate is as much as part of the 'anabolic equation' as protein!

Given that both protein and carbohydrate are needed for muscle growth and maintenance, it's easy to understand how the consensus that high protein/ample carbohydrate/low-fat diets are best for strength athletes has arisen. A diet containing moderate or high levels of fat and plenty of protein/carbohydrate would necessarily contain a lot of extra calories, especially as each gram of fat provides 9kcals of energy – double that of carbohydrate or protein. And as we know, an excessive calorie intake leads to gains in body fat – exactly what most athletes don't want!

Meanwhile, a calorie-controlled moderate/high-fat diet would necessarily have to contain relatively little protein and carbohydrate – again not desirable for an athlete seeking to maintain or build strength. Together, these facts explain why protein is king, and why (not withstanding the growing realisation of the importance of essential fatty acids) fat is almost seen as a dirty word among strength athletes.

'It's easy to understand how the consensus that high protein/ ample carbohydrate/ low-fat diets are best for strength athletes has arisen'

A fly in the high-protein, low-fat ointment?

Gaining and retaining muscle tissue certainly requires ample protein and carbohydrate, but that's not the whole story. After all if it were, consuming larger and larger quantities of protein would lead to ever increasing strength and muscle size – something that obviously doesn't happen. This is because hormones also control the metabolism of muscle tissue and protein turnover. Naturally occurring anabolic hormones such as testosterone and human growth hormone (HGH) act as chemical messengers, directing muscle cells to take up amino acids and synthesise muscle protein. They also stimulate the oxidation of fat for energy, thereby increasing lean muscle mass while decreasing fat mass.

The action of anabolic hormones is balanced by other 'catabolic' hormones, such as adrenocorticotrophic homone and cortisol. These hormones are released during 'fight or flight' situations, where energy production becomes paramount, and tend to produce a breakdown of body tissue. Building or maintaining strength requires a hormonal balance that is more anabolic than catabolic. This explains the illegal use of anabolic steroids, substances that artificially boost anabolic hormone levels *(see box below)*.

Anabolic steroids as drugs

Anabolic (or more correctly, androgenic-anabolic) steroids (AAS) form a family of synthetic drugs derived from the male sex hormone, testosterone and are used to promote muscle growth and increased lean body mass. Although they have many approved medical uses, steroids are sometimes abused by athletes seeking to improve performance.

However, the non-medical use of these drugs carries severe physical and psychological health risks. In males, they can trigger a mechanism in the body, which leads to the shut down the healthy functioning of the male reproductive system, resulting in a number of effects including shrinking of the testicles, reduced sperm count, impotence, premature baldness, enlarged prostate gland and enlarged breasts (gynecomastia).

In females, effects include deepening of the voice, the growth of facial hair and reduction in breast size. More generally, other symptoms are commonly observed, including severe acne, weakened tendons (leading to increased injury risk), severe mood swings, uncontrolled bursts of anger, delusions and paranoia and depression (especially when steroid use is discontinued). The longer-term health effects include increased blood pressure and cholesterol, leading to an increased risk of heart disease, as well as kidney and liver disease.

But can hormonal balance be influenced by nutrition? Leaving aside the issue of exotic sports supplements such as pro-hormones, new evidence has emerged that suggests that protein and fat ratios can impact on hormonal balance, but in a rather surprising way.

Fat and growth hormone

A joint Finnish and American study examined the relationship between dietary intake patterns and the resulting blood concentrations of the anabolic hormones testosterone (T), free testosterone (FT), and growth hormone [10]

In this study, 8 strength athletes and 10 physically active non-athletes were examined at rest as well as after heavy-resistance exercise. During the first part of the study, all the subjects were allowed to eat freely, but kept detailed food diaries. The scientists then examined how these differing dietary patterns among the subjects affected the levels of hormones in each athlete. In the second part of the study, a sub-group of 5 strength athletes and 5 non-athletes kept diaries for a further 4 days before undertaking a high volume, high intensity resistance workout.

What the scientists found surprised them. During the non-active period, a higher fat intakes and lower protein intake was associated with increased levels of anabolic hormones across both groups of subjects.

However, during the phase of the study containing the high intensity resistance exercise, this correlation disappeared for the non-athletes, but remained for the trained strength athletes – *ie* higher fat intakes and lower protein intakes were associated with increased blood levels of anabolic hormones in the strength athletes only. The clear implication is that the role of diet in producing a favourable anabolic environment may be more important for trained athletes.

The researchers went on to conclude that ‘the results suggest a possible link between diet and changes in blood hormones during prolonged strength training, and that diets with insufficient fat and/or excessive protein may compromise the anabolic hormonal environment over a training program’.

The fact that a higher dietary fat and lower protein intake appears to increase anabolic hormone levels, especially in trained athletes, seems counterintuitive and flies in the face of conventional wisdom. But while more research is obviously needed in this area, some other studies also hint that the low-fat/high protein route may not be quite the holy grail we all thought it was.

In one of these studies, the interaction between fat metabolism and muscle-building growth hormone was examined[11]. To do this, the subjects were fasted for 37 hours, in order to suppress their natural production of growth hormone (GH – suppression of growth hormone normally occurs during fasting). They were then infused with the following:

- GH alone
- GH together with a drug called Acipimox, which blocks the release of fat from fat stores and fat metabolism
- No GH with Acipimox
- GH with Acipimox, plus extra lipid (*ie* to provide the body with an extraneous source of fat).

As expected, urinary urea excretion, blood urea and muscle protein breakdown (all are measures of protein catabolism in the body) were increased by almost 50% during the fast when fat metabolism was being suppressed.

Giving extra GH alone reduced the rate of muscle loss during the fast, but when the subjects were also being infused with Acipimox, extra GH didn't reduce the rate of muscle tissue loss. However, when fatty acids were then added to the infusion (to provide a source of fat), the rate of whole body protein degradation dropped to just 15% above baseline values (*ie* the GH was able to exert an effect again), providing strong evidence that fatty acids in the bloodstream are important protein-sparing agents during fasting. The implication is clear; fat seems to plays a decisive role in the process of protein conservation during fasting in humans, possible by helping growth hormone to work more efficiently.

Another fascinating study examined the effect of meat containing diets and vegetarian diets on strength body composition when combined with resistance training [12]. In this 12-week study, nineteen men were split into 2 groups:

- Ten subjects were instructed to continue consuming their normal omnivorous diet (containing a mixture of protein sources including meat) while the resistance training was continued
- The remaining nine men were counselled to select a lacto-ovo vegetarian diet (*ie* exclude all meat) for the duration of the study.

All of the subjects kept food diaries, and while carbohydrate, protein, nutrient and alcohol intakes were not significantly different between the two groups, those on the meat diet tended to consume more fat.

Once again, the results confounded the researchers. Although the 12-week resistance training program produced the same gains in maximal strength (10-38%) in both groups of men, the changes in body composition and skeletal muscle size were significantly different. The meat eaters gained an average of 1.7kgs of lean muscle, while the vegetarian group lost an average of 0.8kgs. Moreover, the meat group lost an average of 1.3kgs of fat, while the vegetarian group actually gained 0.1kg!

‘The meat diet may have produced higher levels of muscle building hormone testosterone’

Although the researchers cautioned that the food diary methods they employed could not be considered 100% accurate, they did conclude that there was a real difference between the two dietary patterns. The exact cause(s) for this difference remains unclear and once again, more research would be needed – for example to investigate whether it was the higher fat content of the meat diet per se that produced these results, or some other factor.

One possible reason advanced by the scientists was that the meat diet may have produced higher levels of the muscle-building hormone testosterone, a phenomenon that has been observed in endurance athletes [13]. Eight male endurance athletes were split into two groups and put on either a lacto-ovo vegetarian diet, or a mixed, meat-rich diet. However the diets

A balancing act inside the body; anabolism v.catabolism

The body is a constant state of flux, building up and breaking down tissue as required. This requires a careful balance of anabolism (tissue synthesis) and catabolism (tissue breakdown).

Naturally occurring anabolic hormones include

- Human growth hormone
- IGF1 and other insulin-like growth factors
- Insulin
- Testosterone
- Estrogen (although associated with feminising characteristics, it's an anabolic hormone!)

Naturally occurring catabolic hormones include

- Cortisol
- Glucagon
- Adrenalin and other catecholamines
- Cytokines

Other hormones are intimately associated with maintaining the correct balance of the catabolic and anabolic states, such as Orexin and Hypocretin (which function as a hormone pair) and melatonin, (derived from serotonin), which plays a role in sleep, aging, and reproduction in mammals.

were formulated so that the protein/fat/carbohydrate ratio was kept pretty much the same (58%/27%/15% on the vegetarian diet, and 58%/28%/14% on the meat diet). After 6 weeks, the groups were reversed, *ie* those on the meat diet switched to the vegetarian diet and vice versa.

The researchers discovered that compared to the vegetarian diet, consuming the meat diet produced significantly higher levels of the anabolic hormone testosterone. They also noticed that the endurance performance time was better for more of the athletes after the meat diet than after the vegetarian diet, although these differences were not large enough to be considered statistically significant.

Conclusion

Do these findings mean that sportsmen and women should abandon the currently accepted nutritional wisdom and switch to higher fat, low protein diets? Of course not! However, these studies perfectly illustrate the complexities of formulating optimum eating regimes for athletes. In particular, they suggest that the practice among some athletes of following extremely low fat diets, or eschewing all red meat from the diet on the grounds that it contains more fat than other protein sources may actually be counterproductive. Much research remains to be done, but in the meantime it seems that a little of what you fancy really may do you some good!

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Glossary

RDA – Recommended Daily Allowance; the daily amount of a nutrient required to produce health and prevent deficiency diseases.
Hormones – Compounds made in the body that act as chemical messengers, telling cells what to do.
Pro-Hormone – Substances (sometimes used by athletes) that don’t

have a significant hormonal effect in themselves, but which can be metabolised into active hormones once ingested.
Anabolic steroids – a family of synthetic drugs derived from the male sex hormone testosterone and which are used to promote muscle growth.
Essential Fatty Acids – certain types of fats that cannot be synthesised in the body, but which are essential for health (*ie* they have to be obtained from the diet).

Part 2: Creatine – is it really safe for long-term use?

Creatine is the number one choice of sports supplement for athletes at all levels – and with good reason. Unlike most products that compete for space on the shelves of 'health food stores' up and down the country, creatine does precisely what it says on the tin: namely boost the body's phosphocreatine energy system, thereby enhancing short-term, high intensity anaerobic efforts. But, while there are few, if any, remaining concerns about short-term use, there are still no guarantees of long-term safety.

'Eschewing all red meat from the diet on the grounds that it contains more fat may actually be counter-productive'

Because creatine is both manufactured in the body and naturally present in a number of foods, most researchers have quite reasonably assumed that its toxicity is low. Numerous past studies on athletes had shown that even the very high doses required to produce rapid creatine saturation in the muscles (10-20 grams per day) seem to be perfectly safe in the short term, despite the occasional anecdotal report of side effects like bloating [1].

Nevertheless, many researchers remained concerned about the potential longer-term health effects of prolonged creatine supplementation, particularly on the health of the kidneys. This was because each day about 2% of the body's store of creatine is broken down to a substance called creatinine, which has to be cleared from the body by the kidneys. Ingesting large doses of creatine over a long period of time could theoretically place a significant extra burden on the kidneys, possibly leading to damage for those with less than perfect kidney function.

But more than 10 years of widespread creatine use and hundreds of published studies have produced little or no evidence that long-term creatine use poses a threat to kidney health. Quite the contrary, in fact. For example, a study carried out earlier this year looked at the effects of long-term high dose creatine supplementation on 175 patients with a disease known as amyotrophic lateral sclerosis, which causes damage to motor neurones in the brain and spinal chord [(2)]. These patients were randomly assigned to 310 days' treatment with either creatine monohydrate or placebo; (animal studies had suggested that extra creatine could delay the progression of this disease).

The researchers monitored the patients carefully for any signs of adverse effects, particularly on kidney function, but found no significant differences between the groups. Given that the creatine group were ingesting 10g per day – three times the dose needed by athletes to maintain muscle creatine saturation – this study provides strong evidence for the safety of long-term supplementation by athletes.

Two years earlier, an even lengthier study looked into the health effects of creatine on 98 college footballers, split into four treatment groups as follows [(3)]:

- No creatine (control);
- Up to 6 months' use;
- 7-12 months' use;
- 13-21 months' use.

The footballers in the three creatine groups were given 15.75g per day of creatine monohydrate for five days and an average of 5g per day thereafter. Urine and fasting blood samples were collected throughout the study to assess a wide range of metabolic parameters, clinical status and kidney function. Analysis of the results showed no measurable differences in metabolism or in kidney function between any of the groups.

Other studies on the link between creatine use and kidney damage have also drawn a blank, although most researchers have continued to advise against long-term creatine use by people with a history of kidney problems, because of the theoretical risks outlined above. Even for such individuals, though, there is little evidence that creatine use poses a risk in reality. Although no studies on long-term creatine use in kidney-impaired humans have been carried out, some animal studies have suggested that there is no risk to speak of.

For example, a study on rats compared the effects of high-dose long-term creatine use in those with healthy kidneys and those with substantial kidney impairment [4]. Both the healthy and kidney-impaired rats were further subdivided into control or creatine groups. The creatine-fed rats were given around 1g per kg of creatine per day, while the control rats received no creatine at all. After four weeks on creatine, the kidney-impaired rats showed no deterioration by comparison with kidney-impaired controls. Indeed, the researchers were unable to detect any significant changes in kidney function at all. This is quite extraordinary when you consider that the human equivalent of this dosage of creatine in rats would be about 70g per day for 3-4 years!

Physiological effects

So does long-term creatine use have a completely clean bill of health? In fact, there remain a number of unanswered questions. For example, some nutritionists have put forward the theory that the water-retaining effect of creatine supplementation could interfere with the normal transport of fluids, which in turn could impair exercise performance in very hot conditions.

However, a very recent study examining the responses of 16 healthy subjects to a heat-stress test seems to indicate that these fears may also be unfounded [5]. The test involved cycling at 55% VO_2max in temperatures of 39°C for 40 minutes on two separate occasions, before and after five days' treatment with either creatine (20g per day) or placebo. Temperature measurements taken during the test showed no between-groups differences for any measured parameters, and the researchers concluded that creatine supplementation had no effect on thermoregulation during exercise at this level of heat.

However, the creatine horizon might not be completely cloud-free for long-term users. For example, a fairly recent study on human metabolism has shown that creatine in the body is metabolised into a substance known as methylamine, which is further converted to formaldehyde [6]. Formaldehyde is well known to damage proteins and DNA via a process known as 'cross-linking'. Some toxicologists believe that the chronic over-production of formaldehyde in the body via this process could lead to such problems as vascular damage and diabetic complications in the very long term.

Another theoretical risk concerns heart rhythm abnormalities (arrhythmias). A recent study cited the case of a young, fit and healthy male who developed atrial fibrillation after ingesting large amounts of creatine [7]. This condition is extremely rare in young people and is normally only induced by excessive use of stimulants or alcohol. Other anecdotal reports have also linked arrhythmias to creatine use.

One adverse effect that appears beyond doubt is the fact that long-term creatine use can significantly impair the body's natural production of creatine. Although creatine occurs naturally in some foods, dietary sources are not normally sufficient to provide for the body's needs, so creatine is synthesised in the body from the amino acid arginine and another precursor molecule called guanidinoacetate. This process is mediated by special enzymes, including amidino-transferase and transamidinase.

Creatine synthesis

What happens to natural creatine synthesis if you consume a large amount of supplemental creatine? Is the natural process impaired and, if so, to what extent? To answer this question, a recently published study examined the effect of creatine supplementation on 16 healthy young adults, randomly assigned to one of two groups [8]:

- Creatine – 20g per day of creatine monohydrate (loading dose) for one week followed by 5g per day (maintenance dose) for a further 19 weeks;
- Control – same protocol as above but with an inert placebo instead of creatine.

The researchers took blood samples at weeks 1, 10 and 20, analysing them for creatine precursor molecules – naturally occurring molecules that are used by the body to synthesise its own creatine and which signify that the process is actually taking place. They found that, by comparison with the control group, the creatine users had substantially reduced levels of the creatine precursor guanidinoacetate – the main building block for creatine synthesis in the body. Guanidinoacetate levels were 50% lower during the creatine loading phase and 30% lower during the maintenance phase. The researchers concluded that a key enzyme (transamidinase) was being inhibited by the supplemental creatine, reducing the ability of the body to make its own.

'So what?', I hear you ask. Surely it makes sense for the body to reduce its own rate of creatine synthesis if it's getting lots in supplemental form? Well, yes it does, but these results raise an important question: what might be the effect of very long-term creatine supplementation on the enzymes used for creatine synthesis? We know that other enzymes in the body can become permanently down-regulated in particular circumstances; for example, those who abstain from dairy produce for very long periods sometimes find that the reintroduction of milk and milk products results in abdominal distress and diarrhoea. This is because during the abstinence period the production by the body of the enzyme lactase, needed to break down the milk sugar lactose, is reduced and may even cease completely, When milk is reintroduced, the lactose it contains can no longer be metabolised properly because lactase is either insufficient or absent, leading to digestive problems.

Could creatine use cause the same kind of problem? Could continual high dose supplementation for very long periods lead to a permanent reduction in the body's ability to synthesise its own creatine? And, if so, how would performance be affected when supplementation is discontinued? The answer is, of course, that we don't yet know. In the study mentioned above [8], the extent of enzyme down-regulation produced by supplemental creatine was reduced when the subjects switched from the loading phase (20g per day) to the maintenance phase (5g per day). But remember that this recovery in creatine synthesis occurred after just one week of supplementation. And, while there are many, many long-term creatine users who report no problems when supplementation is stopped, we don't yet have the data to promise users that there will definitely be no long-term effects.

'A more sensible approach is to use creatine as and when it's needed'

Creatine is one of the best researched of all sports supplements, with an excellent safety record. That said, high dose creatine use does supply the body with much higher intakes of creatine than could ever be achieved naturally, even on diets emphasising creatine-rich foods (see table, opposite), which means there may still be some long-term effects.

What to do?

Pending further research, the best approach is probably to take the path of prudence by avoiding long-term, continuous creatine use. A more sensible approach is to use creatine as and when it's needed – such as during build-up or competition phases. Many athletes have reported that 'cycling' creatine (*ie* alternating periods of use and non-use) works well, and this approach also makes sense from a safety point of view. There are no hard and fast rules about how to structure these periods, although a common strategy is to follow a five-week period of creatine use (one week loading followed by four weeks maintenance) with a wash-out period of 4-5 weeks, where no creatine is taken.

Remember that creatine boosts your anaerobic power, helping you to train more intensely. Even during washout periods, you should still be experiencing the benefits of previous creatine use – *ie* more anaerobic power and strength. Remember, too, that you can avoid the high-dose loading phase by taking less creatine for longer, since 3g per day for 28 days produces the same degree of muscle saturation as 20g per day for five days.

Whichever route you take, don't forget that once muscle saturation has been achieved there is no point in taking any more than the maintenance dose, since any extra will simply be excreted in the urine!

Andrew Hamilton

Andrew Hamilton BSc, MRSC, trained as a chemist and is now a consultant to the fitness industry and an experienced science writer

The importance of purity

Although debate about long-term creatine use tends to focus on safety, the *purity* of the product you use is just as important. Creatine products such as creatine monohydrate can and do vary in purity, with significant differences in the amounts of potentially toxic impurities present. This is because the industrial production of creatine monohydrate (from sarcosine and cyanamide) also produces harmful contaminants such as dicyandiamide, dihydrotriazines and creatinine, which have to be removed subsequently. Regular creatine users should therefore purchase products only from reputable manufacturers who are able to provide a 'Certificate of Analysis'. An inspection of such a certificate should indicate the following:

✓ Appearance – should be white to pale cream
✓ Assay – should be at least 95% via HPLC or HPCE
✓ Moisture content – should be less than or equal to 12.5%
✓ Microbial/pathogenic contamination – should be negative for E coli, S aureus and Salmonella
✓ Yeasts and moulds – should be less than 50 CFUs per gram
✓ Poisons/heavy metals – should be less than 10ppm for lead and mercury
✓ Other contaminants – should be less than 3ppm for arsenic, 30ppm for dicyandiamide and non-detectable for dihydrotriazine.

Jargon buster

Motor neurones Nerves that conduct the electrical signals required for muscles to contract.

VO_2max Maximal oxygen uptake, defined as the maximum amount of oxygen in millilitres a person can use in one minute per kg of body weight.

Metabolism The breakdown of complex organic constituents of the body with the liberation of energy that is required for other processes.

Formaldehyde A toxic chemical (CH2O) that harms cells and DNA when ingested or produced in the body.

Cross linking A process whereby protein molecules become chemically linked to their neighbours and which is associated with degeneration – *eg* the appearance of lines and wrinkles on the skin as ageing occurs.

Vascular damage Cellular damage within the walls of blood vessels, which can lead to such conditions as coronary heart disease

Atrial fibrillation A rapid heart rate in which the upper heart chambers (atria) are stimulated to contract in a very disorganised and abnormal manner.

Precursor A molecule used as a building block for another molecule.

Enzyme A protein synthesised in the body that facilitates a biochemical reaction that would otherwise occur too slowly, or not at all.

Dietary creatine – key sources

The best sources of dietary creatine are meat and fish. However, a quick glance at the creatine content of some of the better sources shows that, while dietary creatine can make a significant contribution to a 2-3g per day maintenance phase, it would be virtually impossible to achieve the multi-gram daily intake required in the loading phase from dietary creatine alone without a huge extra calorie intake, making supplementation unavoidable.

Food	Approx creatine content (grams per lb)	Amount required in lbs (for 5 grams/ day intake)	Calories contained
Herring (raw)	3-4	1.4	1,500
Beef (lean)	2	2.5	1,400
Cod (raw)	1.4	3.6	1,250
Tuna (raw)	1.8	2.8	1,700
Pork (lean)	2	2.5	1,700
Salmon (raw)	2	2.5	2,100
Milk (semi-skimmed)	0.05	160	33,600
Prawns	Trace	Huge amounts!	Huge amounts!

Shoulder Injuries: How to prevent them and how to recover from them

The famous adage about the shoulder joint among people in sport is that when God designed them, he simply wasn't thinking. Shoulders, so crucial in most sports, are also very susceptible to injury. They are also crucial for strength athletes as so many exercises rely on the use of the shoulders. If you want to have effective sessions in the gym, look after you're shoulders. These articles will help you protect your shoulders, or as the case may be, redevelop them.

Part 1: How to avoid shoulder trouble: your guide to achieving balanced upper body development

Chronic shoulder injury is a common problem, and not just for athletes. In the population at large, daily activities like DIY and gardening can produce chronic pain, as can resistance work in the gym, when enthusiasts pile on the weight without paying heed to the need for balanced strengthening.

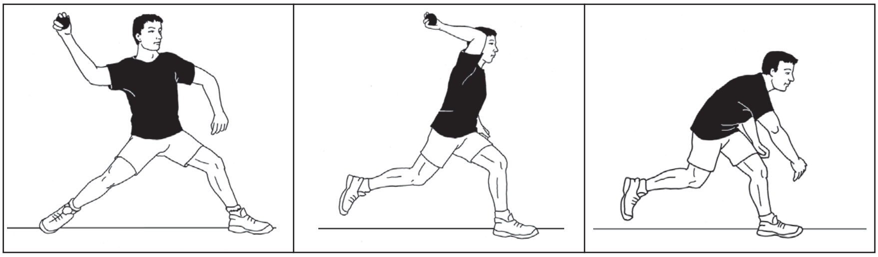
Adults over 50 are more vulnerable in general to rotator cuff tears, with the incidence increasing with age [1]. Among sportspeople, a large group known as the 'overhead athletes' are at increased risk of chronic shoulder injuries. This group covers a broad range of sports, including swimming, tennis, cricket, javelin and baseball, all of which involve variations on the generic throwing action, where the arm moves above the head *(see illustration overleaf)*.

The throwing movement recruits many muscles and combines a large range of arm motion with high forces or speeds at the shoulder joint. All overhead athletes tend to perform many repetitions of the movement, usually with a dominant arm only, as part of their sports training.

For the shoulder and arm to move efficiently requires coordinated movement of the scapula and humerus, known as scapulo-humeral rhythm. For example, arm abduction is accompanied by some upward rotation of the scapula, allowing the deltoid muscle to maintain a good length-tension relationship throughout the full 180° of abduction.

Scapular and humeral coordination also involves the stabilising muscles of the scapula working in concert with the rotator cuff stabilising muscles of the gleno-humeral joint. If the scapula holds its position correctly, the rotator cuff will do its job more effectively. Or, to put it another way, active stability is necessary to avoid excessive stress in the shoulder joint.

Throwing: the stretch-shorten cycle



Movement 1 (left & centre): The arm horizontally extends and laterally rotates backwards. The rear deltoid and lateral rotators are working concentrically and the pectorals, anterior deltoids and medial rotators are being stretched. At the end range of motion the medial rotators will be working eccentrically to control the movement back at the top of the cock position.

Movement 2 (right): The arm horizontally flexes and medially rotates, accelerating the hand to throw. This involves the pectorals, anterior deltoid and medial rotators working concentrically (or shortening, hence stretch-shorten cycle). The pre-stretch facilitates elastic energy return from the muscle tendon unit, making the movement both more powerful and fatigue-resistant. At the end range of medial rotation, the lateral rotators will be working eccentrically to decelerate the arm, controlling shoulder joint forces. This means that the end range of motion concentric medial rotation force must be controlled by eccentric lateral rotation force, and *vice versa*.

Get the balance right

The importance of rotator-cuff muscle strength in throwing was examined by a research team from the West Point Army Hospital in the US [2]. Scoville *et al* looked at the strength of normal subjects without any shoulder injury symptoms, comparing strength ratios of the end range of lateral and medial rotation. Subjects were assessed on an isokinetic dynamometer (which measures joint strength). Full range of motion was defined as 90° of lateral rotation (forearm vertical) to 20° degrees of medial rotation (forearm 20° degrees below the horizontal). The average force produced in the last 30° degrees of each direction was assessed as end range of motion.

The group average strength ratios results were as follows:

Concentric lateral rotation: concentric medial rotation (full ROM)	2:3
Concentric lateral rotation: eccentric medial rotation (end ROM)	1:2.4
Eccentric lateral rotation: concentric medial rotation (end ROM)	1.05:1

The concentric lateral rotation to eccentric medial rotation ratio of 1:2.4 suggests that the medial rotators have easily enough strength to decelerate the arm as it moves back to the cock position. The eccentric lateral rotation to concentric medial rotation ratio of 1.05:1 suggests that the lateral (external) rotators are capable of decelerating the forward motion – but only just.

The findings of this study suggest that normal adults with no shoulder problems possess sufficiently balanced strength for efficient biomechanics of throwing. But it they also show how important it is for overhead athletes to maintain this balance of muscular strength; otherwise the lateral rotators might not be able to cope with the stronger medial rotation force, so compromising the shoulder joint.

Problems tend to arise when athletes focus their training solely on the prime mover muscles, such as pectorals and deltoids, resulting in a relative weakness of the rotator cuff and scapular stabiliser muscles. It is common practice now for overhead athletes to pay extra attention to lateral rotator strengthening. And the same advice applies to all adults who do resistance training: be sure to include exercises for the rotator cuff and scapular stabilisers in order to develop balanced strength in the upper body.

While the Scoville study examined rotation strength alone, we have already noted that throwing combines rotation with horizontal extension and flexion movements. The rear deltoid muscles must, therefore, also act eccentrically to decelerate the arm during the end range, when the pectorals and anterior deltoid are working concentrically. So strengthening programmes must also pay attention to rear shoulder strength, incorporating pulling and rowing movements to balance pressing movements.

‘Problems tend to arise when athletes focus their training solely on the prime mover muscles’

Here, again, gym-goers tend to be most unaware of the need for balanced development, typically focusing on the ‘mirror muscles’ (pectorals, deltoids and biceps) and neglecting the back. The best programme will be one that promotes strength in all muscle groups and develops a balanced physique, front and back.

What goes wrong

Recent research by Kibler and McMullen uses the concept of ‘scapular dyskinesis’: an alteration in the normal position or motion of the scapula during coupled scapulo-humeral movements [3]. They suggest that a variety of symptoms share the same biomechanical fault: the inhibition or disorganisation of activation patterns in scapular stabilising muscles, leading to altered scapular function.

This idea is supported by research from a team from Belgium [4]. Cools *et al* investigated the timing of trapezius muscle activity during a sudden downward falling movement of the arm, comparing the performance of 39 overhead athletes with shoulder impingement against that of 30 overhead athletes with no such impingement.

The trapezius operates on the scapula in three sections: the lower portion depresses, the middle portion retracts, and the upper portion raises it. Cools measured the time that the muscles took to switch on in all three parts of the trapezius and in the middle deltoid, and discovered significant differences between the two groups. Those with impingement showed a delay in muscle activation of the middle and lower trapezius – the muscles that are important for maintaining good shoulder positioning.

Another study from Cools and his team investigated whether 19 overhead athletes with impingement symptoms had differences in their scapular muscle force (measured by isokinetic dynamometer) and electromyographic activity on the affected and uninjured sides [5]. They found that the injured side showed significantly lower peak force during protraction, a significantly lower ratio of protraction to retraction force, and significantly lower electromyographic activity in the lower trapezius muscle during retraction.

Together these findings support the concept of scapular dyskinesis (incorrect movements), involving abnormal recruitment timing and strength of the trapezius muscle – specifically the lower and middle portions. These results underline the importance for injury prevention of good scapular stability in the depression and retraction movements.

Research from Cologne in Germany highlighted changes in flexibility in the shoulders of overhead athletes [6]. Using ultrasound-based measurement, Schmidt-Wiethoff *et al* found that the dominant arms of a group of pro tennis players had a significantly greater range of external rotation than their non-dominant counterparts, while their internal rotation showed a significant deficit by comparison with the non-dominant arms.

Furthermore, the total rotational range of motion of the dominant arms was significantly more limited than that of the non-dominant arms or of a control group. In the control group (not involved in any overhead sports), there were no significant differences in flexibility between their shoulders.

How to protect your shoulders

It would seem from the research that incorrect muscle function (developed through sport specific demands or injury) is most evident in the lower and middle trapezius and lateral rotator cuff muscles. From a practical viewpoint, this means that overhead athletes and those involved in weight training need to spend time on specific strengthening exercises to promote injury prevention and ensure balanced strength and good posture.

Step 1: equalise front and rear strength

The starting point is a balanced programme for front and rear shoulder muscle development. Opposing muscle groups must be trained equally: while exercises for the anterior shoulder and pectorals develop power, training these muscles alone will unbalance the shoulder. A better approach is to programme exercise pairs that work opposing muscles *(see table 1)*. Coaches and therapists should check that equal numbers of sets from each column are written into strength programmes.

Table 1: Front and rear shoulder exercise pairs

Press or push exercise	Opposing pull or row exercise
Bench press	Bench pull or seated row
Dumbbell press	Single arm row
Shoulder press	Lat pulldown
Flies lateral raise	Prone flies or bent-over
Lateral raises	Cable lateral pull-downs

Step 2: develop good pulling form

Pull or row exercises must be performed with correct technique in order to ensure that the middle trapezius, rhomboids and lower trapezius muscles are properly recruited. For example, with the lat pull-down, a popular exercise for the upper back and rear shoulder muscles involving adduction of the arm, the exercise begins with the arms above the head. During the pull-down movement, the exerciser must focus on using the lower trapezius muscles to depress the scapula while the large latissimus dorsi muscles pull the elbows downwards.

Similarly, during the return movement it is important to make the lower trapezius muscle 'keep hold' of the scapula as the arms rise with the weight. This recruitment creates the correct scapulo-humeral rhythm. Without correct use of the lower traps, the lat pull-down is performed in a hunched shoulder position, which promotes poor mechanics.

The same coaching principle applies to rowing exercises. These involve horizontal extension of the arm, using the strong latissimus dorsi muscles, and require concurrent scapular retraction from the middle trapezius and rhomboids.

Exercisers should focus on retracting the scapula at the same time as the elbow is pulled back, and keeping the scapula retracted as the arm goes forwards, with the weight on the return movement.

If the scapula is not stabilized, the athlete will perform the exercise in round-shouldered (kyphotic) posture, which again will result in poor shoulder joint mechanics.

Step 3: isolate the rotator cuff

The small but crucial muscles of the rotator cuff should be targeted along with the lower traps to avoid developing dysfunction or weakness. In the following four exercises, pay attention to the coaching points.

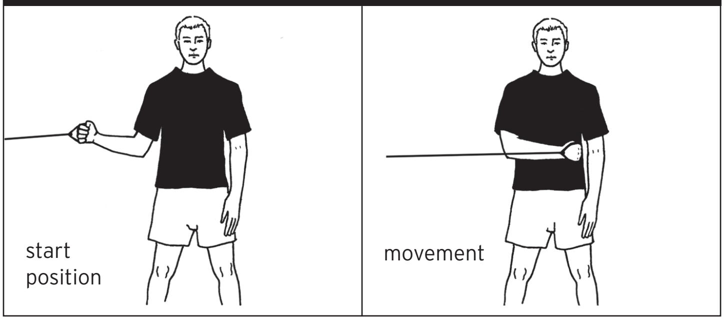
Exercise 1: internal shoulder rotation

Use a resistance band or a pulley cable machine for this movement.

Muscles targeted

subscapularis and pectoralis minor, the shoulder's medial rotators.

Exercise 1



Start position

- Stand with good posture, abs in and shoulders wide;
- Grasp the handle out to the side, palm facing forward;
- Tuck your elbow firmly into your side and fix an elbow angle of 90°.

Movement

- Pull arm across your body;
- Finish with the palm facing into your body;
- Keep the elbow positioned close to your side, to ensure the movement targets shoulder rotation alone;
- Hold upper body still, to prevent other muscles assisting the shoulder, so that only your arm moves;
- Return to the start position slowly, with control, and repeat.

Exercise 2: external shoulder rotation

Use a resistance band or pulley machine.

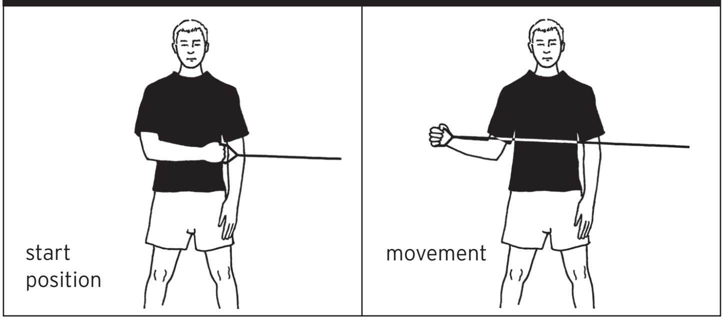
Muscles targeted

Infraspinatus and teres minor, the shoulder's external rotators.

Start position

- Stand with good posture, abs in and shoulders wide;
- Grasp the handle with your forearm across your body, palm facing into your body;
- Hold your elbow close to your side and fix an elbow angle of 90°.

Exercise 2



Movement

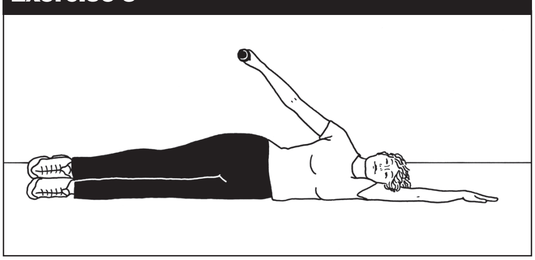
- Pull the arm out and away from your body;
- Finish with the palm facing forward;
- Keep the elbow positioned close to your side, to ensure the movement targets shoulder rotation alone;
- Hold upper body still, to prevent other muscles assisted the shoulder, so that only your arm moves;
- Return to the start position slowly, with control, and repeat.

Exercise 3: side lying raise

Muscles targeted

Supraspinatus (top of the rotator cuff), assisted by the deltoid and infraspinatus. This exercise is particularly effective at recruiting rotator cuff muscles while avoiding putting the shoulder joint through a stressful range of motion, and is therefore beneficial for those with shoulder injury.

Exercise 3



Start position

- Lie on your side with your body stretched out straight;
- With a dumbbell in your hand, place top arm straight along your body so that your hand lies by your hips;
- Use your scapular muscles to pull your top shoulder into a wide position, avoiding hunching or rounding.

Movement

- Lift the dumbbell straight up until your arm makes a 45° degree angle to your body;
- Ensure your body does not roll or sway, so that only your arm moves;
- Lower the arm slowly, with control, and repeat.

Exercise 4: human arrow

Muscles targeted

Lower trapezius, focusing on scapular depression. This movement can take a little time to learn, so don't expect yourself – or your clients – to get it first time.

Start position

- Lie on your front with your arms by your sides, palms facing upward and fingers pointing towards your feet;
- With nose just off the ground, focus eyes on the floor;
- Do not lift your head, so your neck remains relaxed;
- Engage your abdominals and pelvic floor to keep your lumbar spine in place;
- Let your shoulders fall forward and rounded to the floor, keeping upper back relaxed.

Movement

- Pull your shoulder blades back and down so that your fingers slide down your side towards your feet. Feel that you are extending your arms downward;
- Your upper back will extend slightly and all your muscles around your scapula will feel strong. You will feel your

shoulder blades pull downwards into your back if you engage the lower traps correctly;

- Do not extend your lumbar spine and lift up off the floor. The low back should remain flat, as the exercise is designed to isolate the scapular muscles. It is not a dorsal raise;
- Hold the position for 10 seconds and then relax;
- Repeat 10 times.

Raphael Brandon

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Part 2: A detailed guide on how to restore high-level shoulder strength

Beware: what follows is highly practical! While a comprehensive understanding of the dynamics of the glenohumeral complex is critical for proper implementation of rehabilitation programmes for high-level athletes with shoulder injuries, the emphasis in this article is squarely on post-clinical rehab. Many therapists feel inadequate when it comes to communicating with strength and conditioning coaches regarding top-end shoulder rehabilitation, so this piece is designed for those who would appreciate some guidance on the principles behind gym-based rehab to restore to their athletes a functional and strong shoulder complex.

These principles are most appropriate for athletes in the following situations:

- Late-stage rehab after shoulder stabilisation surgery (more than 12 weeks post operative)
- Conservatively managed shoulder instability
- Acromioclavicular joint pathology and surgery
- Non acute shoulder impingement syndromes and tensile tendon problems.

Movement not muscles

When we describe exercise selection for the upper quadrant, it is more appropriate to think about movement direction rather than muscle groups. So instead of breaking down the weights plan according to, say, deltoid, pectorals, latissimus dorsi and rotator cuff, we gain a better appreciation of *balanced* programming if we think about movement directions. The strength coach Ian King1 describes shoulder strength training based on the four dynamic movements along the push and pull axis. I have taken this idea and developed it to include three more movement types.

Seven movement directions

The seven types of movement we need to train for are:

- Horizontal pushing
- Horizontal pulling
- Vertical pushing
- Vertical pulling
- Internal rotation
- External rotation
- Diagonals

Horizontal pushing

In essence this involves horizontal flexion of the shoulder. Examples of exercises focusing on this movement direction are: bench press (and all its derivatives), flyes and push ups. The main muscle contributors are: pectorals, anterior deltoid, triceps and scapular protractors such as serratus anterior.

Horizontal pulling

This involves horizontal extension of the shoulder. Choice exercises are: seated row, single arm rows, barbell bent over rows, reverse flyes and dorian rows *(see below)*. The prime movers in this direction are latissimus dorsi, posterior deltoid, the elbow flexors and scapular retractors such as middle trapezius and rhomboids.

Vertical pushing

This involves the combined anatomical movements of glenohumeral abduction and flexion, along with scapular elevation/external rotation. It encompasses all shoulder press movements, lateral raises, front raises, upright rows (actually a pull but included here in terms of muscles used) and shrugs. These work the anterior and middle deltoids, clavicular head of pectoralis major and upper trapezius.

Vertical pulling

The combined movements of glenohumeral adduction and extension, along with scapular retraction/downward rotation/depression. Chin ups, lat pulldowns and all the variations involve these movements. The muscle focus is on latissimus dorsi, the teres group, posterior deltoid, lower trapezius.

Internal rotation

Self explanatory as a movement. Heavily focused on pectoralis major, latissimus dorsi and subscapularis.

External rotation

Recruitment of the infraspinatus, supraspinatus and posterior deltoid.

Diagonals

Based on the fundamental principles of proprioceptive neuromuscular facilitation (PNF) patterns of movement. PNF patterns are founded on the premise that the body only knows about patterned and functional movements. That is, when a muscle such as pectoralis major contracts, it wants to perform all three of its actions: horizontal flexion, adduction and internal rotation. Therefore, strength exercises for the shoulder should incorporate all the relevant components, alongside their opposing movements. The best way to do this is with diagonal movements. The movement directions outlined in Table 1 below are known as the diagonal 1 (D1) and diagonal 2 (D2) pattern2.

Table 1: Diagonal movement patterns

D1 starts from
abduction/external rotation/ flexion and moves towards adduction/internal rotation/ extension.

D2 starts from
abduction/ internal rotation/ extension and moves towards adduction/ external rotation/ flexion.

Functional diagonals

The therapist must not forget that the body moves in a kinetic chain. Shoulder movements are heavily linked to hip movements via the 'myofascial slings' acting over the skeletal structure. For an in-depth explanation of these slings see *SIB 36*.

In a nutshell, a great way to perform diagonals using the cable machine in the gym is to do them in standing. That way the hip and lower limb muscles are involved via their link through the myofascial slings. As a brief example, the posterior oblique sling (latissimus dorsi, thoracolumbar fascia and contralateral gluteus maximus) is best worked using the diagonal movements described above in standing while isometrically tensing the opposite gluteus maximus .

Common mistakes

Internal v external rotation

The shoulder's internal rotators are much bigger and nastier than the external rotators. If you think about it, the bulk of the pectoralis major, latissimus dorsi and subscapularis (all internals) far outweighs the size of the minuscule but highly important external rotators (infraspinatus, posterior deltoids, teres minor and supraspinatus).

Despite this clear imbalance, most gym programs seem to focus primarily on the internal rotators. The most popular upper body exercises are the bench press (pecs – internal rotators) and lat pulldowns/chin ups (latissimus – internal rotators). Without proper balancing of the external rotators, a gym trained athlete will over time adopt that 'carrying suitcases' look: glenohumeral internal rotation with scapular protraction.

The pectorals and latissimus become tight and facilitated, with the posterior deltoids, posterior cuff and scapular retractors (middle trapezius and rhomboids) becoming weak and lengthened. This will lead to anterior translation of the humeral head and potentially damage to the anterior structures and subacromial structures when the arm is taken into an elevated position. This becomes a problem when overhead elevation is repeatedly performed.

The best high level exercise for the external rotators is 2 to 1 shoulder external rotations. In side lying, use both hands to concentrically lift a dumbbell into full external rotation (the '2' component), and then use only the one arm to eccentrically lower the dumbbell (the '1' component). This allows the external rotators to be maximally loaded, as the concentric component is assisted through its weakest part with both hands *(see figs 1 and 2)*.

Figure 1: 2 to 1 dumbell external rotations, concentric

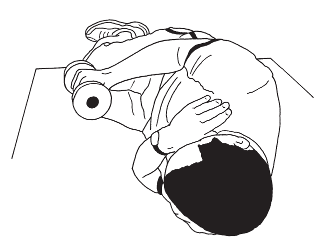
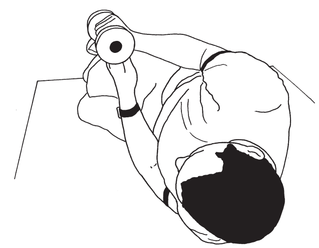


Figure 2: 2 to 1 dumbell external rotations, eccentric



Scapular protractors v scapular retractors

The main focus of movement involved here is horizontal push and horizontal pull. Traditionally the 'pulling' movements have been poorly performed and undervalued in strength programs. It is commonly argued that this is because the individual cannot see the pull muscles, so they don't put much time and care into training them. I believe the real reason is that no exercises truly load the scapular retractors and shoulder extensors the same way as one can load the scapular protractors and shoulder flexors. If you think about it, it's much harder to pull the same poundages as one can push. If an individual can bench press 150kg, it is difficult to pull the same amount of weight. Or is it?

The Dorian row is the daddy of all horizontal pulling movements, because when an athlete is well trained, they can achieve similar weights to those they are bench pressing. This allows the 'balance' of push and pull to be addressed.

I named this exercise after the great English bodybuilder Dorian Yates. He perfected a method of performing bent-over rows by using a higher trunk angle and supinated grip on the bar. The angles involved (hip is 30 degrees from vertical and knee 30-40 degrees, depending on length of leg and leverage) allow the lifter to handle much heavier weight while really focusing on the scapular retractors and shoulder extensors. Ensure that the bar starts against the thigh just above the knee *(see figs 3 and 4)*.

Figure 3: Dorian row, start position

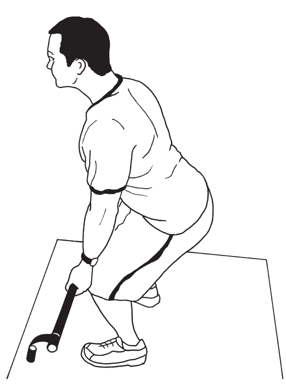


Figure 4: Dorian row, maximum retraction

Guidelines for programming

1. Prioritise the weakest movements

In most cases, the weakest and most underdeveloped movements will be horizontal pulls and vertical pulls. External rotation will generally be weaker and under-utilised compared to internal rotation.

2. Form before weight

In initial programming, tempo of the movement is critical as it allows the rotator cuff enough time to dynamically control glenohumeral joint position, and the scapular stabilisers to control scapular movements. So speeds such as 2:2:2 (2 second eccentric, 2 second hold, 2 second concentric) are a good starting point before moving on to faster and more dynamic lifting speeds.

3. Aim for balance

If you consider an athlete to have excellent development of a movement direction such as horizontal push, but poor development of horizontal pull, then make sure they redress this imbalance. If necessary, you could forbid an athlete from performing push movements until their pull movements catch up in terms of weight used. I have often seen Rugby players with impingement-type syndromes caused by too much bench pressing. By forbidding them from doing bench presses until their strength on a pulling exercise catches up, very often their shoulder pain clears up without active treatment, rehab or even medication, and never recurs.

4. Don't fatigue the rotator cuff

Rotator cuff work is often included in an upper body lifting program as a form of 'prehab' before moving on to the heavy compound movement component of a program. This makes sense to pre-fire the rotator cuff muscles so they are involved in the dynamic control of shoulder movement with other lifts. However, in the 'prehab' component, keep the volume and intensity short. Too much cuff work may fatigue these and undermine their role during the heavier lifting component. Leave the fatigue work until the end of the program.

5. Stretch

Spend 25-35% of the allocated training time on stretching. So in a one hour training/lifting session, 15-20 minutes should be spent stretching. This allows full range of available shoulder motion to be achieved with lifting, and will enable the habitually lengthened muscles (eg, rhomboids) to work against reduced resistance from the stronger muscles (such as pec major/minor) which tend to hold the shoulder in internal rotation and scapula in protraction. For most people, the four key areas that need to be lengthened are latissimus dorsi, pec major and minor, short external rotators such as infraspinatus and scapular elevators such as trapezius and levator scapulae.

Sample Programme

Athlete is 16 weeks post-shoulder reconstruction. Has full range of motion but needs to start focusing on heavier lifting to prepare shoulder for contact training in four weeks.

Chris Mallac

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Workout 1 (early in the week): Horizontal Pulling/Vertical Pushing

Exercise	Sets	Reps	Tempo (sec: sec:sec)	Other
1. Stretch (10 mins): lats, pecs, posterior cuff and upper traps				
2. Side lying external rotation	1	10		1 up 1 down; eg: 5kg plate
3. Side lying external rotation	2	8		2 up 1 down; eg: 10-15kg dumbbell
4. Prone flutters (face down, arms by sides with elbows locked out, retract scapula and hold)		2		30 sec hold
5. Prone flyes	2	8	2;2;2	
6. Dorian rows SUPERSET WITH	1 1 1	8 6 4	2;2;2 2;2;2 2;2;2	
7. Seated dumbell shoulder press palms forward palms facing body Arnold press (palms start facing body but twist to end forwards)	1 1 1	8 8 8	2;2;2 2;2;2 2;2;2	
8. Single arm row	3	6	2;1;2	
9. Alternate front/side raises	3	8 (4 each direction)	2;1;2	
10. Standing cable diagonals (high cable)	2	6 (each direction)		
11. Stretch (10 mins): lats, pecs, posterior cuff and upper traps				
12. Side lying external rotation	1	10		1 up 1 down; eg: 5kg plate
13. Side lying external rotation	2	8		2 up 1 down; eg: 10-15kg dumbbell
14. Prone flutters (as before)		2		30 sec hold

Workout 2 (later in the week): Horizontal Pushing/Vertical Pulling

Exercise	Sets	Reps	Tempo (sec: sec:sec)	Other
1. Stretch (10 mins): lats, pecs, posterior cuff and upper traps				
2. Side lying external rotation	1	10		1 up 1 down; *eg:* 5kg plate
3. Side lying external rotation	2	8		2 up 1 down; *eg:* 10-15kg dumbbell
4. Wall slides	2	10		
5. Dumbell bench press SUPERSET WITH	1 1 1	10 8 6	2:2:2 2:2:2 2:2:2	
6. Lat pulldowns	1 1 1	0 8 6	2;2;2 2;2;2 2;2;2	
7. Incline close grip bench press	3	6	2;1;2	
8. Chin ups	3	6	2;1;2	
9. Standing cable diagonals (low cable)	2	6 each direction		
10. Stretch (10 mins): lats, pecs, posterior cuff and upper traps				
11. Side lying external rotation	1	10		1 up 1 down; *eg:* 5kg plate
12. Side lying external rotation	2	8		2 up 1 down; *eg:* 10-15kg dumbbell
13. Wall slides	2	10		2 up 1 down; *eg:* 10-15kg dumbbell

(Supersetting involves alternating between sets of the two specified exercises without rest, thereby performing six sets of two exercises before resting.)

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The minimal equipment guide to resistance training, with an emphasis on rehabilitation

Strengthening exercises have obvious importance for the rehab programmes that sports therapists design for clients or patients. In recent years rehabilitation knowledge has focused on core stability and the importance of correcting muscle imbalances. Usually this means concentrating on the smaller 'stabiliser' muscles. Exercises for these muscle groups are commonly (although not exclusively) performed without weights or using simple resistance bands, which enables professionals conveniently to be able to prescribe home-based and minimal-equipment exercise regimes.

Lest we forget, however, strength in the large 'mobiliser' muscles is also important to rehabilitate many common injuries. For example:

- research shows gastroc-soleus strength is associated with reduced Achilles tendinitis risk;
- quadriceps strength, particularly in the vastus medialis, is associated with reduced risk of patellofemoral pain and is essential for successful rehabilitation from knee ligament injuries;
- back extensor (erector spinae group) strength endurance is associated with a reduced likelihood of getting low back pain;
- and it is essential to regain – safely -- shoulder joint strength after a joint sprain or fracture.

The modern gym, equipped with machines for all muscles groups and free weights, is the ideal place to develop strength. It gives sports therapists a wide choice of exercises and an easy, regulated means of progression. Resistance machines, with their numbered and graduated weight stacks, make prescriptions for a progressive programme straightforward and safe.

But what do you do when the client or patient has no ready access to a fitness facility and they are limited to bodyweight exercises for their rehab? In this case, rather than simply moving the pin on a weight-stack, it will be necessary to introduce a shift of body position or a new exercise in order to achieve progression.

The aim of this short series of articles is to provide sports therapists with guidelines for safe and effective home-based rehab programmes using minimal equipment, starting with the principles of exercise planning and moving on to practical advice for key mobiliser muscle groups.

Training principles

Different goals require different 'doses' of exercise training. A dose of training comprises three main components: intensity (weight), volume (set and reps) and frequency (sessions per week).

Rehabilitation training tends to focus on developing general strength and strength endurance. This is for three perfectly sound reasons. First, chronic injuries are usually related to repeated stresses and the ability of the muscle-tendon unit to tolerate accumulated forces. Secondly patients recovering from sprains, fractures or operations need to rebuild muscle mass lost during a period of immobility. Thirdly maximal strength training requires very high intensity (at least 80% of maximum force), which could be counter-productive for rehabilitation purposes. If maximal strength training is to be part of a recovery programme, it must be built in at the end of the rehab progression, after general strength and muscle mass have been rebuilt.

Intensity

The term **repetition maximum** (rep max or RM) refers to the maximum number of times one can perform a movement at a specific weight, and is the standard method for defining the intensity of strength training. 1RM is the maximum weight that the individual can lift, as they will only be able to manage a single lift at that weight. 8-12 RM is considered a suitable intensity of training for gaining general strength and building muscle mass. 15 – 20 RM is considered suitable for strength endurance benefits.

For rehab purposes, parameters within the 8 – 20 RM range will provide appropriate intensity. If the same exercise can be performed for more than 20 repetitions without rest, the training benefit for strength or strength endurance will be small: in effect the exercise level is too easy. The support professional needs to evaluate intensity for each exercise against the desired rehab goal, which is relatively simple when you have a weight stack to play with, but much harder with minimal or no equipment.

For bodyweight-only exercises, the individual's own mass and body position relative to the moving limbs and gravity define the amount of 'weight'. The only way to change the load is to change either the position or the movement. This is why the range of movement performed is key to the difficulty of the exercise. As an exercise is performed, the working muscles are subject to different levels of force, depending upon the joint angle and the distance of the point of load from the pivot point. In all the exercises outlined in this series, it is necessary to maintain the range of movement as the difficulty of the exercises increase, in order to progress properly.

Where resistance bands are being used, apart from range of movement, the length and thickness of the band are the two main variables of intensity and should be monitored carefully accordingly.

Volume and frequency

In general two to four sets of 8-20 reps is considered sufficient volume for each exercise. A rest of 60 to 90 seconds is recommended between sets; the patient should run out of effort in the final set. For example, using a 15 RM weight, a patient would probably be able to perform three sets of 12 repetitions with 60 seconds rest between each set. The last set would be very difficult, in order to achieve the 'overload' which produces training benefit. In some cases it will be appropriate to begin with only one set of an exercise, as this will achieve sufficient training benefit in the earliest stage of rehab.

Large muscle groups can be trained two to three times per week with at least 48 hours rest between training sessions. Once a week may be enough to maintain strength but will not develop it. More than three sessions may not allow sufficient recovery for the muscle-tendon adaptations to occur. Smaller muscle groups can be trained four to five times per week, if you are pursuing an aggressive rehab programme, but three times is probably enough for most people's needs.

Progression

Training benefit comes from overloading the muscles, thereby forcing them to strengthen. So once a muscle has responded to the initial 'dose' of training, the dose has to be increased to gain further improvements.

As seen above, intensity and volume are the two main variables by which exercises can be progressed. For rehab programmes I am in favour of first increasing volume, keeping the weight constant. Then, once the patient can competently perform a certain number of sets and reps, the load should be increased. This is a cautious and safe way to progress.

Table 1 below details a method of evaluating load levels and overall difficulty of an exercise. It is a version of the "RPE scale 0-10" (Rate of Perceived Exertion). RPE is a useful rehab tool, giving subjective feedback that can help the therapist to assess more accurately when and how to progress the programme. It is also a very important way of helping the patient learn to evaluate their body's response to being challenged.

For weight training, use RPE in this way. After the client has completed the required number of sets (assuming they can do this successfully), ask: 'On a scale of 0 to 10, how difficult was the last set?' Use Table 1 to help you decide whether and when

to make changes to that exercise. Remember, the last set needs to be tough for training benefit to occur.
Tip: If the client replies: 'it was ok', which they often do, repeat the question and make them specify a number!

Table 1: Rate of Perceived Exertion

RPE	Difficulty	Decision
<5	Too easy	Significantly increase the reps or the load
6 – 7	Quite easy	Increase reps, sets or load – progress to next level
8 – 9	Working well	Suitably level for rehabilitation training. Keep reps and loads the same
9.5 – 10	Max effort	Very difficult. Arguably too hard for rehab, so reduce load, sets/reps or change the exercise

One warning, however. The RPE feedback system is a tool, not a rule to govern all progression. Use your judgement to ensure you do not rush your patients. When increasing the load, keep in mind that tendon strength takes longer to develop than muscle strength. This is why I recommend increasing the repetitions at a particular load up to a target level before stepping up the weights.

Specificity

The final training principle important for rehab programmes is the specificity of the exercise movement. Research has shown that the range and speed of movement, and the type of contraction performed in training all result in specific improvements. For example, isometric contractions of the quadriceps at a 90 degree knee angle will greatly improve static strength in this position but not significantly improve dynamic strength across the whole range of knee motion.

The specificity argument is especially important when thinking about the transfer of strength capabilities into daily life or sporting movements. It sounds obvious, but the goal of the rehab programme is to enable the patient to be pain-free while they run, play sport, work or do the housework. The goal of rehab is not to enable the patient simply to excel at a selection of exercises. The exercise prescription is the means to the end.

Numerous research studies have shown that exercises using free weights – which involve multiple joints and force the body to provide its own support – have greater 'mechanical correspondence' to ergonomic and sporting movements. In contrast, machine-based strength exercises tend to involve single muscles, with the machine providing the support. Therefore the transfer of a training effect to real life is considered superior from programmes based on free weights. This logic extends well to minimal equipment rehab programmes, as bodyweight exercises are indeed "free weight" movements, minus the additional load provided by barbell, dumbbells *etc*.

Closed v open chain

The relative merits of closed versus open kinetic chain exercises have also been researched and argued over extensively over the past 10 years.

Closed-chain exercises are movements where the end of the limb being exercised is in contact with the floor or a fixed object. They are often multi-joint movements, and tend to be free-weight movements such as squats (although some machines, such as the leg press, are closed-chain exercises).

Open-chain exercises are movements where the end of the limb moves freely and the joint is fixed. These movements are typically single-joint and single-muscle movements, often performed on machines, for example the leg extension and leg curl.

The general consensus among researchers and clinicians is that closed-chain exercises are more effective for rehabilitation purposes. These movements involve the mobiliser as well as co-contraction of the stabiliser muscle groups. They have greater proprioception benefits than open-chain movements. The strength gained using the closed-chain exercises can be more readily transferred to sport or daily life movements and so are more purposeful in rehab.

The exercises

For each muscle group, the exercises described will begin with light movements/positions and progress to heavy movements or positions, showing how it is possible to continue to gain strength without weights machines.

Group 1: Quadriceps

This exercise progression is for patients needing to increase quadriceps strength. Closed-chain knee exercises produce superior EMG ratios of vastus medialis:vastus lateralis to open-chain exercises. Note, also, the large number of muscle groups involved in the movements.

Table 2: Quadriceps series

Exercise	Start sets x reps	Target sets x reps
Split squat	3 x 10 each	3 x 15 each
Lunges – back	3 x 8 each	3 x 15 each
Single leg squat – toe tap for balance	3 x 10 each	3 x 15 each
Single leg squat	3 x 10 each	3 x 15 each
Single leg squat + dumbbell	3 x 8 each	3 x 15 each

Begin with the first exercise alone, at the start level of sets and reps. Progress to the target level sets and reps. Once this can be accomplished at an RPE of 6 to 7 out of 10 *(see Table 1, p117)*, move on to the next exercise.

Main muscles trained:

Quadriceps
Gluteus maximus

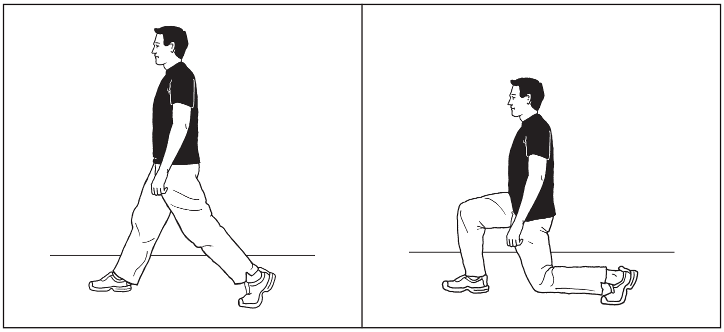
Stabiliser muscles and secondary muscles involved:

Gluteus medius
Obliques
Erector spinae
Adductors
Hamstrings

Suitable for rehab in:
Knee ligament sprain
Patellofemoral pain
Post-operative knee procedures

Techniques:
I urge you to pay attention to the details, particularly those defining the range of motion required (see comments above).If a constant approach to range of motion is not maintained, the series does not work as a progression.

1. Split squat (split lunge)



Start position:
- Stand with good posture, feet hip-width apart, and take a big step forward (about 1m)
- Hips will be in the centrally planted above feet
- Shoulders are above hips, to prevent any forward lean
- Feet remain hip-width apart
- Hips are square to the front and pelvis is in neutral (seen from the side).

Descent:
- Bend the front knee and lower hips straight down
- Keep trunk upright during the lowering
- Keep the front knee aligned with front foot as the knee bends (aim the knee to track over the little toe)

- Do not allow the front knee to advance beyond the toes (seen from the side)
- Finish when front knee is at a 90-degree angle. Do not let the back knee touch the floor
- If the knee joint is painful, reduce the range of the dip. Do not progress to the next exercise until full range can be performed pain-free.

Ascent:
- Push down into the floor with front leg and straighten knee
- Keep front knee aligned with front toes
- Raise hips straight up, keeping trunk upright
- The pelvis should remain square to the front and neutral throughout the movement

Rationale:
- This is a relatively easy movement, with most adults being able to perform 10-20 reps without difficulty. This makes it a good start point for injury rehab
- The front leg does most of the work, but significant weight is taken on the back leg, reducing the overall load on the front
- The knee position is controlled, with limited dorsiflexion, thereby reducing tibio-femoral joint forces. This means the gluteus maximus contributes significantly to the movement
- Reducing the range of motion on the front leg will make the exercise less stressful if required, and it is easy for the patient to reproduce this limited range unsupervised.

2. Rear lunges

Start position:
- Stand with good posture, feet hip-width apart
- Hips are square to the front; pelvis is in neutral (seen from the side).

Decent:
- Lift the left leg off the floor slightly

- Bend the right knee and lower hips down and backwards
- Control this descent using the right quadriceps and gluteals for as long as possible
- During the lowering, reach back with left foot (about 1m) and place it on the floor
- Aim to keep most of the weight on the right
- Keep trunk upright during lowering
- Keep front knee aligned with front foot (aim the knee to track over the little toe) as the knee bends
- Do not allow the front knee to advance beyond the toes (seen from the side)
- Finish with right knee at 90 degrees and left knee bent beneath hips.

Ascent:

- Push down into the floor with the right leg and begin to straighten knee, standing up and forward
- Lift left leg off the floor as soon as possible and complete the ascent using only the right leg
- Keep front knee aligned with front toes
- Finish standing upright, two feet on the floor
- Pelvis should remain square to the front throughout the movement
- The pelvis should return to the neutral position at the top of the ascen.t

Repeat for the other leg.

Rationale:

- This is more demanding than the split squat because during some of the movement all the weight is supported on the working leg
- The support leg takes the weight only during the second half of the descent and the first half of the ascent, where the knee bend and quadriceps force is greatest
- Again the knee position is controlled, with limited dorsiflexion, thereby reducing tibio-femoral joint forces.

This means the gluteus maximus contributes significantly to the movement
- 90-degree knee position must be attained during this exercise otherwise it will not be a significant progression from the split squat.

3. Single leg squat, toe tap for balance

Start position:
- Stand with good posture, feet hip-width apart
- Hips are square to the front and pelvis is in neutral (seen from the side)
- Point left foot downwards, place the big toe on the floor, allowing the right leg to take virtually all the weight
- Let arms hang down each side for balance.

Descent:
- Bend right knee and squat down. The left knee will also bend, but the work is done with the right side
- Allow the trunk to lean forward slightly during the squat down
- Also, allow the ankle to flex and knee to move ahead of toes slightly during the squat down. This allows a full range of movement
- Keep front knee aligned with front foot as the knee bends (aim the knee to track over the little toe)
- Finish with right knee at 90 degrees.

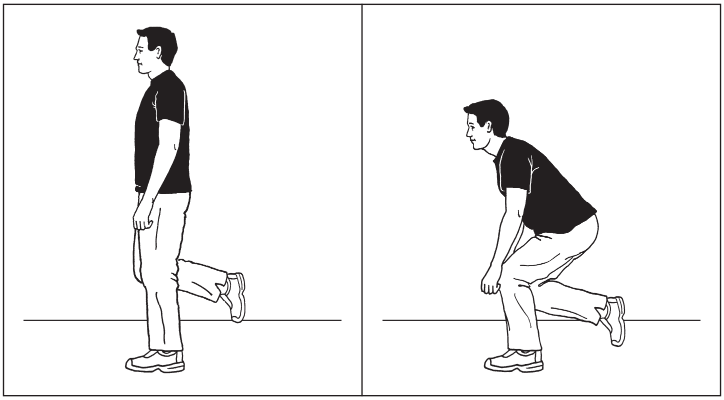
Ascent:
- Push down into the floor with right leg and stand up
- Keep front knee aligned with front toes
- Finish standing upright, left big toe remaining in contact with the floor, weight on the right
- Pelvis should remain square to the front throughout the movement
- Back remains straight, despite a forward lean going down
- Pelvis should return to the neutral position at the top of the ascent.

Complete one set on the right and then one set on the left.

Rationale:

- This is more demanding than the lunge as virtually all the weight is taken on one leg throughout the full range of movement
- The toe-tap position enables the patient to keep balanced throughout the full range of motion, allowing the complete movement to be performed well
- Contrary to popular myth, allowing the knee to flex forward beyond the toe-line is correct squatting technique. Although it increases the tibio-femoral forces, it also promotes increased quadriceps force, thereby increasing the strength benefit for the quadriceps. If the knee is fixed at the toe-line during the squat, hips and low back will produce more force relative to the quadriceps
- A 90-degree knee position must be attained during this exercise otherwise it will not be a significant progression from the lunge. Shortening the range makes the exercise easy.

4. One leg Squat



Technique:

- As above, but with all weight on one leg and no toe tap for balance

- Allow the free leg to bend slightly. This exercise can be performed on a step, with the free leg off the side
- Hips must stay square to the front and pelvis level (seen from the rear) as the movement is performed.

Rationale:
- Full range of motion with full bodyweight placed on one leg, plus the increased balance challenge makes this even more difficult
- This is an excellent exercise demanding advanced hip stability as well as excellent quadriceps strength
- Any adult who can perform 3 sets of 15 reps on one leg with perfect balance, alignment and range of motion down to a 90-degree knee angle each rep has developed good functional strength
- Elite athletes, however, may need to be stronger.

5. One leg squat with dumbbells

Technique:
- As above but with a 5kg dumbbell held upon each shoulder with arms flexed
- The weights on the shoulders increases bodyweight, and therefore the load on the leg
- Wearing a rucksack evenly weighted eg, with sand, would achieve the same effect

Rationale:
- Just about qualifying as minimal equipment, the addition of dumbbells or weighted rucksack allows further progression.
- The dumbbells, held close to the body, increase the load on the quadriceps significantly, and also the balance challenge of the exercise (less so with rucksack).
- If the weight is held out in front, the increase in force is produced in the hips and low back rather than the quadriceps.

Group 2: Calf muscles: gastrocnemius and soleus

Main muscles trained

Gastrocnemius and soleus.

Suitable for rehab from

Achilles tendinitis, medial tibial pain, plantar fasciitis.

Two different variations of the standard calf raise exercise are used to ensure optimum benefit to both gastrocnemius and soleus.

The straight-knee version concentrates the training effect on the large gastrocnemius: this portion of the calf attaches above the knee and so is lengthened when the knee is straight. Longer muscles can produce more force.

In the bent-knee version, the effectiveness of gastrocnemius is reduced with the shortened muscle position, thereby placing a greater work load on the shorter soleus. Both versions of the exercise are performed upon a step in order to achieve a full range of motion in the ankle joint.

Table 2 Calf exercise series

Exercise	Start sets x reps	Target sets x reps
Calf raise, double legs, knee straight	2 x 10	3 x 20
Calf raise, double legs, knee bent	2 x 10	3 x 20
Calf raise, single leg, knee straight	2 x 10 each leg	3 x 20 each leg
Calf raise, single leg , knee bent	2 x 10 each leg	3 x 20 each leg
Calf raise, single leg + loaded rucksack, knee straight	3 x 20 each leg; 10kg rucksack	3 x 20 each leg; 40kg rucksack
Calf raise, single leg + loaded rucksack, knee bent	3 x 20 each leg; 10kg rucksack	3 x 20 each leg; 40kg rucksack

Progression

Begin with the double-leg versions at the start level of sets and reps. Progress to the target level sets and reps. Once this can be accomplished at RPE 6 to 7 out of 10 (see Table 1 above), move on to the single-leg versions, again at the start level. Once target is achieved, add load using the rucksack.

Technique and range of motion

Please pay attention to the details, particularly those defining the required range of motion.

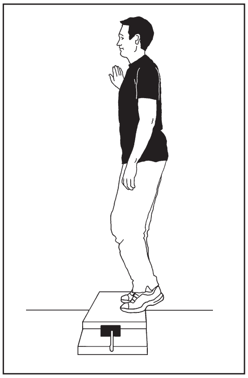
1. Calf raise, double leg, straight knee

Start position

- Stand with the balls of your feet on a step or stair
- Rear half of the feet are off the step
- Stand with your knees completely straight
- Stand upright with good posture: tummy in, chest out and shoulders back
- Place your fingers on a wall or stair rail for balance
- Do not lean or place your weight on to your hands as this will reduce the effectiveness on the calf muscles.

Movement

- Lower your heels until you feel a small stretch in your calf/ Achilles
- Slowly – for a count of two -- push up on to your toes
- Push all the way up, evenly, placing weight through both your big and little toe joints. This helps you to plantarflex the ankle with good alignment
- Maintain good posture throughout the movement
- Slowly lower down – for a count of three – until you feel the stretch; then continue.



2. Calf raise, double leg, bent knee

Start position

- Stand with the balls of your feet on a step or stair
- Rear half of the feet are off the step
- Do a 'knee squat' bending down until your knees are about 40 degrees flexed

- Hold the knee squat position with your knees slightly ahead of your toes and hips above your heels
- Set your upper body upright with good posture: tummy in, chest out and shoulders back
- Place your fingers on a wall or stair-rail for balance
- Do not lean or place your weight on to your hands as this will reduce the effectiveness on the calf muscles.

Movement

- As for straight leg, except:
- It is ESSENTIAL to maintain the knee squat position throughout
- If you allow the knee to extend as you push up on to the toes you will significantly reduce the effectiveness of the exercise
- Use your quads to brace the knee squat position at 40 degrees.

3. Calf raise, single leg, straight knee

Start position

- Stand with the ball of one foot on the step/stair
- Stand with your knee completely straight
- Bend your other knee so your leg does not get in the way
- Stand upright with good posture using “fingertip” balance as above
- Set pelvis using your core muscles
- Ensure pelvis is level and that you do not lean or place weight on one hand.

Movement

- As for double-leg, except:
- As you push up on to the toes, ensure you do not ‘hitch’ the hip
- It is even more essential that you do not lean or place weight on to your hands.

4. Calf raise, single leg, bent knee

Start position
- Stand with the ball of one foot on the step/stair
- Perform a single knee squat as described above
- Hold the 40-degree knee bend position
- Bend your other knee so your leg does not get in the way
- Stand upright with good posture, using "fingertip" balance
- Set pelvis using your core muscles
- Ensure pelvis is level.

Movement
- As for double leg, except:
- As you push up on to the toes, ensure you do not 'hitch' the hip
- It is even more essential that you do not lean or place weight on to your hands
- Remember – NO CHEATING by extending your knee.

5. Calf raise, single leg adding load with rucksack
- Perform the exercise with a rucksack on your back
- Bottles of water, sandbags or weights in the rucksack increase the load on the calf muscles
- 10kg in the rucksack will be a significant increase in bodyweight
- Progress by adding 10kg up to 40kg total load.
- If you do have access to a barbell, feel free to use this instead!
- With the increased load, pay extra attention to pelvis, ensuring it remains level throughout.

Group 3: Back extensors: erector spinae

Main muscles trained
Erector spinae group.

Assisting muscle groups
Multifidis, transverse abdominis, obliques.

Suitable for rehab from
Low back pain
Back injury.

These exercises are chosen to begin with gentle loading and do not involve hyperextension of the spine, which limits the lumbar compression forces. The "superman" exercises is low load and only trains one side of erector spinae at a time, hence the need to hold the position for a duration to provide sufficient training effect.

The back raise exercise involves greater load on the muscles, but the swiss ball allows the range of movement to run from flexed to neutral extension. This makes it superior to the dorsal raise exercise performed on the floor which hyperextends the spine (involving high compression forces). The progression focuses solely upon developing strength endurance, as this is most relevant for rehab purposes.

Table 3: Back exercise series

Exercise	Start sets x reps	Target sets x reps
Superman, leg only	2 x 10 each leg, hold each rep for 5 seconds	3 x 10 each leg, hold each rep for 10 seconds
Superman, arm and leg	3 x 10 each side, hold each rep for 10 seconds	3 x 20 each side, hold each rep for 10 seconds
Swiss Ball back raise (stop at extension)	3 x 10	3 x 20
Swiss Ball back raise, superman arms (stop at extension)	3 x 10	3 x 20

Progression
Start with the first exercise and progress from the start level to the target level of sets and reps. Once this can be accomplished at RPE of 6 to 7 out of 10 (see Table 1 above), move up to the next exercise, and so on.

Technique

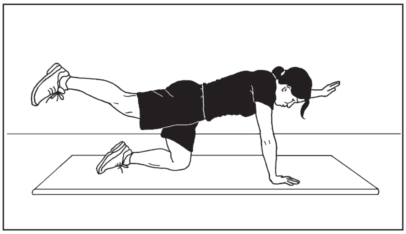
1. Superman, leg only

Start position
- Kneel upon all fours, hands below shoulders and knees below hips
- Adjust your lumbar spine to neutral position
- Ensure your upper back is also extended, chest out and shoulders back
- Set your core muscles, bracing your abdominal and obliques
- Stay relaxed and keep breathing.

Movement
- Slowly slide one leg backwards, extending the knee and lifting the foot slightly
- As you extend the leg back use your core muscles to maintain neutral lumbar and level pelvis
- Do not lift the leg above the horizontal
- Do not extend the lumbar spine
- Hold the leg extended for the required number of seconds

2. Superman, arm and leg

Start position
- As for previous exercise



Movement
- Slowly slide one leg backwards, extending the knee and lifting the foot slightly
- At the same time slide your hand forwards, lifting the arm
- As you extend the leg back and arm up, use your core muscles to maintain neutral lumbar and level pelvis
- Hold the extended position for the required number of seconds

3. Back Raise, Swiss ball

Start position
- Lie face down with your hips on a Swiss ball
- Use an appropriate ball size for your height. You should be able to place your feet on the floor with a slight knee bend and feel balanced with your hips on the top of the ball
- Place your hands by your head
- Allow your spine to flex around the ball.

Movement
- Slowly raise your chest up off the ball
- Stop when your back is straight – not hyperextended
- Pause at the top for one count and then lower slowly, flexing around the ball.
- Keep arms, legs and hips still during the movement.

4. Back raise, superman arms, Swiss ball

Start position
- As for previous exercise, except:
- you hold your arms extended out in front of your body

Movement
- As for previous exercise
- Ensure you keep your arms still as you perform the movement.

Group Four: the upper-body push-pull muscles – the shoulders, pectorals and latissimus dorsi

This is perhaps the most difficult area of the body for which to devise a progressive resistance programme without the use of gym equipment or free weights. It is common to devise programmes for balanced strength in the shoulder using machines such as the seated row, lat pulldown and chest press, plus dumbbell exercises. One minimal equipment option is to replace the machines and weights with resistance bands. You can perform lateral raises, bent-over row and even a lat pulldown of sorts with bands.

However, another option is to prescribe old-fashioned isometric exercises for the shoulder. Isometric exercises have great benefits for rehabilitation programmes because by definition they involve no movement and so can be performed in joint positions that produce no pain or excessive stress, which avoids jeopardising the healing process of the injury. In addition, useful isometric exercises can be performed in any house without any equipment.

Some isometric exercises, of course, are extremely fashionable, such as the plank and the gluteal bridge. These core stability exercises involve sub-maximal contractions, which are usually held for long durations (30-plus seconds) until fatigue. This means that the main benefit will be improvements to local muscular endurance: increasing the fatigue resistance of the muscles being worked.

To develop strength, isometric exercises have to be performed in a certain manner. The research supports maximal or near-maximal voluntary contractions held for 3-10 seconds. Unlike with weights work, you can perform these exercises daily and the literature suggests that the average adult can improve their muscle force this way by 0.5-1% per day following this kind of regime of isometric contractions (well-trained athletes would not achieve the same rate of strength development). The development of strength is confined to the 20 degree arc either side of the joint angle at which the isometric contraction is performed(1).

The exercises described below cannot be considered a substitute for the specific rotator-cuff or scapula stabilising work that any shoulder rehab programme will need – so you probably will have to get the resistance bands out as well. But as closed-chain isometric exercises, the stabilising muscles around the joint will be recruited to maintain good posture and joint position.

The limitation of using isometric exercises is that the strength gained during the static contraction does not promote dynamic function. Sports performers will have to add in dynamic functional movements before their rehab is complete.

The exercises are also very safe. Performed against a wall or in a doorway, the shoulder joint is positioned so that joint compression forces are not high. The patient is fully in control of how much effort they apply, which determines how much force is generated in the muscles – so they are unlikely to over-strain.

As there is no eccentric component, there is less risk of delayed onset muscle soreness and it may be possible to perform the exercises most days of the week. If you try the exercises for yourself you will quickly realise, as you feel the tension, that it is possible to get excellent recruitment of the muscles and that the muscles will fatigue – and therefore gain a training benefit – quite quickly.

Upper body isometrics series

Main muscles trained

Deltoids
Pectorals
Latissimus dorsi
Rhomboids.

Suitable for rehab from

Any upper-body injury that has resulted in loss of strength or atrophy of musculature.

Exercise	Start sets x reps	Target sets x reps
Single arm isometric press 1. Elbow 90 degrees 2. Elbow 140 degrees	5 x 5 sec hold each arm, for each exercise	10 x 10 sec holds
Isometric lateral raise 1. Arms by side 2. Arms at 45 degrees	5 x 5 sec hold each arm, for each exercise	10 x 10 sec holds
Single arm isometric pull 1. Elbow 160 degrees 2. Elbow 90 degrees	5 x 5 sec hold each arm, for each exercise	10 x 10 sec holds

Progression

When you perform the isometric contractions always aim to pull or push against the wall or doorway with a big effort. Think 9 out of 10 push or pull. This high-level effort will ensure a near maximal voluntary contraction so the strength benefit can be gained. If you cannot recruit the muscles with high force it is a sign that the injury has inhibited the muscle, in which case the exercise will be very beneficial at re-educating the muscle.

When you start these exercises you will find 5 reps of 5 sec contractions will reduce your ability to produce the high level of force. Soon you will be able to maintain 10 reps of 10 secs of strong contraction. Increase one second at a time until you do 5 x 10 secs and then increase one rep at a time until you reach 10 x 10.

Technique and arm positions

Please pay attention to the details, particularly those defining the position of the arm and elbow angle. There are two different positions for each exercise, because isometric strength development is highly muscle-length specific, with a small carry-over benefit. By training the muscle at two positions, you will be able to develop strength more evenly throughout the range of motion.

1. Single arm isometric press – elbow 90 degrees

- Stand in a doorway facing the threshold with one foot slightly in front of the other for stability
- Stand upright with good posture – tummy in, chest out and shoulders back
- Place one hand on the wooden frame, positioning yourself so your elbow is bent to 90 degrees
- The height of your hand will be the same as your shoulder, but keep your elbow below your shoulder to protect the shoulder joint
- Set your abs to control your body position, keep still when you push
- Push hard with your hand against the doorframe

- You will feel the chest and front shoulder muscles contracting. You will also feel the abs working hard to keep your body still
- Make sure your body is rigid, use your shoulder stabilisers to keep the joint in a good position. Avoid shrugging
- Breathe in just before each contraction and breathe out as you push.

2. Single arm isometric press – elbow 140 degrees

Same as above but position yourself a little further away from the frame, so that your elbow angle is about 140 degrees. Keep your hand at shoulder height.

3. Isometric lateral raise – arm by side

- Stand next to a wall, sideways on, with one foot slightly in front of the other for stability
- Stand upright with good posture – tummy in, chest out and shoulders back
- Place the back of your hand against the wall
- Your hand will be a few inches from your side
- Set your abs to control your body position, keep still when you push
- Push hard with your hand against the wall
- You will feel the shoulder muscles contracting. You will also feel the abs working keep your body still
- Make sure your body is rigid, use your shoulder stabilisers to keep the joint in a good position. Avoid shrugging
- Breathe in just before each contraction and breathe out as you push.

4. Isometric lateral raise – arm at 45 degrees

- Same as exercise 3 but position yourself a little farther away from the wall, bend your arm to 90 degrees and raise your arm to 45 degrees to the side so your forearm is against the wall
- As you push keep your forearm flat against the wall.

5. Single arm isometric pull – elbow 160 degrees

- Stand facing the threshold and to the right of a doorway with one foot slightly in front of the other for stability
- Stand upright with good posture – tummy in, chest out and shoulders back
- Place your right hand on the wall to the side of the door – you will use this hand to stabilise your body
- Extend your left arm through the door to grip the frame on the other side of the threshold, hand just below shoulder height and elbow at about 160 degrees
- Set your abs and push your right hand into the wall a little for stability
- Pull left hand hard towards you on the doorframe
- You will feel the rear shoulder and latissimus muscles contracting. Focus on trying to pull the elbow back, so your shoulder muscles rather than your biceps create the most tension
- Make sure your body is rigid, use your shoulder stabilisers to keep the joint in a good position. Avoid shrugging
- Breathe in just before each contraction and breathe out as you push
- Swap to the left hand side of the doorway and repeat for the right hand.

6. Single arm isometric pull – elbow 90 degrees

Same as 5, but stand closer to the doorway and grip the frame so that your elbow is at 90 degrees.

Raphael Brandon

Reference

1. Baechle 1994. Essentials of Strength and Conditioning Human Kinetics.

Notes

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