STRENGTH TRAINING

new advances for maximum gains

A SPECIAL REPORT FROM

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The research newsletter on stamina, strength and fitness

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From the editor

Once upon a time, strength training was the sole preserve of musclemen seeking bodily perfection in dark and sweaty gyms. Over the last 30 years however, a revolution has taken place. Sport scientists, coaches, trainers and athletes alike have realised that building strength and winning performance go hand in hand. All other things being equal, the stronger you are, the more power and force your muscles can produce and the less likely they are to fatigue, the faster you can accelerate and move, and the greater your resistance to injury. Moreover, these strength benefits apply across the board - even to endurance athletes!

Although we now understand the immense benefits that strength training can provide, the question of exactly how best to train for strength has remained largely unanswered. That’s because until very recently, the molecular biochemistry and physiology of muscle growth and development has been obscure and poorly understood. However, new advances in science have lifted the lid on what was once a seemingly impenetrable area, leading to startling conclusions. In particular, this new strength science looks set to blow many of the traditional beliefs and notions about strength training out of the water!

In this special report, we’ve assembled the very latest research on strength training, in particular how and why you should train for maximum strength and power gains, and just as importantly, how to achieve your strength goals in the minimum possible time. There’s also new research showing how athletes seeking both strength and endurance can train both efficiently without compromising the other, and how to apply the latest strength training science meet your specific sport requirements.

If you’re really serious about achieving your maximum sporting potential, maybe it’s time to take advantage of the latest strength science and steal a march on your opponents!

Andrew Hamilton BSc Hons MRSC

Get back to basics: building base strength whatever your sport

At a glance

- The concept of base strength is outlined;
- The importance of developing base strength for sportsmen and women is explained;
- A structured yet flexible eight-week programme for building base strength is provided.

There's no disputing the performance benefits of strength training for almost all sports. However, building base strength is essential and one of the most fundamental fundamental rules of base strength training is that, before focusing on sport-specific strength, you need to build up general strength capabilities. James Marshall explains how to achieve this goal with a two-month training plan…

With the advent of internet video workouts, it's very easy for junior or novice athletes to look at top athletes doing workouts and try to emulate them. If world champion 'X' is shown doing single- leg hops over 30 metres, then you can guarantee that the following week, physio couches all over the country will be laden with people who have tried (unsuccessfully) to emulate this routine! Unfortunately, copying drills *ad hoc*, without looking at how they might fit into an overall training plan, is all too common.

Why is strength necessary?

In some sports, strength work is still seen as a hindrance to the real work of endless sub-maximal monotonous drills and training runs. In other sports, such as judo or boxing or athletic field events, strength is recognised as an asset, but is not always trained systematically. In sports such as rugby, strength may be confused with size, with bigger players not necessarily being more powerful or stronger than their smaller counterparts.

Strength is the basis for speed, power, agility, and of course the ability to generate force. The timing and synchronisation of the muscle contractions are what gives the muscle specific strength; so in order to reproduce sport-specific strength, you have to replicate similar types of movements during your strength training.

Fatigue is directly related to technical and tactical work in all sports; if you become fatigued then your tactical judgement is affected, and your technical ability is less reliable. Better-conditioned athletes can maintain higher intensities for longer with less fatigue, which improves technical performance. Being stronger means both that you will be able to beat an equivalent opponent who is less strong, and that you will use proportionately less energy. In judo, for example, if you weigh 80kg and can deadlift 160kg, and your similar opponent can only deadlift 80kg, then when you lift them up to throw them down, you are using just 50% of your maximum effort while they would use 100%. You can do a lot more 50% efforts in a match than you can do 100% efforts, so by being stronger it allows you to do more work overall.

Strength is also an important factor in injury prevention. For example, one of the reasons that females are four to seven times more likely than males to suffer anterior cruciate ligament (ACL) injury is a lack of lower-limb strength [1-4]. But whatever your gender, in order to sustain the injury prevention benefits of strength training, you need to strength train throughout the year rather than just relying on a six-week pre-season blast[5].

What is base strength training?

Before training using sport-specific movements, you need to gain an overall strength base, which can take years of training [6-10]. If the movement pattern of this base strength training is sufficiently broad and the types of exercises used are varied, you can continue to develop your sporting skills while still having enough stimuli in your strength training to produce adaptation – *ie* strength gains.

This base strength training does not necessarily require significantly more load or volume. Instead, by using dynamically challenging exercises that require hand-eye and body-limb coordination, you will develop better movements, which will aid your sport performance. Even if you're an experienced athlete with many years of training in different forms of exercise, it's still worthwhile doing some non-specific work as a form of variety in the off-season, for two reasons:

1. At the end of the season, your body will probably be tired, stiff, sore and not in peak condition. It may not be able to withstand the loads involved in sport-specific training – *eg* speed or power work – straight away. Non-specific work, however, can enable you to train for balance by addressing areas of weakness/imbalance before you move on to sport-specific training;

2. The importance of mental freshness cannot be overestimated. One of the key causes of over-training is repetitive, monotonous training [11]. Off-season base training allows you to perform different exercises and activities, maybe in different and more stimulating environments than you have become used to.

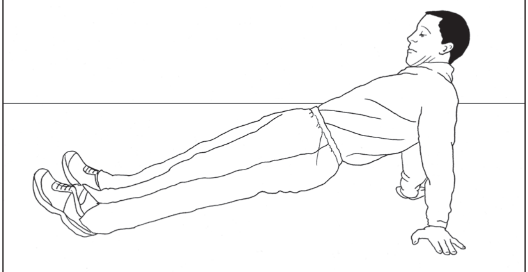
'If the movement pattern of base strength training is sufficiently broad and the types of exercises used varied, you can continue to develop your sporting skills whilst still having enough stimuli in your strength training to produce adaptation – ie strength gains'

Planning your training

For the purposes of this article I am assuming a two-month period of base training. This is an arbitrary figure, but you can extend or contract the basic principle, depending on the length of your off-season. The first thing to do is assess how many weeks you have available to train, how much time each week, what facilities you have, and which areas of strength need working on. Regarding the last point, this could include a review of any injuries you have suffered and would like to help prevent next season or where you felt weaker as the season went on. Once you have this information, you should split your training into two phases:

1. The transition phase – A fun, refreshing, non-specific period of training that includes localised strength development, injury prevention, joint strengthening exercises, flexibility training and endurance training.

Figure 1: Supine plank



2. The foundation phase – The hard core of fitness training, which works on localised muscle groups, using a variety of equipment and where progression and overload are initiated.

Within this two-month period, the first two weeks would comprise the transition phase and the last six weeks the foundation phase. If you have a shorter overall period, you should still use a two-week transition phase and reduce the foundation phase accordingly. Some ideas for training follow, but these are generic ideas and you should adapt your training to your individual needs and circumstances. Remember, there is no one magic exercise that is better than another; it's the timing, application and quality of the movement that counts.

Transition phase schedule (weeks 1-2)

This comprises three sessions a week of localised strength work, 30 minutes a session. Also, three flexibility sessions per week and two sessions of fun activities not related to your sport and not quantified in terms of times or distances – such as tennis, squash, swimming, volleyball, horse riding, etc.

Suggested warm-up: Either: 10 minutes of rock climbing – try to transverse across an indoor climbing wall; or try climbing a rope 10 times; or commando crawl, hands-and-knees crawl and bear crawl across a 10-metre area for 10 minutes.

Session: Try two to three sets of 10-12 repetitions of five of the following exercises in each session. You should change these each time you train, so that you don't do the same thing two sessions in a row:

- **Shoulder shrugs** – Hang from a bar (keep your arms straight). Try to move your head up to the bar by pulling your shoulder blades down your back;

Table 1: Schematic plan for foundation phase (weeks 3-8)			
Week 3	LS 1 (1/20/30)	LS 2 (1/10/60) DB	LS 1 (2/20/30)
Week 4	LS 2 (1/12/60) BB	LS 1 (3/20/30)	LS 2 (2/10/60) MB
Week 5	LS 1(3/25/30)	Overall (1/10/60-120)	LS 2 (3/10/60) SB
Week 6	LS 1(3/30/30)	Overall (1/12/60-120)	LS 2 (3/12/60) DB
Week 7	LS 1(3/30/30)	Overall (2/10/60-120)	S-P (2/5/120)
Week 8	LS 2(3/12/60) BB	Overall (2/12/60-120)	S-P (3/5/120)

Key: LS = localised strength, Overall= overall strength , SP= strength-power
DB = dumbbells, BB = barbells, MB = medicine balls, SB= sandbag.
The figures in brackets represent sets/reps/rest in seconds.

● **Perpendicular press-ups** – Do a press-up, but take one arm off the floor and point it to the ceiling, then come down and repeat on the other side;
● **Ankle bounces** – Keep your knees straight and use your ankles to jump a little way off the floor;
● **Multi-directional lunge** – Start with feet shoulder-width apart. Step forward with one leg and bend both front and back knees to 90 degrees, then return to start position. Now step in a different direction, to the side, or backwards and combinations of back and to the side. Try six reps each leg;
● **Plank** – Prone, supine (*see figure 1*), and side- hold for 30 seconds in each position. If this is easily done on the elbows, then make it more difficult by doing it with extended limbs, or having only one foot on the floor.

Foundation phase (weeks 3-8)

Here again we will focus on training three times a week for strength. Weeks 3-4 will consist of three 'localised strength' workouts. Weeks 5 and 6 consist of two localised strength and one 'overall strength' workouts. Weeks 7 and 8 consist of one localised strength workout, one overall strength workout and one 'strength-power' session (*see table 1 above*).

Localised strength workouts

Session 1 is mainly body weight exercises. Session 2 (overleaf) is equipment-based. Use dumbbells, barbells, medicine balls or sandbags for variety.

Session 1:

Start with one set of 20 reps of each exercise, then progress to three sets first over two weeks, building gradually to 30 reps per set. This may be difficult for some of the exercises, so just do as many as you can, then try to add one to two more reps each session.

- **Pull-ups** – Hang from a bar and pull your chin above it;
- **Squats** – Feet shoulder-width apart, sit down on an imaginary chair and stand up again;
- **Dips** – Using a parallel dip bar, or a chair, lower your body as far as you can and then extend arms to come up;
- **Crunches** – Lie on your back, knees bent at right angles, feet on floor. Move chest towards knees and back down again;
- **Back extensions** – Lie on front, hands on head and raise chest off floor;
- **Press-ups**;
- **Hanging leg raises** – Hang from bar, raise ankles to hands. If this is hard, bend your knees and bring them high towards your chest.
- **Lateral hop with squats** – Stand on one leg, hop sideways onto the other leg and then bend it to so that the thigh is parallel to the floor, stand back up and hop back to the starting leg and squat.

Session 2:

In these exercises, try using a weight that allows you to perform 10 reps safely. Progress to 12 reps; then, when you can achieve this, add a little weight and go back to 10 reps. Start with one set and progress to three sets over weeks 3-5.

- **Front squat** – Hold the weight on the front of your chest or top of front of your shoulders. Sit down on an imaginary chair and then stand up again;
- **Overhead press** – Sit/stand upright with the weight by your chest and push it above your head in a straight line, so that your elbows are in line with your ears, then lower it again;
- **Upright row** – Hold the weight in front of your thighs (palms facing towards you). Pull it upwards until it is under your chin, with your elbows above shoulder height, then lower it again;

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- **Weighted crunches** – Hold the weight on your chest and then do a crunch (see Session 1 if you need a reminder of how to do this);
- **Good mornings** – Either put the weight across the back of your shoulders or hold it level with your thighs. Bend your knees slightly and then bend forward from the waist until your back is parallel with the floor. Keep your back straight, don't hunch; then return to starting position;
- **Standing rotations** – Put the weight on the back of your shoulders. Keeping feet still, knees slightly bent, twist upper body to each side in turn.

Overall strength workouts

These exercises use more muscle groups in combination with each other, so are more challenging. Allow 1-2 minutes rest between each set, starting with one set of each. Again, you can vary this workout by altering the equipment used and resistance. Sets and progression are the same as for Session 2 of the localised strength (above).

- **Double arm get-ups** – Lie on your back with a weight on your chest, or, if using a barbell, lie under it. First sit up, then stand up, keeping the weight above your head at all times. Return to lying position but still keeping the weight above your head until you sit down;
- **Sumo squat with upright row to chin** – Stand with feet quite wide apart. Hold weight with hands close together, below the knees; straighten legs and pull the weight up under your chin then lower slowly. Keep your head up and back straight throughout the lift;
- **Reverse curl and press** – Stand with feet shoulder-width apart. Hold the weight against your upper thighs with palms facing towards you. Bend your arms to bring the weight to your chest then push the weight above your head. Lower the weight in reverse movement;
- **Tomahawks** – Stand with feet shoulder-width apart. Bring the weight from outside your left foot to above the right side of your head, repeat on the other side.
- **Front squat with press** – Hold the weight level with your upper chest. Sit down on an imaginary chair, then stand up and, in the same movement, push the weight above your head. Bring the weight back down to your chest and repeat.

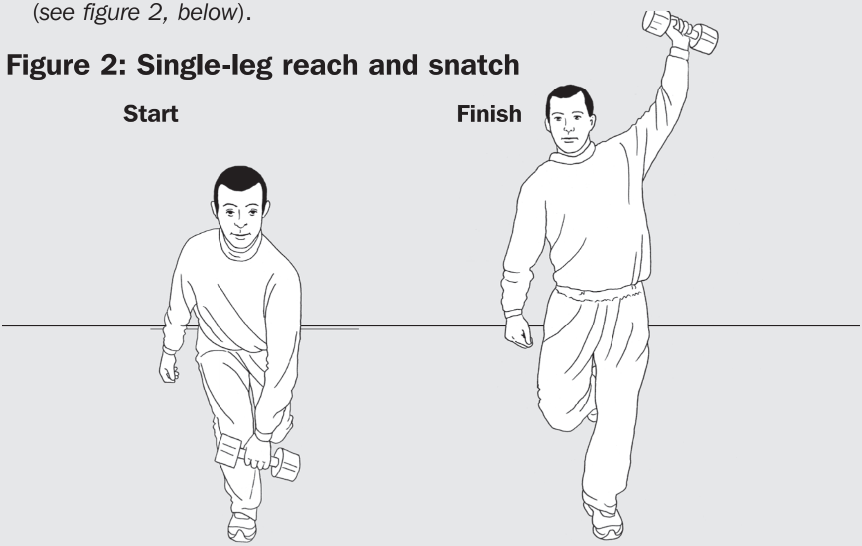
All the three sessions above (localised sessions 1 and 2, and overall strength) can be performed in a circuit fashion, progressing from one exercise to the next. Allow a one-minute recovery between the exercises.

Strength-power session

Do five reps of each exercise, rest for two minutes, then repeat. For the second week, do three sets.

- **Jumping jack with dumbbells** – Stand with feet together and hold the dumbbells level with your shoulders. Jump your feet apart and, at the same time, push the dumbbells above your head. Jump your feet back together, lowering the dumbbells at the same time;
- **Dumbbell swings** – Stand with feet quite wide apart. Hold one dumbbell between your legs and then swing it above your head, keeping your arm straight;
- **Squat jumps** – Hold the dumbbells by your sides and jump up as high as you can, making sure that you land safely. Then jump again.
- **Single-leg reach and snatch** – Stand on your left leg, hold the dumbbell in your right hand and outside your left foot. Jump on to your right leg and pull the dumbbell to above the right side of your head. Then change sides and repeat (*see figure 2, below*).

Figure 2: Single-leg reach and snatch



Core strength – is it overrated?

Although strength work begins from the core, this doesn't mean that core work should become the main focus of training. One study on running and core stability training showed that despite an improved 'core strength' there was no improvement in running economy, running posture or VO_2max in the subjects [12].

A study on Division 1 American Football players showed that core stability was only moderately related to strength and performance[13]. Here the authors compared core stability with 1RM (maximum weight that could be lifted for one rep) bench press, power clean and back squat, as well as countermovement jump, 10-yard shuttle runs and 20- and 40-yard sprints. The problem with this study was that the core stability tests were a measure of muscular endurance, but the performance tests all lasted less than 10 seconds. Also, this could be a chicken and egg situation – in order to back squat or power clean a large weight you must have a strong core, so was it the loading of these exercises that gave athletes a strong core, or a strong core that helped them lift the weight?

The bottom line is that most initial research has come from a clinical setting where patients with low back pain have been shown to have weak core muscles. Having a strong core should help prevent low back pain and then also allow you to withstand more strenuous activities that will then help youto be better at your sport. But having a strong core in itself has not been shown to help sports performance directly.

Summary

Planning your training will allow you to develop base strength that will provide a platform for more specific work to follow. This two-month sojourn away from normal training is necessary both physically and mentally. The exercises given here are just examples, and don't have to be followed religiously; the principles of variety and complexity of movements are what counts.

Practical implications

- Athletes should be aware of the importance of building strength fundamentals before moving on to sport-specific work;
- The start of the season is an ideal time to work on base strength; the programme provided in this article is a suggested route that can be adapted for a wide variety of sports.

References

1. American Journal of Sports Medicine 23, 694-701 (1995)

2. Am J Sports Med 22, 364-371 (1994)

3. Am J Sports Med 10 297-299 (1982)

4. Clinical Sports Medicine 287-302 (2000)

5. British J Sports Med 41,627-638 (2007)

6. Jesse, J, Wrestling Physical Conditioning Encyclopedia. Athletic Press: Pasadena, California (1986)

7. Foran, W, High Performance Sports Conditioning. Champaign, Illinois: Human Kinetics (2001)

8. Javorek, I, Javorek 'Complex' Conditioning. Self-published (2004)

9. Bompa, T, Periodization: Theory and Methodology of Training. Champaign, Illinois: Human Kinetics (1999)

10. Kurz, T. Science of Sports Training. Sation Publishing, USA (2004)

11. Kellmann, M. Enhancing Recovery. Champaign, Illinois: Human Kinetics (2002)

12. JSCR 18(3):522-528 (2004)

13. JSCR 22 (6), 1750-1754 (2008)

Squats – new research on an old favourite

At a glance:

- The importance of leg strength for athletes and the relationship between strength and power is explained;
- The execution and potential benefits of chain squats and squat jumps are described and recent research findings detailed;
- Suggestions are made on how athletes should use chain squats and squat jumps in a training routine.

The barbell squat is the king of all strength exercises bar none. However, squats are not only technically demanding, they're also one of the most exhausting exercises in the gym. But according to James Marshall, research suggests that squats and their variations have much to offer power athletes seeking a competitive edge.

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

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

Sprinters can generate forces of up to three and half times their body weight when racing, so having sufficient leg strength

JARGONBUSTER

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

Cross-bridge contractile activity
The ability of the contractile filaments in muscle fibres to slide over one another using special protein molecules (cross-bridges) to pull the filaments together and produce a muscle contraction. With a shorter muscle length, more of these protein cross-bridges are able to attach, producing a stronger contraction

to generate this force without injury is necessary [2]. This explains the commonly quoted guideline that a power athlete needs to be able to squat a weight equivalent to twice their body weight – *eg* an 80kg male rugby player should be able to squat 160kg.

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

Strength before power

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

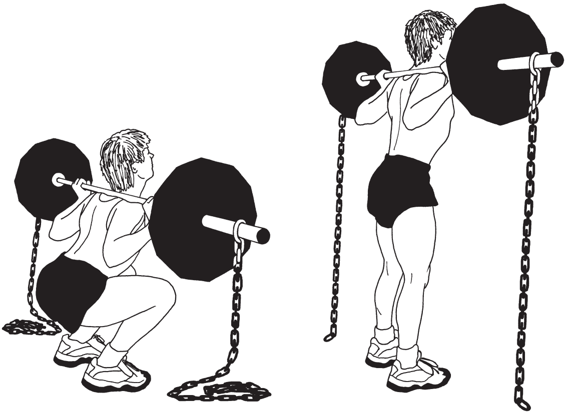
Post activation potentiation has not been fully explained yet, but the effects are the basis behind the theory of complex training, which combines strength and power exercises into small sets, where the muscles' ability to produce a more powerful contraction is improved by performing strength exercises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

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

Chain squats

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

The chain is attached to the top of the barbell, with some



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

At the bottom of the squat, when the quadriceps muscles are lengthened, there is less cross-bridge activation and the legs are at a mechanical disadvantage. So, although the external resistance is constant (the barbell), the force produced by the muscles isn't constant due to mechanical changes.

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

An alternative method is to use elastic bands or tubing, with one end fixed to the floor and the other to the barbell. Again, as

'One of the advantages of using chains and bands is that additional loads can be lifted; this additional load may produce greater force production and therefore strength gains'

the squatter descends less resistance is produced because the tension in the elastic is reduced, but more resistance is produced on the ascent due to the elastic lengthening and tensing.

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

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

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

Chain squat research

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

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

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

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

Squat jumps

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

However, the time and effort that it would be necessary to invest in developing the technical proficiency in these lifts to allow the athlete to lift loads that develop power, may be better spent in performing other

Description of exercises

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

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

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

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● Check that your heels remain flat on the ground during the entire lowering phase. Raising the heels increases the risk of injury to the knees by shifting the centre of gravity forward, in turn placing extra stress on the lower back;
● When the thighs are parallel with the floor, contract the thighs, buttocks and lower back, then begin the lift. Keep the upward movement smooth, but try and develop some 'drive' through the movement remembering to follow the same path as that through which you descended. The torso and back should remain erect and the hips remain under the bar throughout the ascent.

Squat jumps – This exercise is commonly performed with a barbell across the shoulders and with a much lighter weight than the squat.
● Stand with feet shoulder-width apart, descend until thighs are parallel to the floor as described above and then jump up with feet leaving the floor;
● Don't pause at the bottom part of the squat jump. Land on both feet and cushion the landing with a small bend of the knees, then return to standing position;
● Try not to make a noise when landing; this will help remind you to land with a cushioned knee, rather than a jolt.

Safety precautions – The squat is a very common exercise (every time you lower yourself into and raise yourself out of a chair without using your hands you are performing the squat action); however, care must be taken when loading the spine.
● If you have any lower back problems, or knee, hip or ankle joint problems, then you should get these treated before squatting unsupervised;
● If you cannot perform 10 squats with just your own body weight, then no load should be added across your shoulders;
● Squat jumps are more dynamic and can cause a jarring effect on the back and neck if not performed correctly. Do not perform loaded squat jumps if you cannot squat with a load equal to your body weight on the barbell.

‘Too heavy a load will slow the jump down. The velocity of the jump has to be enough to allow maximal power output to be achieved’

exercises that have similar benefits, but require less coaching – the squat jump being one such exercise.

How much load should be placed on the athlete? Well, the assumption made here is that they have already established a strength base (non-strength trained subjects respond differently to the squat jump than trained individuals, with loads as little as 5kg creating a decrease in peak instantaneous power) (7). However, too heavy a load will slow the jump down. The velocity of the jump has to be enough to allow maximal power output to be achieved.

Fortunately, measuring power output, or looking at changes in performance such as 20-metre sprint times, can identify the optimal load for squat jumps. One study looked at using either 30% or 80% loads of the subjects’ 1RM squat to perform squat jumps and then measure the changes in performance (8).

The 26 subjects followed an eight-week, twice-weekly training programme performing four sets of five jumps after warming up, with three minutes rest between sets. Both groups improved their 1RM and their peak power. The 30% group increased their peak velocity and decreased their 20m sprint times. The 80% group increased their 20m sprint times. So while both training modes were effective in increasing peak power and 1RM strength, the lighter loads had a much better impact on speed of movement.

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

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

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

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

Practical implications

- Weighted chain squats load muscles in a different manner to standard squats, and should be considered by athletes and coaches as a useful strength alternative to standard squats;
- Where speed is important, squat jumps are also a useful addition providing the correct loadings are used.

References

1. *JSCR 2005; 19(2):349-357*
2. *Bompa, T (1999) Periodization*
3. *JSCR 2005; 19(4):893-897*
4. *JSCR 2006; 20(1):162-166*
5. *JSCR 2002; 16(4):547-550*
6. *JSCR 2006; 20(2):268-272*
7. *J Sport Sci 2001; 19(2):99-105*
8. *JSCR 2002; 16(1):75-82*
9. *JSCR 2001; 15(1):92-97*

Training for strength – does intensity really rule?

At a glance:

- The differing types of strength are outlined and commonly used training systems identified;
- The role of intensity in building muscle mass is discussed and the link between lactate production and generating intensity is explained;
- The relationship between muscle mass recruited and optimum % of 1-rep max training is discussed, together with training to failure and optimum inter-set rest.

Unless you're a bodybuilder, ultimate muscle mass is far less important that the strength and power gains it can potentially bring. John Shepherd looks at the latest research, training theory and methods from a number of sports to determine the best ways to achieve maximum strength and power.

It's often thought that to develop maximum strength you need bigger muscles. To a degree this is true as bigger muscles can exert more force than smaller ones. However, athletes with the biggest muscles are not necessarily the strongest in terms of maximum lift ability. For example, a body builder may not be as strong as an Olympic or power lifter, despite having larger muscles.

Body weight is also a crucial determining factor as the lightest athlete may actually be the most powerful/strongest in terms of their power-to-weight ratio. A 70kg athlete who can squat 190kg has a higher power-to-weight and strength ratio than a 90kg athlete whose best squat is 200kg.

To gain strength (and/or size) the **weight training system**

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Weight training system
The exact combination of loading (weight), repetitions, set numbers, exercise order and combinations of exercises

Anabolic
Hormonal response resulting in increased growth

Growth hormone
A key anabolic hormone whose levels are elevated by exercise

Testosterone
An anabolic male sex hormone (also found in women) again elevated after exercise

Fast-twitch muscle fibre
Muscle fibres that produce high-intensity contractions necessary for power and size increase

employed must have a significant **anabolic** effect. This will stimulate increased muscle growth through the release of **growth hormone** and **testosterone**. These workouts also need to target **fast-twitch muscle fibre**.

Intensity rules?

A team of researchers from Finland investigated hormonal and neuromuscular responses and recovery in strength athletes versus non-athletes during heavy resistance exercise(1). Eight strength trained athletes and eight physically active but inexperienced athletes participated in the study. The 16 participants performed the 'forced' (FR) and 'maximum' (MR) repetitions training protocol – both of which are intense training systems. The MR protocol included 12 repetition maximum (12RM) squats for four sets with 2 minutes' recovery in between sets. For the FR protocol, the initial load was higher than in MR so that the subject could lift approximately eight repetitions on their own plus four with assistance.

Before and after the lifting protocols blood samples were taken to determine testosterone, **cortisol** and growth hormone concentrations and **blood lactate**. The researchers also measured maximal voluntary **isometric** force and **EMG** activity of the leg extensor muscles (quadriceps) before and after the workouts and 24 and 48 hours later. It was discovered that the concentrations of the hormones measured increased significantly after both protocols. However, the responses tended to be higher in the FR group, compared to the MR group. The researchers concluded that this could indicate a greater potential for strength increase, due to the increased anabolic muscle building and strength increasing response.

The researchers also discovered that testosterone concentrations were significantly higher for both the FR and MR protocols in the strength trained athletes. This could be attributed to the fact that these athletes were better able physically and (perhaps more importantly) mentally recruiting greater amounts of muscle fibre. This led the researchers to conclude that,

'*… at least in experienced strength athletes, the forced-repetition protocol is a viable alternative to the more traditional maximum-repetition protocol and may even be a superior approach*.' So going 'beyond the last rep/reps' (with assistance) seems to offer greater maximum strength gain potential.

Lactate release and intensity

Many bodybuilders believe that workouts producing higher levels of lactate will stimulate a greater anabolic response. One bodybuilding weight training system currently in vogue involves 10 sets of 10 repetitions with a 2-minutes' recovery between

Table 1: Different strength types and how to train for them

Strength type	Primary purpose	Most commonly used weight training system	Common sports applications
Strength endurance	To develop muscles' ability to produce repeated contractions under conditions of fatigue	High reps, 15 plus with light loadings, 30-50% 1RM and short recoveries	Field sports, rowing, martial arts
Power	To enable fast and powerful movements to be produced	Medium number of reps, 6-10 with medium to heavy loadings, 70-80% 1RM	Sprints, long jump, football, javelin,shot put
Maximum strength	To enable maximum loads to be lifted	Low numbers of reps 1-5, with heavy loading, 80-100% 1RM	Power lifting, Olympic lifting, shot put
Size with strength	To increase muscle size	Medium to high numbers of reps, 8-12 with medium to heavy loading, 70-80% plus of 1RM	Bodybuilding or sports such as American football where increased size is a valuable asset

There are different types of 'strength types' of which maximum strength is just one. Table 1 provides an overview of the way these 'strength types' can be developed using weight training. Most sports will require some or all of the strength types to be developed to one degree or another and the weight-training programme should reflect this. 1RM refers to 'one repetition maximum' – the maximum amount of weight achievable on one lift.

sets, with the weight at 80% of 1RM. These workouts work different body parts over four sessions a week, using a **split-routine** methodology.

During the workout, the first four sets are performed as quickly as possible, but with adherence to correct form. This workout is particularly interesting as it combines medium to heavy weights with 100 repetitions per body part, which would

Relationship between % of 1RM training load and exercise being performed

Very often athletes and their coaches perform and plan sessions that use the same number of repetitions across all exercises, for example 3 x 8 repetitions at 75% 1RM on squat, bench press, clean and lunge. A team of researchers from Connecticut set out to discover whether doing this was indeed the most effective way of increasing strength[4].

Their study involved trained (T) and untrained (UT) men. Specifically they wanted to determine what the maximal number of repetitions were that the two groups could perform doing free weight exercises at various percentages of 1RM. Eight T and eight UT men were tested for 1RM strength; they then performed 1 set to failure at 60, 80, and 90% of 1RM in the back squat, bench press and arm curl.

The team discovered that more back squat repetitions could be performed than bench presses or arm curls at 60%, 80 and 90%1RM for T and UT (although this was less pronounced at the higher 1RM percentages). No differences in number of repetitions performed at a given exercise intensity were noted between T and UT (except during bench press at 90% 1RM).

The team concluded that the number of repetitions performed at a given percent of 1RM is influenced by the amount of muscle mass used during the exercise, as more repetitions can be performed during the back squat than either the bench press or arm curl. They also concluded that the training status of the individual has a minimal impact on the number of repetitions performed at relative exercise intensities.

The implications for athlete and coach searching for increased maximum strength are fairly obvious in this respect; the number of repetitions employed at all percentages of 1RM should reflect the amount of muscle mass recruited by the exercise – *ie* the greater the muscle mass recruited in the exercise, the more repetitions the athlete should complete.

– if the loadings were lighter – develop strength-endurance. However, this workout is designed to produce strength with bulk – hence the addition to the traditional strength types in table 1, 'size with strength'.

This workout is incredibly tough. High levels of lactate will be produced in muscles; this indicates greater levels of anaerobic glycolysis (the breakdown of carbohydrate in muscles without oxygen), which in turn indicates a greater muscle stimulus. This should result in an increased potential for post-workout strength gains and crucially for bodybuilders, bigger muscles due to the sheer amount of muscle fibre recruitment, muscle protein breakdown and re-synthesis, and the magnitude of the crucial anabolic hormonal release.

A very interesting piece of research from India looked at the lactate responses of five Olympic weightlifters across their different lifts, the clean and jerk (CJ) and the snatch (SN) and different weight training systems across three workout types[2]:

- One repetition lift (ORL) – for this workout, the Olympic lifters lifted 30, 40, 50 and 60kg once with an interval of 5 minutes between lifts;
- Multiple set session (MSS);
- One set session (OSS).

Both the MSS and OSS consisted of six sets of lifts, with sets of 50% 1RM x 6, 60% 1RM x 5, 70% 1RM x 4, 80% 1RM x 3, 90% 1RM x 2, and 100% 1RM x 1. In MSS, 3 to 3.5 minutes' recovery was allowed between successive sets, whereas in OSS the interval was approximately 24 hours between each single set.

Not surprisingly from what has so far been presented lactate levels were very low in the ORL condition. In the MSS lactate response reached peak at an intermediate set (when reps were still relatively high and load relatively heavy). For the OSS workout it was maximum after the first set and then declined gradually (ie the set with the most reps produced the highest lactate concentrations on the first day). What about the actual lifts? Lactate levels were significantly higher for the clean and

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Cortisol
A hormone released from the adrenal gland that stimulates protein breakdown

Blood lactate
A by-product of intense exercise when carbohydrate is broken down for energy without sufficient oxygen, the accumulation of which

Isometric
Muscular contraction than involves no movement

EMG
Measurement of electrical activity in a muscle

Split routine
Weight-training system that trains one body part/ muscle group over one workout and another over another workout

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Periodised
Training plan that systematically and progressively builds fitness

Catabolic
Refers to the breakdown of body tissues such as muscle protein – detrimental to muscle and strength gains

jerk as opposed to the snatch. This led the researchers to conclude that, '… (a) anaerobic glycolysis is not stimulated considerably when the lifting time is only 4-5 seconds, (b) repetition of lift plays a more important role than intensity in lactate production, (c) CJ is more strenuous than SN for a given percentage of 1RM.'

So, we have a further vindication for higher numbers of repetitions producing the greatest potential for lactate production and therefore greater gains due to the subsequent response. It is apparent that the heaviest lifting does not necessarily produce the best physiological conditions for maximum strength gain.

Continuing with the intensity theme, a team of researchers from the Spanish Olympic Committee looked at the effects of three intensities of weight training(3). The team used the following lifts as their measures: the snatch, clean and jerk and squat, and 29 trained junior weightlifters were randomly assigned to 1 of 3 groups:

1) Low-intensity group (LIG)
2) Moderate-intensity group (MIG)
3) High-intensity group (HIG)

All subjects trained for 10 weeks, 4-5 days a week and followed a periodised training routine using the same exercises and training volume (expressed as total number of repetitions performed at intensities equal to or greater than 60% of 1RM).

However, there were different numbers of repetitions at intensities of 90-100% of 1RM for the three groups over the 10-week period. These were 46 repetitions for the LIG group, 93 for the MIG group and 184 for the HIG group. The key findings were as follows:

1) The MIG and LIGs displayed a significant increase for clean and jerk (10.5% and 3% for MIG and LIG, respectively) and squat (9.5% and 5.3% for MIG and LIG, respectively);
2) The increase in strength for the HIG increase occurred only in the squat (6.9%).

Inter-set rest and muscle strength

Rest has already been identified as a crucial factor in influencing the strength outcomes of weight training workouts. A review of relevant research indicated that shorter recoveries between sets seemed to be best for muscle size increases[5]. Again this was attributed to the greater concentrations of the anabolic hormones produced.

In terms of maximum strength, 1-2 minutes' rest was regarded as adequate. However, other researchers have discovered that strength increases are very specifically correlated to the reduction of rest between sets – ie the shorter the rest period the greater the strength gains.

A team from Australia discovered that sets with virtually no recovery between them (just a matter of seconds) produced superior strength gains to sets with a couple of minutes' rest between them for the bench press (9.7% and 4.9% respectively)[6].

However, interestingly, there were no differences in power outputs among the surveys of junior elite football and basketball players, as measured by 'bench throws' between either training protocols. So we have a further conundrum in the strength boosting stakes; the same workout albeit with different inter-set rest times appearing to have different strength gaining effects. This is very important for coach and athlete to dwell on. If maximum strength is the desired outcome then less rest seems to be a significant factor in a workout. If power is more desirable – as it is for the majority of sports – then a longer (2-4 minute) rest should be taken between sets.

This led the researchers to conclude that over the 10-week period the MIG protocol in particular produced the greatest enhancements in weightlifting performance compared with low and high volumes of high relative training intensities in experienced, trained young weightlifters.

So, as in the previous study, it appears that medium rather than maximum intensity loadings may optimally stimulate muscle fibre. In these scenarios the moderate weights are heavy enough to hit fast-twitch fibres, yet light enough to be moved relatively quickly, which seems to be the way to generate a highly desirable optimum anabolic hormonal response. So what about the lesser performance of the HIG group? Their performance could have been mitigated by the stress of the workouts. They could have simply been too tough and created a negative hormonal response in the survey's participants with particular reference to cortisol – of which more later.

Training to failure

'It appears that medium rather than maximum intensity loadings may optimally stimulate muscle fibre. In these scenarios the moderate weights are heavy enough to hit fast-twitch fibres, yet light enough to be moved'

It was indicated previously that forced repetitions can bring about superior strength gains. However, research by another Spanish team provides yet another variation in physiological response[7]. The study involved an 11-week programme of weight training to failure and non-failure. This was then followed by an identical 5-week peaking period of maximal strength and power training for both groups involved in the study.

The team examined the underlying physiological changes in basal circulating anabolic and catabolic hormones. Forty-two physically active men were matched and then randomly assigned to either a 'training to failure' group (RF), a 'non-failure group' (NRF) or a control group (C). Muscular strength and power were measured – the former by 1RM and the latter by bench throws. Blood analysis was also employed to determine basal hormonal concentrations. These tests were performed before and after 6, 11 and 16 weeks of training.

Both RF and NRF resulted in similar gains in 1RM bench press (23%), parallel squat (22-23%), muscle power output of the arm (27-28%), leg extensor strength (26-29%) and maximal number of repetitions performed during parallel squat (66-69%). However, the RF group experienced larger gains in the maximal number of repetitions performed during the bench press.

In terms of the peaking phase, prior NRF resulted in larger gains in muscle power output of the lower extremities, whereas after RF it resulted in larger gains in the maximal number of repetitions performed during the bench press. The researchers explained this (again) as a consequence of hormonal response. They noted that during the peaking phase, the NRF protocol resulted in reduced resting cortisol concentrations and an elevation in resting serum total testosterone concentration. This is a hormonal combination ripe for positive strength adaptation (high levels can have a catabolic effect). The researchers concluded that their investigation demonstrated a potential beneficial stimulus of NRF for improving strength and power, especially during the subsequent peaking training period. However, performing sets to failure resulted in greater gains in local muscular endurance.

Conclusions

Gaining the maximum amount of strength from your weight training is a far from simple matter. As we have seen, factors such as intensity, rest and hormonal response all play crucial roles. This is not helped by the myriad of research that is often contradictory. Although intensity seems to be the most important factor in achieving greater strength, it will be up to coach and athlete to carefully monitor and crucially plan their training to achieve the greatest returns using the systems that best suit their needs and those of their sport.

Practical implications

- There is no simple formula for designing a protocol that produces maximum strength and power gains;
- Coaches and athletes should be aware that high set volumes and poor recovery are not conducive to maximal strength gains;
- Forced reps and high intensity sets are potentially beneficial provided adequate recovery is allowed.

References

1. Can J Appl Physiol 2004; 29(5):527-43
2. Indian J Physiol Pharmacol 2001;45(2): 239-44
3. J Strength Cond Res 2006; 20(1):73-81
4. J Strength Cond Res 2006; 20(4):819-23
5. J Strength Cond Res 2006; 20(4):978-84
6. J Sports Med Phys Fitness 2004; 44(4):361-7
7. J Appl Physiol 2006; 100(5):1647-56. Epub 2006 Jan 12

Work, rest and play for maximum power

At a glance

- The link between strength, power, power to weight and sports performance is explained;
- Research on optimum recovery periods for maximum strength and power gains is presented;
- The importance of exercise order as a 'rest factor' is explained.

Just what is the optimum rest period between sets to derive maximum explosive power and strength from your weight training workouts? John Shepherd looks at what the latest research has to say…

How long you rest between reps and sets when weight training can have more of an effect on maximising your strength and power returns and building lean muscle than you might realise. Maximum strength is achieved by lifting as heavy weights as possible – 80 to 100% of **1-repetition maximum** (1RM) over low (1-4) rep ranges. In contrast, power is generally developed by using medium to heavy weights (60-80% of 1 RM) over medium rep ranges (6-12).

Most coaches will probably argue that both strength and power require relatively long recoveries between sets if the athlete is to achieve 'maximum strength and power, as well as promoting quality lifting' with little fade. However, when pressed as to exactly how long the athlete should recover between sets and reps, they may be less sure.

Whereas 'a couple of minutes' might be enough for a maximum strength developing session comprising 3 x 3 reps at

90%1RM, will it be enough for a 4 x 10 reps at 75% of 1RM power sessions, where the weights are moved as fast as possible? Some coaches may also argue that a shorter recovery is better, due to a greater hormonal and muscle building response, something we'll come to later.

Thoughts of an expert

Tudor Bompa is one of the world's foremost strength and conditioning experts and is the only coach to have produced an Olympic champion in a power event (javelin) and a world champion in an endurance event (rowing).

Bompa has devised numerous strength training protocols for what he calls the 'periodisation of strength' – the progressive development of strength through various resistance training methods, notably weight training, which is specifically relevant to improving sports performance (1).

Limitations on space prevent a detailed analysis of his theories; however, a focus on what he calls 'the maximum load method' is a useful starting point for the analysis of rest between reps and sets when weight training. This focus is also considered relevant because it is argued that developing this type of strength is critically important when it comes to producing strength that directly benefits power athletes. Box 1 explains the some of the benefits of the maximum load method.

For Bompa, rest is a crucial training variable in the development of strength and power through the maximum load method. This is clearly put into context by the requirement of these workouts to create as he puts it, 'the highest possible tension in a muscle' (1). As a consequence, exercises must work the prime movers involved in the athlete's chosen sport – for example, the calf muscles, hamstrings, quads, glutes and hip-flexors of a sprinter.

The reps must be also be kept low (1-4) to enable the athlete to achieve the highest possible muscle tensions. And crucially, the rest period must be long enough to enable a 'full out attack' on each lift. Experienced athletes know that they only have a certain amount of 'energy' for these types of workouts; Bompa

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1-repetition maximum
The maximum amount of weight that can be lifted (with good form) for one repetition

Motor unit
Nerves and bundles of muscle fibres that produce muscular action in a specific muscle

Fast twitch muscle fibre
Muscle fibres primarily responsible for producing speed and power

Box 1: some important benefits of Bompa's maximum load method

- The maximum load method (MLM) increases **motor unit** activation resulting in high recruitment of **fast twitch fibre**;
- This method has a high neural (mental focus) requirement, which can translate to improved sports performance by enabling the increased recruitment of fast twitch muscle fibre;
- MLM is important in sports where increased power is required but without an increase in muscle mass. Increased mass could increase the athlete's weight and therefore interfere with power capability (as a consequence of altered androgen (growth) hormonal stimulation);
- MLM improves synchronisation of muscle groups under heavy loading, resulting in improved sports performance and a 'smoother' and more skilled performance while recruiting maximum amounts of fast twitch muscle fibre and performing powerful activities. This results in improved dynamic sports skills.

is also aware of this and therefore argues that only 3-5 exercises should be included in a relevant workout. If there are more then the athlete will be unable to maintain the desired workout intensity, both physically and mentally.

To this end, he advocates a recovery of between 3-6 minutes between sets for optimisation of performance. Six minutes may seem an awful long of time between a set comprising of perhaps only two lifts, but Bompa argues that it is needed to allow the athlete to put maximum effort into each lift. As he puts it, 'To stimulate the necessary physiological and morphological central nervous system changes, higher number of sets should always take precedence over a higher number of reps.' Not only does this generous rest period allow 'maximum commitment' for every set from the athlete, but it also allows ample replenishment of creatine phosphate and adenosine tri-phosphate (ATP), the body's high-energy compounds between sets.

Recovery and hormonal response

Athletes and coaches may rightly believe that shorter recoveries induce greater muscle hypertrophy (growth), especially when

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Immediate and short-term anaerobic energy systems
Energy systems that can produce quick, powerful muscular contractions, without reliance on oxygen

Power to weight ratio
The amount of power that can be produced per kilo of bodyweight – an important indicator of sports performance

Mesocycles
Medium length training phases, lasting usually 3-6 weeks

combined with lifting medium to heavy weights fast. This is a protocol used extensively in bodybuilding. They may also believe that this is the best way to improve sports speed, for example. Training in such a way will boost growth hormone and testosterone production, increasing the potential for increased muscle size, as well as developing muscular power. And since a larger muscle is often equated with greater power potential it is easy to see this correlation.

Shorter recoveries

A growing body of research indicates that short recoveries between sets and reps, and the use of medium to heavy weights over 8-12 rep ranges maximises the release of the strength and muscle building hormones, testosterone and growth hormone. For example, Brazilian researchers discovered that a 30 seconds' recovery between sets for women, who performed the same 4 exercise lower body weights programme, produced superior growth hormone release compared to 60 and 120 second rest periods (incidentally, no difference was found between the 60 and 120 second protocols) [(2)]. Other research has indicated that the more dynamic the exercise, the greater the hormonal response [(3)].

However, this could be detrimental to sports performance because weight gained could reduce **power to weight ratio**, which is crucial for performance in many sports. The good news is that a muscle can be made to be a great deal more powerful without a significant increase in size and weight. But in order to achieve this, the rest period between sets and reps becomes very important.

Recovery and power

Researchers from Australia looked at the effects that breaking down a 6-rep maximum session (this requires the athlete to lift a load that would induce failure on the 7th rep if performed) into single, double and triple rep sets had on strength gains in 26 elite junior male basketball and soccer players[(4)]. To test this, three 'inter-repetition' groups were established:

Why the need to develop maximum strength for speed and power sports?

Bompa believes that speed, power and agility can only be significantly enhanced by the development of increased maximum strength, predominately created via the periodisation of strength and a maximum load phase. Basically, if the athlete is able to recruit stronger and more fast twitch muscle fibres, they will become more powerful, faster and agile. Training for power alone is not considered adequate to achieve this.

1. Singles group; performed 6 x 1 repetition with 20-seconds' rest periods between each repetition;
2. Doubles group; performed 3 x 2 repetitions with 50 seconds between each pair of repetitions;
3. Triples group; performed 2 x 3 repetitions with 100 seconds' rest between each 3 repetitions.

The subjects performed bench presses using their 6RM load and the power output for each repetition was recorded.

The researchers discovered that significantly increased power outputs (25-49%) were achieved over the later repetitions (numbers 4-6) of all three loading schemes above. Significantly greater total power output (21.6-25.1%) was observed for the inter-repetition rest interventions (schemes 2 and 3) when compared to traditional continuous 6RM total power output (scheme 1).

The researchers concluded that 'utilising inter-repetition rest intervals enables greater repetition and total power output in comparison to traditional loading parameters'. This could equate to the development of greater power potential for specific sports training and competition, subject to a relevant sport specific conditioning programme.

Researchers from Illinois compared squat strength gains and volume (total amount of weight lifted) when resting for 2 minutes or 4 minutes between sets over multiple **mesocycles** [5]. Fifteen trained men were matched and randomly assigned to either a 2-minute (7 subjects) or a 4-minute (8 subjects) rest

Hormones, the endoctrine system and weight training

Hormones are 'chemical messengers' produced by the endocrine system and endocrine glands, such as the hypothalamus in the brain and the gonads. The major function of hormones is to change the rates of specific reactions in specific target cells. Muscle fibres, like the rest of the body, are constituted from cells and the way a hormone interacts with these can significantly affect training adaptation.

Growth hormone (GH) – GH is released from the anterior pituitary gland in the brain soon after exercise commences. GH is often regarded as the 'sport hormone' because it is involved in numerous anabolic functions, relating to cell proliferation and division throughout the body. Specifically, GH stimulates bone, cartilage and muscle growth and can play a very significant role in lean muscle mass and fat deterioration/accumulation. This explains why it has been used as an illegal ergogenic aid! GH release via exercise is also augmented by a further chemical reaction. Basically, hormones that would otherwise act to blunt GH production (eg somatostatin) are suppressed by the production of other chemicals produced during exercise (endogenous opiates). In short, GH's ergogenic training-induced effect can contribute toward creating a leaner, stronger more powerful athlete.

Testosterone – testosterone is produced in men through the testes and in women (though to a much lesser extent) via the ovaries. The primary role of testosterone is to augment the release of GH and also to interact with the brain and nervous system. For example, an increased level of testosterone can produce greater feelings of aggressiveness/dominance. The mechanisms behind this process (and other hormonal influences on behaviour) are complex.

Cortisol – is released from the adrenal gland and its levels are also elevated by exercise. Cortisol stimulates protein breakdown, leading to the creation of energy in the form of glucose in the liver. This is not so good for those looking to build muscle, as amino acids (released via dietary protein breakdown) become preferentially used for energy production rather than muscle building.

interval group. Each performed the same training programme.

Two workouts were performed a week; one was labelled 'heavy' and the other 'light'. The workout intensity was varied, as were the number of sets and repetitions. However, each group stuck to their designated recovery periods. The researchers looked at the differences in strength gains and the loads, intensity, volume and repetitions utilised per set and compared these between the groups.

Both groups demonstrated large strength gains, although the magnitude of these gains was not significant between the two groups. However, during all mesocycles, the 4-minute group demonstrated significantly higher total volumes for the heavy workouts – they were able to lift more weight as a consequence of their longer recoveries. The team therefore concluded that, 'athletes attempting to achieve specific volume goals may need longer rest intervals initially, but may later adapt so that shorter rest intervals can be utilised without excessive fatigue, leaving additional time to focus on other conditioning priorities.'

This research provides part-corroboration for longer recoveries between sets when weight training for increased strength. It is possible to argue that once the gains in strength for the high volume group began to tail off over a number of mesocycles, a different training methodology should have been implemented in order to capitalise on this increased volume.

At this point it is crucial to appreciate that sports strength is different to 'strength gains for strength's sake only'. Gaining strength is an adjunct (although crucial) to the conditioning needs of the athlete. There is no point in gaining strength for athletic purposes unless that strength then becomes usable – hence the need for a specifically prepared and relevant training programme.

'A growing body of research indicates that short recoveries between sets and reps, and the use of medium to heavy weights over 8-12 rep ranges maximises the release of the strength and muscle building hormones'

Exercise order as a rest factor

The order of exercises in a weights workout can have a significant influence on the outcomes of a workout and should be considered as a rest variable. If you perform all your sets on one exercise consecutively with a specific rest period, is this the same as performing the same exercises after three, four or five different exercises have been performed before it in a 'circuit' style workout? Very few research studies have actually explored this theme, but one from Holland has [6].

The specific purpose of the study was to, 'examine the effect of exercise order on back squat performance in the context of a whole-body workout'. Nine resistance-trained male subjects performed back squats, using the following system – 4 sets at 85% of 1RM, on 2 separate occasions.

Protocol A involved the squat being performed first;
Protocol B involved the squat being performed after a whole-body resistance-exercise session.

The researchers measured the number of repetitions, average power, and rating of perceived exertion (RPE) for each protocol from the subjects.

What they discovered was that while there were no significant differences in RPE values between the 2 protocols, all subjects performed significantly more repetitions during the first set of protocol A (squats), compared with protocol B. However, and rather surprisingly, the average power for the squats was higher during protocol B compared with protocol A. The team summarised their findings thus, '…. performing the barbell back squat first in an exercise session allowed the completion of more total repetitions.'

But why did protocol B produce (on average) more power than A? The researchers theorised that the greater power outputs for the squat were more than likely attributable to the preceding power exercise, the hang pull, and an effect called postactivation potentiation. This effect can be achieved by performing a dynamic exercise (in this case the hang pull) to enhance the activation of the neuromuscular system, which then enhances the performance of one subsequent exercise (in this case the squat).

Conclusion

The length of the rest period between exercises and sets in a weight training workout can have a big influence on the outcomes of a workout and this can have crucial sports training implications. The coach and athlete must think carefully about this and general weight training programme design, if they wish to maximise sports specific transference.

It appears that for increasing speed and power potential, optimum recovery needs to be longer than may have been previously thought, for example 3-6 minutes for maximum load weight training. The order of exercise is also important.

Practical implications

- Athletes and coaches should be aware that rest and exercise order are crucial variables to consider when designing a weight training programme;
- Research indicates that for maximum power, low rep sets combined with long rests may be particularly effective.

References

1. The Periodisation Of Strength (2nd edition), Bompa T, Human Kinetics 2005

2. J Sci Med Sport. 2007 Dec 17 (4): 560-567

3. Indian J Physiol Pharmacol. 2001 Apr; 45 (2): 239-44

4. J Strength Cond Res. 2006 Feb; 20 (1): 172-6

5. J Strength Cond Res. 2008 Jan; 22 (1): 146-52

6. J Strength Cond Res. 2006 Feb; 20 (1): 141-4

Girl power is good for young sportswomen!

At a glance

- The benefits of strength training for young female athletes are outlined;
- A 'general preparation phase' is described, which serves as an ideal introduction to strength conditioning for junior females;
- More advanced dumbbell circuits are given, together with jumping and landing drills, to reduce injury risks.

Strength training is critical for maximum sporting performance, but it's still an alien and uncomfortable concept for many junior female athletes who are often unaware of the benefits or, if not, are unsure how to begin. The solution, according to James Marshall, is a six-month general preparation programme, which can serve as the perfect introduction.

The higher the level at which a sport is played, the better the physical performance parameters such as aerobic power, speed, strength and vertical jumping ability are likely to be – an association observed in Australian volleyball players and male rugby league players[1,2]. However, are the higher fitness levels due to natural athleticism, or is it due to better access to fitness advice and facilities? Would a better fitness level at a younger age help an athlete improve their playing skills and progress them to a higher playing level earlier?

At elite levels, physical fitness is very important because (as studies on elite Australian female rugby league players have shown[3]) poor physical capacity limits the ability to play at a higher level. Ideally, athletes should be selected at a young age then given correct coaching in skills and tactics, as well as a progressive conditioning programme to enable them to perform at high intensities throughout matches. Unfortunately, limited funding and accessibility usually mean that this type of support only becomes available once the player has already broken into a squad or team at a representative level.

Many male athletes have some conditioning background, and whether this is correct or not, they usually see the benefits of strength training for their sport(4). However, this is not the case for younger female athletes; by not starting a strength programme early enough, these athletes may not only increase their chance of injury, but also reduce their ability to play as hard as they otherwise could.

In this article, we'll look specifically at junior female athletes aged 14-18 years old. Research shows that once female athletes begin resistance training (RT), they not only enjoy it, but it also may help promote their own self-image(5). Indeed, this may be of wider significance for all young females, as their overall physical activity tends to decline after the age of 16, and starting an RT programme that enhances body image may be useful in preventing this(4).

Jargonbuster

General preparation phase (GPP)
The initial stage of training that develops sound technique and the capacity to deal with future workloads.

Benefits of strength training

Why should junior female athletes strength train? Isn't just being fit and healthy, and playing sport sufficient? Unfortunately, this isn't the case. The two major reasons for RT in junior female athletes are injury prevention and playing performance. Female athletes appear to have a higher incidence of lower-limb injuries than male athletes with studies showing that they are two to eight times more likely to suffer knee injuries(6-9). This may be linked to strength and flexibility imbalances in the lower limb, both of which can be addressed through correct training.

One study from 1991 used a pre-season screening test in female college athletes from a variety of sports, and showed that 40% of the 138 athletes studied suffered an injury that season(10). The authors also found that there was a trend for higher injury rates to be associated with knee flexor or hip extensor imbalances of 15% or more on either side of the body. What coach can afford to lose nearly half of their players through injury in a season? If even only a portion of those injuries could be prevented through correct training, surely that would help the team or squad?

Getting started

In his book *Track and Field*, Gerhardt Schmolinsky states that the length of the 'foundation training' depends on the age of the athlete, general training background, and on the volume and intensity of workouts. It usually lasts three to four years. 'Build up training' usually starts at the age of 13 or 14, takes about four to six years and should not be completed before the age of 17 or after 22[15].

Injury causes and prevention in adolescents

The incidence of injury has been shown to be worse in younger children than in college age athletes, and sport is the biggest cause of injury in young adolescents[11,12]. A review of literature on sporting injuries in adolescents by Abernethy and Bleakely highlighted the importance of preparation before playing sport[13]. In their review the authors listed some of the proven strategies that assist in limiting sporting injuries. They are:

- Pre-season training
- Functional training
- Education
- Strength and balance training programmes that are continued throughout the season

In the pre-season, the athlete can be taught the use of landing techniques, strength training for the lower limb (especially for females), flexibility, game-related agility and aerobic fitness. These techniques can then be incorporated into a structured warm-up and used throughout the season. Interestingly, with the exception of gumshields, the evidence for use of equipment for reducing injury risk was inconclusive. The role of coaching must also be taken into account, with correct technique and safe tactics being taught.

Attitudes to resistance training in young females

If female athletes are more likely to get injured than males, and strength/flexibility imbalances are a potential cause of this at college age, surely it makes sense to prevent this earlier on? One reason this may not be happening is a misunderstanding of what RT involves. Proper education and progression leads to confident, strong and effective female athletes. Improper education and no progression can lead to female exercisers and athletes who are often intimidated by their training environment and who lose confidence. There should also be an element of fun, without losing sight of safety, which enables the athletes to enjoy themselves. This is a massive generalisation but it is a real coaching issue; it's a well-known fact that other sports such as swimming lose female athletes when progression, fun and ability are not catered for(14).

It's important to realise that there are no shortcuts. A 17-year-old female athlete who has no prior RT experience should not be doing the same work as a 16-year-old female athlete who has two years' RT experience. Instead, she should again start from the beginning with a foundation programme.

All athletes should ideally have a pre-training musculoskeletal assessment to assess flexibility and strength levels. The major area to look at is possible imbalances between limbs and between muscle groups in flexibility and strength. Strength testing has to be done carefully with novice trainers; setting a lesser weight and then asking the athlete to lift that as many times as possible is safer than and equally as effective as maximal 1-repetition tests(16). For example, rather than attempt a 1-rep max, you might ask your athlete to back squat with just a 10kg or 20kg bar on the shoulders and see how many times they can do that with good form.

The **general preparation phase (GPP)** is important to help introduce the athlete to the training environment, develop core and limb strength, to teach safe and effective techniques and also to introduce the training habit. One of the simplest ways of developing strength is to use the athlete's own body weight. Two such circuits are shown in table 1 opposite.

Table 1: General preparation phase body weight circuits

Circuit 1	Circuit 2
⁕ **Press-ups** ⁕ **Crunches** ⁕ **Squats** ⁕ **Back extensions** ⁕ **Bench jumps**	⁕ **Bench dips** ⁕ **Half-pikes** ⁕ **Single-leg squats** ⁕ **Reverse press-ups** ⁕ **Alternate-leg squat thrusts**

Exercise descriptions:

⁕ **Press-ups** – Lie on the floor face down with your hands next to your shoulders, raise your body off the floor by extending your arms, then lower again.

⁕ **Crunches** – Lie with your back on the floor, legs bent, feet flat on the floor. Place your hands on your thighs and lift your head and upper back off the floor sliding your hands up your thighs until they are on your kneecaps. Lower yourself back down again.

⁕ **Squats** – Stand with feet shoulder-width apart, bend your knees and lower your backside towards the floor, keeping your feet flat on the floor. Then stand up straight and repeat.

⁕ **Bench jumps** – Jump up on to a bench and back down again with both feet.

⁕ **Bench dips** – Sit on a bench with legs extended out in front of you, hands by your sides, raise your bum off the bench and onto the floor using your arms.

⁕ **Half-pikes** – Lie on the floor with legs vertical, arms straight above your head with hands on the floor. Reach up to your toes and back down again.

⁕ **Single-leg squats** – On one leg, lower your backside down to a bench and stand back up again without using your hands. Keep your supporting foot flat on the floor.

⁕ **Reverse press-ups** – Lie on your back, knees bent, feet flat on the floor. Bring your hands back over your head and place your palms flat on the floor. Lift your head and back off the floor by straightening your arms.

⁕ **Alternate-leg squat thrusts** – Start in a press-up position, bring one foot forward with your knee between your elbows, then return the foot back while simultaneously bringing the other foot forward.

Table 2: Junior training dumbbell circuits

Circuit 1	Circuit 2
⁕ **High-pull snatch** ⁕ **Squat-push press** ⁕ **Bent-over row** ⁕ **Squat jump, raise to armpits** ⁕ **Parallel overhead press** ⁕ **High-pull snatch**	⁕ **Inward/outward rotation** ⁕ **Alternate-leg lunges** ⁕ **Upright row** ⁕ **Rotational-push press** ⁕ **Lateral raise** ⁕ **Squat-jump push press**

Exercise descriptions:

⁕ **High-pull snatch** – Hold the dumbbells level with the middle of your thighs, raise them above your ahead as though you're pulling your T-shirt up. Come up on to your toes and then lower again.

⁕ **Squat-push press** – Hold the dumbbells level with your shoulders, squat down until your thighs are parallel with the floor, then extend your legs, come up on to your toes and at the same time extend your arms so the dumbbells are above your head. Lower again into the squat position to repeat.

⁕ **Bent-over row** – Bend forward from the hips, keeping your back straight until it's parallel with the floor. In this position, raise the dumbbells to your chest and lower them until your arms are straight.

⁕ **Squat jump, raise to armpits** – Bend both knees until your thighs are parallel with the floor and then jump as high in the air as you can. At the same time bring the dumbbells up to your armpits, then land and let your arms hang down by your sides.

⁕ **Parallel overhead press** – Start with the dumbbells level with your shoulders, palms facing towards each other. Extend your arms above your head then lower them.

⁕ **Inward/outward rotation** – Hold the dumbbells out in front of you arms straight and parallel to the floor. Bring them into your chest and then out to the side and then to the front again in a circular motion, but keeping them at shoulder height. Reverse this direction after six repetitions.

⁕ **Alternate-leg lunges** – Holding the dumbbells by your side, step forward with one leg and bend the front knee and back knees to about 90 degrees, keeping your back straight. Push off the front knee and return to start position then repeat on the other leg.

* **Upright row** – Start with the dumbbells on your upper thighs, palms facing towards you. Pull them up to chest height with your elbows coming higher than your shoulders. Rise up on your toes as you do this.
* **Rotational push press** – Start with the dumbbells level with your shoulders, palms facing towards each other. Extend your arms above your head, and turn the dumbbells 90 degrees until your palms are facing forwards, then lower them and rotate back to the start position.
* **Lateral raise** – Hold the dumbbells by your sides and raise them sideways to the same height as your shoulders keeping your arms straight. Then lower them.
* **Squat-jump push press** – Start with the dumbbells at shoulder height, palms facing towards each other. Bend both knees until your thighs are parallel with the floor and then jump as high in the air as you can. At the same time extend your arms above your head, then land and lower the dumbbells to the start position.

An example of how to organise these body weight circuits would be to do 20 repetitions of each exercise and then move on to the next one, performing all five exercises in a continuous fashion. After each set, rest one minute then repeat. Do five sets in total.

To make the session easier, try fewer repetitions of each exercise, or add 10 seconds rest in between exercises. To make it harder, perform the five sets in a continuous fashion without rest. Even harder would be to do the total repetitions of the first exercise before moving on to doing the total repetitions of the second exercises so 100 press-ups immediately followed by 100 crunches and so on.

One of the important things for junior coaching is making the sessions fun and varied. The use of lots of different exercises, changing the format of circuits, adding medicine balls, elastic bands or household objects such as chairs ensures that the athlete has to constantly adjust and improve.

Once the athlete has become confident in this environment, the coach can start to introduce the use of dumbbells. Dumbbell circuits are popular among high school and college coaches in the US including ex Romanian weightlifter Istvan Javorek, who pioneered the use of dumbbell circuits as part of general athletic preparation and now uses them as a basis for all new athletes entering his program[17]. Two such circuits are shown in table 2 on page 56.

'Changing the exercises each session keeps the athlete interested and means that the body has to adapt to a new stimulus each session'

These dumbbell circuits are performed in a continuous fashion, with six repetitions of each exercise being performed before moving straight on to the next one. After each set, rest for 90-120 seconds and then repeat. Look to build up to six sets first after which you can look to increase the weight of the dumbbells.

There are literally hundreds of different combinations that can be performed using dumbbells; it's down to the coach to think about the relevant movement patterns and how to incorporate them. Start by thinking of pushing, pulling, squatting, jumping and rotating. Then think about using one or two dumbbells at a time, seated, standing, one leg, two legs and so on. Changing the exercises each session keeps the athlete interested and means that the body has to adapt to a new stimulus each session.

Jumping and landing techniques

Simple jumping and landing techniques can be introduced at this stage – not as lengthy individual sessions, but as part of the warm-up, or as part of the circuits. Training females on landing techniques has been shown to help landing mechanics, which in turn assist in preventing knee injuries[18].

Concurrently with body weight and dumbbell exercises, you can start to introduce technical barbell work in order to help the athlete gain a sound technique with low loads through repetition over time. This can be done with broom handles or 5, 10 or 20kg bars and should not be fatiguing. It can be done as part of the warm-up or cool-down as a sub-maximal portion of the exercise session.

Training should be performed three to four times a week in the off-season and can be conducted before or after the team

Six-month plan for general preparation phase (GPP)

Month 1 – education of benefits of conditioning, introduction of body circuits

Month 2 – education of landing techniques, introduction of core training

Month 3 – education of different types of flexibility techniques, use of medicine balls and non-traditional weighted implements

Month 4 – start dumbbell circuits

Month 5 – develop individual and team warm-ups incorporating balance/flexibility exercises

Month 6 – start barbell education with simple lifts and unloaded bars

training. The sessions should only be 20-30 minutes long, not including the education and demonstration of the exercises. The athletes can do the body circuits and landing techniques at home. I demonstrate and conduct a session with the athletes first, then get them to practice at home, then review it the following week.

The longer term

Once an athlete has been training regularly for six months, skill level, confidence and fitness will be improved. However, in the words of Arnold Schwarzenegger, this is not the time to 'lift heavy'. Instead, the variety and intensity of the exercises must be developed. Some coaches recommend that an athlete should use strength-specific exercises and exercises with a barbell, such as barbell squats, only after three years of preliminary general preparation[19].

The use of multiple sets can be more effective in developing strength initially, and in female tennis players the use of periodised training routines that vary the load and volume of the weights during the course of the week has been shown to be more beneficial than keeping them the same from session to session[20,21]. Technical work is key and the teaching of more complex lifts such as the snatch can be taught throughout the GPP, as long as the load is sub-maximal (unless your sport is weightlifting of course). Keeping the sessions varied, progressive and fun as well as technically correct will enable your female athletes to develop a sound conditioning base that will reduce the chances of injury and help them perform more effectively in competition.

Practical implications

- Young female athletes can gain very significant benefits from strength training; however, coaches will often need to overcome the prevailing mindset that 'young girls shouldn't weight train';
- Coaches should initially structure training into a general preparation phase, designed to help introduce the athlete to the training environment, develop core and limb strength, to teach safe and effective techniques and also to introduce the training habit;
- After 6 months of general preparation, the variety and intensity of exercise can be increased.

References

1. JSCR 21 2007; 3: 902-908
2. JSCR 16 2002; 4: 581-585
3. JSCR 21 2007; 3: 875-881
4. JSCR 18 2004; 1: 108-114
5. JSCR 16 2002; 4: 645-648
6. AJSM 23 1995; 694-701
7. AJSM 22 1994; 364-371
8. AJSM 1982; 10: 297-299
9. Clinical Sports Medicine 2000; 287-302
10. AJSM 1991; 19: 76-81
11. Clin J Sports Med 2005; 13: 256-68
12. Br J Sports Med 2003; 37: 354-5
13. Br J Sports Med 2007; 41, 627-638
14. J Sports Med & Physical Fitness 2003; 43: 530-534
15. G Schmolinsky (ed). Track and Field: The East German Textbook, p104; Sport Books Publisher 2006
16. JSCR 21 2007; 4: 1018-1022

17. Istvan Javorek. Javorek Complex Conditioning; 2004.
18. JSCR 18 2004; 4: 703-707
19. Vladimir Zatsiorsky. Science and Practice of Strength Training; Human Kinetics 2006
20. JSCR 21 2007; 4: 1113-1116
21. AJSM 28 2000; 626-633

Grappling with success – lessons to be learned from wrestling strength training

At a glance

- The physiological demands of wrestling are discussed;
- Protocols for strength, power and circuit training in wrestling are outlined;
- The importance of body mass management and core strength is explained;
- Examples of a wrestling periodisation plan and specific exercises are given.

Freestyle wrestling is a demanding sport that requires careful attention to strength conditioning. But according to Andy Harrison, these techniques are equally applicable to other weight category sports, such as judo and boxing.

With few exceptions, success as an athlete requires the development of an appropriate and effective resistance training strategy. The appropriate programme design requires a careful analysis of the demands of the activity or activities to be targeted (*see box below*) and to be effective, any programme must also follow a general periodisation model and incorporate training principles such as specificity and progression.

Demands of wrestling

A wrestling match is decided by either a fall, or if no fall occurs, by a scoring system that quantifies which wrestler is superior at controlling the opponent. Matches consist of three two-minute rounds separated by 30 seconds' rest. Competition is characterised

Demand analysis

When completing an analysis of a sport for the purpose of conditioning design, consideration must be given to the metabolic and biomechanical demands of the activity. Successful athletes from the sport should be profiled in order to establish a physical and physiological template. The analysis should also consider common injuries within the sport to enable the selection of exercises that will assist with injury prevention.

by short-duration, high-intensity, intermittent exercise followed by periods of constant pulling, pushing, lifting and gripping movements in preparation for the next explosive effort.

The movement patterns primarily consist of grappling in order to gain dominance, so that the subsequent short bursts of effort can exploit this advantageous position. Such sparring can occur either in standing or ground positions, depending on the situation, tactics or individual strengths of the athlete.

‘Strength is a major component of power and therefore the blending of strength development with power-endurance development is a priority for wrestling success’

Both the aerobic and anaerobic energy systems are taxed during wrestling competition. The anaerobic system provides the short, quick, all-out bursts of maximal power that characterise this sport, while the aerobic system contributes to the athlete’s ability to sustain effort for the duration of the match and to recover during the brief periods of rest or reduced effort(1). Therefore, in order to offset fatigue and maintain technique, high levels of physical fitness are necessary.

Unsurprisingly, absolute strength is typically greater in heavier wrestlers than their lightweight counterparts; however, the reverse is true for relative strength(2). When comparing successful with less successful wrestlers or the experienced to the novice, it appears that greater strength is advantageous.

The greatest differences have been observed in the tests for upper body strength. Following rule changes in the 1970s that placed the emphasis upon aggressive wrestling and scoring over holding and blocking, dynamic rather than isometric strength has become a more crucial performance measure.

As with most combat sports, the above demands need to be

Programme design

When designing a resistance programme for a sport, consideration must be given to variables such as volume, intensity, rest intervals and exercise selection. The goal is to manipulate these variables in a manner that targets and develops the actions that an athlete undertakes during competition, and which have been identified as crucial in the 'demand analysis'.

analysed in the context of the restrictions imposed by weight classifications within wrestling, and their implications upon strength training and conditioning.

Competitive events are organised by weight division; optimal body composition is therefore paramount as athletes are matched by body mass and must 'make weight' prior to each event. During the season, wrestlers will attempt to maximise their lean tissue while minimising body fat and total body mass. A possible exception is the open class heavy weight division, in which additional non-force-producing body mass may provide an advantage.

Programme design must be considered within a periodisation plan that prioritises and develops the physical and physiological adaptations of the athlete as they build towards their targeted competition/s. As with most sports there are several factors that must be considered when constructing a periodised plan specific for wrestling. For example, circuit training will not increase muscular power; however, it will enhance performance when fatigue sets in. That said, attention to absolute strength and power in a non-fatigued state should not be omitted during pre- and in-season training. Strength is a major component of power and therefore the blending of strength development with power-endurance development is a priority for wrestling success.

Wrestling programme variables

The following provides a brief overview of several types of programme variables that can be manipulated in order to best prepare the wrestler:

Jargonbuster

Plyometrics
A form of power training, consisting of an eccentric contraction, followed by a concentric contraction

Proprioception
Awareness of movement and position of the body

Circuit resistance training: The main purpose of this work is to enhance the endurance capacity of the body, and key to achieving this is the management of the work:rest ratio. Typically, rest periods between exercises can begin at 90 seconds and then progress down towards 60 seconds or lower. A timeframe of four to six weeks should be allowed to make this gradual reduction, while completion of six to eight further weeks of this type of work will be needed in order to optimise adaptation. The phase of the training and the development level of the athlete will dictate the number of circuits per session (from two to five) and sessions per week (two to three). The resistances required to create the appropriate physiological stress will range within the 10-15RM area – *ie* muscular failure should be reached somewhere between the 10th and 15th rep.
Strength training: The above demand analysis highlights the necessity for strength development in order to optimise both attacking and defensive technique. To do this multi-joint exercises should be employed, performed with multi-planar actions – *eg* bench presses, lat pulldowns *etc* – at different angles. Compared with circuit resistance training, the rest periods are longer (two to four minutes) and require heavier loading (6RM and lower).
Power training: The successful execution of wrestling technique requires the athlete to be explosive, which requires power. Again multi-joint exercises should be employed; however, now the intent is to move the mass as quickly as possible. Repetitions can range from one to six (average two to four repetitions) with loads from 30 to 40% of 1RM for higher mechanical loading to higher percentages (60-85% of 1RM) for improving power outputs at higher force levels. Adequate rest should be allowed (three minutes plus) to ensure that maximal effort can be attained. This type of resistance power training can also be supplemented by **plyometric** type work.

Inclusion of 'Olympic lifts' is a key component generally when aiming to develop strength and power capabilities. Their inclusion within a wrestling conditioning programme is crucial. These lifts require high levels of coordination and are very similar to throws and several other movement patterns completed during competition. The technical competency necessary to complete this type of work will also positively impact upon wrestling skills such as balance and **proprioception**. The inclusion of single-leg exercises can also be used to improve an athlete's ability to maintain and regain balance during competition.

Completing exercises without wrist straps or using towels and ropes should be incorporated in order to develop grip strength, which is necessary for the successful execution of holds and throws. Body-weight exercises such as pull-ups and rope climbing are also excellent choices. However, most forearm exercises should be performed in an isometric manner in order to match the contraction type typical for wrestling.

The ability to maintain strength and power under anaerobic conditions is trainable by manipulating the order of exercises in a programme. Circuit training should be incorporated in order to develop muscular endurance, while prescribing 'Olympic lifts' or plyometric exercises at the end of a programme requires the athlete to exert high levels of power when already in a fatigued state (suggested for advanced athletes only). Longer duration (30-60 seconds) plyometric exercises or timed Olympic lifts can also help develop power endurance.

'The "programme design" considerations detailed within this article hold true for the majority of sports. The skill lies within blending these together to achieve the desired outcome'

Core development and isometric strength

The ability to exert and withstand rotational forces is a key aspect of wrestling success. Therefore prescription of resistance exercises that target the core area (abdominals, lower back and gluteal muscles of the buttocks) is crucial to enable the efficient transfer of forces from the lower to the upper body. This type of work should generally be included in the off- and pre-season periods but may also be prescribed in technical sessions (with the coach's agreement) during the in-season.

Practically every wrestling move can have a static component

Jargonbuster

Eccentric component
Movement in which the ends of the muscle are drawn further apart

and pulling and pushing moves may develop into static actions. Therefore, besides the need for isometric grip strength, the importance of isometric muscle action must be emphasised in a wrestling-specific programme. This can be completed using simple partner exercises, manual resistance or the previously mentioned rope and towel work. Again, the duration of the activity (isometric contraction) should be manipulated based on the athlete's need (greater in heavier weight categories) and on the phase of the training cycle.

Optimal gains in strength are the result of either a small number of long-duration muscle actions or a high number of shorter-duration muscle actions. Joint angle specificity must also be considered when designing an isometric training programme. Strength will be developed only at the specific joint angle at which the exercise is performed. This must be balanced with the fact that not every joint angle can be trained because it would simply require too much time!

Body mass management

The categorisation of athletes by weight demands high levels of strength relative to body weight. Wrestlers should therefore strive to improve maximal force and power production while retaining the ability to 'make weight'. Manipulation of volume and rest periods in resistance training plus high volume/low-intensity aerobic conditioning can play a role in addressing the issues of both weight management and body composition. This may need to be completed in conjunction with professionally designed nutrition strategy.

With the exception of the heavier weight categories, excessive muscle bulk may be undesirable in the sport. However, all athletes will benefit from improvements in body composition (increased muscle mass alongside fat loss) without altered body mass. Relative strength can be targeted by incorporating body-weight exercises (pull ups, dips, rope climbing, partner exercises, *etc*). As time under tension is minimal and the **eccentric component** negligible, 'Olympic lifts' can also be utilised without a necessary increase in body weight.

Injury prevention

Within wrestling, primary sites for upper body injuries are the shoulders, neck and elbows. For the lower body, knee-related problems are the most common. A resistance programme should aim to strengthen and stabilise the sites and structures of common injuries. In addition to muscular strength, increasing the range of motion around these joints may also help in injury prevention.

Muscular strength work with an injury prevention focus should generally be included as part of the off-season preparation phase but may also be prescribed as assistant movements during the pre-season and in-season periods. However, wrestlers should incorporate flexibility exercises throughout the year.

'In addition to muscular strength, increasing the range of motion around these joints may also help in injury prevention'

Discussion

Research has highlighted the following parameters as influencing wrestling performance: body mass and composition, muscular strength, muscular endurance, muscular power, flexibility, anaerobic power and cardiovascular fitness.

These characteristics comprise the overall physiological profile of a successful wrestler. In fact it has been shown that physiological variables alone can account for up to 45% of the variance between successful and unsuccessful Olympic contenders[3]. However, it must be remembered that wrestling is a technical sport and that these characteristics form only the platform upon which the athlete must base their technical skill and strategy. Clearly it is possible for an individual to possess excellent physiological capacities and lack the sport-specific components necessary to gain competitive success.

In order to maximise the transfer of training gains, exercises selected for a sports-specific resistance programme should match the recruitment patterns and muscle actions of the activity as identified by the demand analysis. Generally the 'programme design' considerations detailed within this article hold true for the majority of sports. The skill lies within blending these together to achieve the desired outcome.

Many of the examples provided here (*see tables below*) are valid for other weight category sports, most notably those involving an element of gripping and grappling such as judo and submission fighting. Some of these examples (single-leg Olympic lifts, isometric exercises, *etc*) may also transfer and provide benefit to other sports with similar activities such as rugby.

Wrestling-specific exercises

Strength training:
- Incline, decline or flat chest press
- Lat pull-down, pull-ups, rows
- Good mornings, dead lifts, linear/lateral lunges
- Arm curls, triceps extensions, wrist curls

Power training:
- Snatch, power clean, push-press
- Overhead/back squats
- Weighted squat jump
- 1-legged snatches or 1-arm cleans

Circuit training:
- Dumbbell shoulder press
- Lunges
- Pull-down
- Seated rows
- Core work
- Arm curls
- Squat
- Bench Press
- Deadlifts
- Hang cleans

Isometric training:
- Bear hug
- Grip strength style grips

Wrestling-specific periodisation plan

Off-season (general preparation)	● Resistance training (circuits, injury prevention, core stability) ● Aerobic endurance (low-intensity/long duration)
Off-season	● Resistance training (injury prevention, core stability) ● Aerobic endurance (intervals, 1:1 work/rest ratio)
Pre-season	● Maximal strength training ● Anaerobic capacity (interval training)
In-season	● Muscular endurance (circuits, body-weight exercises) ● Anaerobic capacity (intervals) ● Power/power endurance

Practical implications

- Wrestling demands high levels of power and absolute strenght as well as excellent strength to weight ratio; suitable programmes to build wrestling strength are therefore often transferable to other weight category sports as well as body contact sports such as rugby;
- Circuits, Olympic lifts, power and core training should all be included on an effective strength programme for wrestlers.

References

1. J Strength Conditioning Res 2000; 14(2):162-9
2. Sports Medicine 2002; 32(4):225-233)
3. Physician Sports Med 1995; 3(12):31-4

Maximising strength – time to tear up the old rulebook?

At a glance

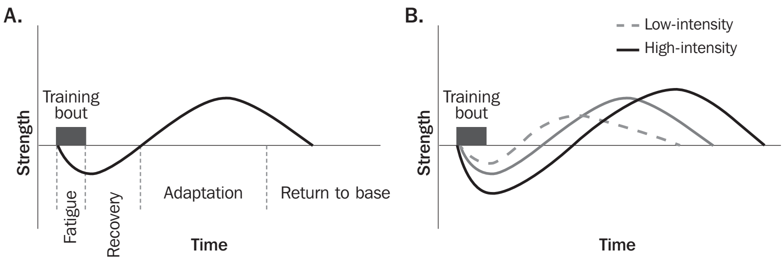
- The physiological responses to strength training are outlined and the role of a key regulator of muscle growth called mTOR is explained;
- Research showing how to optimise mTOR activation and so increase muscle growth is presented;
- Practical training recommendations are given for maximum strength gains.

For thousands of years, athletes have used resistance training to increase their strength and performance. But as Keith Baar and Mike Gittleson explain, recent scientific advances suggest that the traditional methods of resistance training might not be the most effective way to do this...

Over 2,500 years ago, Milo of Crotona, a Greek farmer and Olympic wrestler, performed his morning exercises with a calf draped across his shoulders. As the calf grew so did Milo's strength. At the time of the Olympiad, his strength was so great that he could complete his exercises with the calf, now a full-grown bull, on his shoulders, making his strength unparalleled. The scientific theory described in this fable has been termed the 'overload principle' – *ie* that strength gains occur as a result of systematic and progressive exercise of sufficient frequency, intensity and duration to cause adaptation.

While we have recognised the importance of the overload principle for a very long time, the exact frequency, intensity and

Figure 1: A schematic diagram of the adaptation of muscle to a single bout of exercise



A) Acute resistance exercise progressively results in fatigue, recovery, and adaptation. B) Changing the intensity of the resistance exercise decreases (low-intensity) or increases (high-intensity) the time of each of the phases after resistance exercise.

duration of exercise to maximally increase muscle strength is still open to debate. A number of factors impact optimal training frequency, how hard to train and how long to train. These include the equipment and coaching available, individual rates of recovery after hard weight training and the individual's ability to sustain intense exercise.

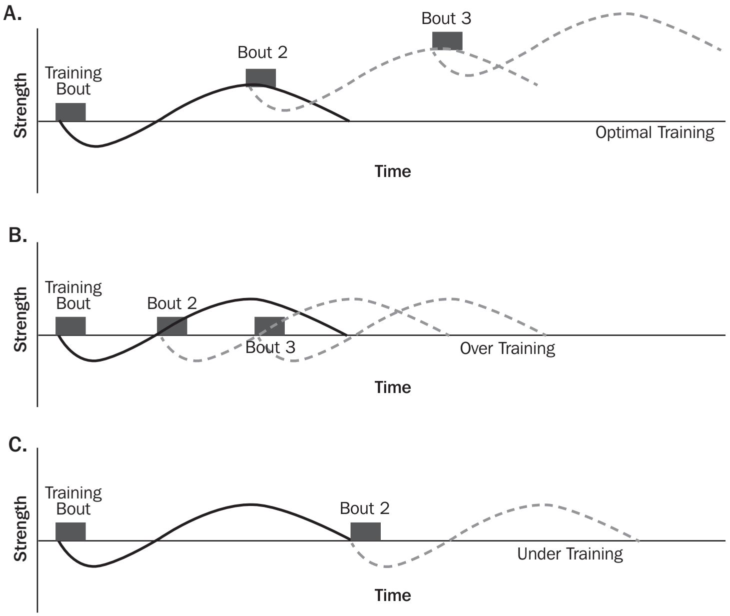
Response to training

It is easiest to view an individual's response to resistance exercise in pictorial form (*see figure 1*). A training session can be separated into four phases (*see figure 1A*):

1. The training bout itself where the muscle fatigues and strength decreases;
2. The recovery phase, including both the immediate recovery from the exercise and the delayed recovery when damaged muscle fibres are removed and replaced;
3. The adaptation or supercompensation phase;
4. The return phase where any strength gains from the bout of exercise are lost.

Changing the intensity of the exercise increases or decreases the length of each of the phases (*figure 1B*) making it even

Figure 2: Schematic representation of the effect of timing training on the adaptive response



The effects on strength over a period of time of A) optimal timing of training, B) training too frequently and C) not training frequently enough

harder for the strength coach to time the next training session.

The goal of the athlete and coach is to provide the next training session at the optimal frequency (*see figure 2*). If each of the sessions is optimally timed (at the peak of the adaptation phase), the athlete will increase strength at a maximal rate. If the sessions are too frequent (as is common for elite athletes – *see figure 2B*), the muscle doesn't have sufficient time to adapt and strength gains are slow. Poor strength gains are also seen if the sessions are not frequent enough.

Molecular response to training

So what is it that actually causes an increase in strength? One

‘The heavier the weight, or the greater the absolute amount of power produced by the muscle, the better the activation of mTOR’

possibility is that muscle repair results in a newer, stronger muscle. But while it is true that muscles repair themselves after a training session, there’s nothing in the repair process itself that causes the muscles to grow stronger. This can be seen by comparing muscle strength following a training session to muscle strength after a minor muscle injury. In both cases, muscle repair has occurred. However, only the training session increases muscle strength.

If not repair, then what? In every scientific model of muscle hypertrophy (growth), including mice, rats, rabbits, chickens and humans, the first response to a strength-training session is an increase in protein synthesis. If the increase in protein synthesis is more than the increase in muscle breakdown, the muscle will get bigger and stronger.

Over the past 10 years molecular exercise physiologists have identified the key regulator of muscle protein synthesis after strength-training. The technical name for this protein is the ‘mammalian target of rapamycin’, or mTOR for short. The activity of mTOR is directly related to the intensity of the training session and, over time, to the increase in muscle size and strength[1] (*see figure 3*).

Maximising muscle growth

If activating mTOR is the key to increasing strength, then understanding how to maximally activate this enzyme will tell us how to optimise our strength-training. To do this, we have to understand what turns mTOR on and off, and from a number of beautiful scientific studies, this is now clear.

The load on a muscle is directly related to the activation of mTOR. This means that the heavier the weight, or the greater the absolute amount of power produced by the muscle, the better the activation of mTOR[2]. The only time where this relationship is not seen is when the weight-lifting is done while blood flow is restricted, but this is only really applicable to populations that can’t lift heavy weights for medical reasons. Therefore, the goal should be to lift as much weight as possible.

On the other side of the equation, mTOR activity is blocked by metabolic stress. This means that we want to use as little muscular ATP (an energy yielding molecule used in muscle contraction) as possible when we are doing our resistance training. The best way to decrease ATP consumption is to not work very long and to do exercises that use less ATP. Put together, this means that the best way to increase the activity of mTOR is to do exercise at high absolute power and low energy cost.

'The best way to increase the activity of mTOR is to do exercise at high absolute power and low energy cost'

There are two ways to produce high power in muscle (*see figure 4*). The first is to perform shortening (concentric) muscle contractions with a medium amount of force, while the second is to perform lengthening (eccentric) contractions at a high force. Because of the architecture of our muscles we are able to produce about 1.8 times as much force when our muscles are lengthening than when they are shortening, resulting in much more power (even though it is negative).

Even though shortening and lengthening contractions can both result in high absolute power, they have very different energy costs. Shortening contractions are the most energy-consuming contractions, isometric contractions are the least energy-consuming (but result in the lowest amount of power) and lengthening contractions are in-between, requiring one-half of the ATP of shortening contractions(3). This information suggests activation of mTOR (and therefore strength gains) should be greatest when training with forced lengthening contractions against a very high load.

Training to maximise mTOR activation

The type of contraction is one thing that can be used to maximise mTOR activation, but are there others? The short answer is yes. Here, we will discuss one nutritional strategy and a few training programme factors that can maximise activation of mTOR.

One of the things that can activate mTOR inside muscles is an increase in circulating blood amino acids (from digested protein). Specifically, foods that are high in the branched chain amino acids (*eg* leucine) such as milk, can increase the response to resistance exercise. We have known for some time that adding amino acids to a strength-training programme can

Box 1: Programme rules for maximising mTOR activation and strength gains

- **Target:** The weight is increased when the athlete completes a fixed number of repetitions. Targets are normally used at the beginning of a training program, when increases are made more rapidly.
- **Range:** Contains both upper and lower limits of repetitions (*eg* six to eight reps). When the athlete performs the reps at the lower limit of the range (*ie* six reps) the weight remains the same and the number of repetitions increases through the range. The weight is increased only when the athlete completes the upper limit of the repetition range (*ie* eight reps) and the number of repetitions is decreased to the lower limit.
- **Number of repetitions:** As stated above, sets should last no longer than 60 seconds. Therefore, each set should have no more than 10 reps. Since forced repetitions are to be used, the maximal number of positive reps should be eight so that two forced reps can be added.
- **Adding weight:** When progressing, the weight added should be at least twice the smallest weight available in the gym – eg if the smallest weight in the gym is 1kg, the smallest weight that should be added is 2kg.
- **No progression:** If the athlete shows no progress for three workouts, the weight is reduced. The weight removed should be half of the last added weight and the number of reps should stay the same.
- **Momentary muscular failure:** Momentary muscular failure is achieved when the athlete can no longer either lift the weight or provide resistance during the negative phase.

improve the resulting increase in strength, and now we think that we know why. When amino acids are taken into muscle, they can directly activate mTOR and improve protein synthesis and muscle growth.

There is also the suggestion that when we consume amino acids might be important in the effects on mTOR and protein synthesis, but this is still controversial. We have just finished experiments that suggest that the if amino acids are taken within one hour after training they will have a bigger effect then if they are taken later. This is because we have found that the 'leucine transporter' is increased in muscle between 30 and 90 minutes post-training and this might be important in mTOR activation and therefore strength gains.

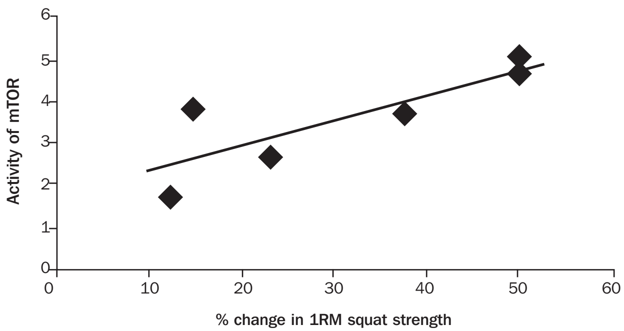
It is important to remember that keeping amino acid levels high for extended periods of time can actually result in a decrease in both protein synthesis and insulin sensitivity[4]. Therefore, it is unwise consume to excessive amounts of protein.

Programme features to optimise mTOR activation

Although we said we want to maximise power when we train, there is a caveat. The highest absolute power is seen when performing fast lengthening contractions with a lot of weight (high jerk), or heavy plyometric exercises. This type of exercise is very effective in activating mTOR, but unfortunately can be very bad for tendon health, and as a result can lead to injuries. Since the tendon adapts more slowly than muscle, if heavy plyometric exercises are used, providing adequate recovery time following these exercises is absolutely essential.

Another consequence of the slow recovery rate of tendon for high-jerk resistance exercise is the use of periodised training. Non-linear periodised programmes result in greater strength

Figure 3: The relationship between the activity of mTOR and strength gains



The activity of muscle protein synthesis regulator mTOR 30 minutes after strength training is directly related to the increase in squat strength after 14 weeks of training. This suggests that mTOR activity causes muscle growth.

'In order to minimise the metabolic stress of each set, the programme should preferably consist of only one set, which should end with two to three forced repetitions'

gains than traditional linear progression methods. Athough it has been demonstrated numerous times, there doesn't seem to be a reason for this at the muscle level. Instead, this likely represents the fact that the majority of elite athletes are overtraining and periodically decreasing the load allows the required rest for muscle adaptation and tendon recovery from the high-jerk exercises.

An alternative way to promote tendon health is to use slow lengthening, or forced contractions. This type of movement has been shown to improve tendon health and recovery from injury. Further, since there is no need for prolonged tendon rest periods, linear progression programmes can be used effectively when this type of movement is included.

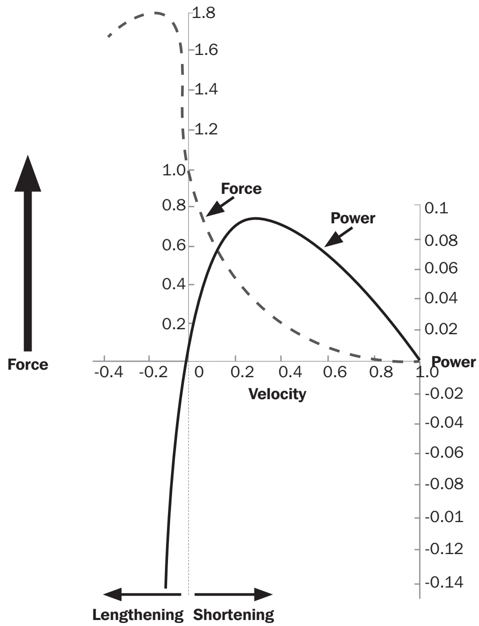
Second, since minimising metabolic stress is one of the keys to activation of mTOR, each set should last less than 60 seconds. This is the amount of high-energy phosphate stored in a normal muscle. Any longer and the muscle will turn on processes that shut down mTOR, decreasing the response to the training. When performing controlled repetitions this means a maximum of 10 reps per set is optimal for strength gains.

Last, in order to minimise the metabolic stress of each set, the programme should preferably consist of only one set, which should end with two to three forced repetitions. If more than one set is used, enough time must be taken between sets to allow full recovery of phosphocreatine and ATP. This takes two to three times as long as the exercise itself (around two to four minutes).

Putting together a strength programme

So how can these ideas be put together into a coherent programme to optimise strength gains? What follows is a programme built on the molecular ideas described above and the experience of 30 years of working with elite strength athletes. This programme is a linear progression system that uses one set to momentary muscular failure and push-pull methodology to maximise power and minimise metabolic stress (*see box 1*).

Figure 4: Force-velocity (relative power) relationship in muscle



The force-velocity relationship in muscle is depicted by the dotted line with the relative power superimposed with the black line. Note that there are two areas where there is high power, one during shortening (positive power) and one during lengthening (negative power).

Correct form

During the positive phase:

- Limit momentum: *do not* bounce or throw the weight upwards;
- Limit leverage: *do not* change the angle of any joint other than the target joint;
- Constant tension throughout the exercise: *do not* rest on the way down or at the bottom of the movement;
- Shortening of the target muscle should take one to two seconds; the weight should then be stopped at the top of the

movement before lowering the weight with tension during the lengthening phase.

During the negative phase (forced repetitions):

- When the athlete can no longer lift the weight, the coach and athlete combine for a number of forced repetitions. In this phase, the coach assists in the shortening phase and then challenges the athlete to lower as much weight as possible taking six to eight seconds. The coach can also provide extra resistance if needed.

Push-pull methodology

To minimise the metabolic stress on each muscle group, athletes should progress from a pushing exercise to a pulling exercise and vice-versa. A pushing exercise is a movement away from centre of body during the shortening contraction of the target muscle (*eg* chest/shoulder/triceps press, leg extension, leg press). A pulling exercise is a movement toward centre of body during the shortening contraction of the target muscle (*eg* pulldown, row, biceps curl, leg curl). Progressing from a pushing to a pulling exercise allows full recovery and resynthesis of ATP and PCr in helper muscles between exercises, decreasing metabolic stress and allowing better activation of mTOR.

Recovery

After a workout, your body begins recovery by replenishing oxygen supply, high-energy phosphate fuels and glycogen (carbohydrate) in muscle, and importantly begins to degrade and synthesise muscle proteins. This requires rest and proper nutrition. The amount of rest varies from athlete to athlete and with the intensity of exercise as discussed above, while proper nutrition can be as simple as consuming 6g of essential amino acids and 35g carbohydrate (700mls of skimmed milk is sufficient to provide these) within 30 minutes of training[5].

References

1. Eur J Appl Physiol. 2008, 102: 145-52

Practical implications

- Athletes wishing to build strength should aim to produce high intensity with low energy costs in their workouts to maximise mTOR activation;
- High-rep or multiple sets should be discouraged; instead, single sets of six to eight reps with two to three assisted forced (negative) reps are preferred;
- Sets should be performed in a 'push-pull fashion and where more than one set is performed, at least two minutes should elapse between sets.

2. Am J Physiol. 1999, 276: C120-7
3. J Appl Physiol. 1997, 83: 867-74
4. J Biol Chem. 2001, 276: 38052-60
5. Clin Sports Med. 2007, 26: 17-36

Cheat those genes! The science of simultaneously maximising strength and endurance

At a glance

- The fundamentals of metabolic pathways in endurance and strength training are outlined;
- Recent research on the roles of our genes and two key enzymes called AMPK and mTORC1 in facilitating adaptation to endurance and strength training are explained;
- Training strategies are given to help athletes maximise their strength and endurance gains when performing concurrent training.

Many sports require not just high levels of strength but excellent levels of endurance too. The problem is though that for hundreds of thousands of years, humans have evolved to be either as strong or as tireless as possible, but not both. As Keith Baar explains, however, recent science has provided clues as to how to legally move past the obstacles that evolution put in the way of developing both strength and endurance.

Traditionally, the title 'World's Greatest Athlete' is bestowed upon the winner of the decathlon. The reason for this is that a champion decathlete exhibits the ultimate combination of strength and endurance. Despite this, many have argued that since these athletes would never beat a world-class specialist in any of the 10 individual events that make up the decathlon, they can't be the greatest athlete in the world. However, what makes

Strength and endurance definitions

Endurance – Endurance exercise is long-duration exercise performed at a submaximal effort. Since, by definition, these sports are performed at a submaximal effort, the muscles' ability to use oxygen to produce energy in the form of **ATP** goes a long way towards determining our performance. When we train, we improve the aerobic production (*ie*, with oxygen) of ATP by increasing the number of fat and sugar transporters, as well as metabolic enzymes and mitochondrial proteins.

Strength – Muscular strength is determined by a number of factors including limb length, muscle fibre angle (pinnation), **collagen** stiffness within the muscle and tendon, and the number of muscle proteins in parallel (muscle cross-sectional area). To increase muscle strength we exercise in short bouts at close to maximal effort to increase protein synthesis, induce muscle remodelling, and increase muscle mass (hypertrophy).

the decathlete the single greatest athlete lies in their mastering *both* strength and endurance events.

The basic reason is that, within our bodies, the two processes of building strength and endurance are diametrically opposed: in other words, one tends to prevent the other. Therefore, to master both strength and endurance, we have to overcome limitations that have been laid down in our genes over hundreds of thousands of years.

It is not just decathletes that need to master both endurance and strength. All motor-endurance sports – for example, cycling, swimming and rowing – require both, as do many games, including rugby, basketball and ice hockey. Therefore, knowing how to optimise both strength and endurance is one of the keys to success for the modern sportsman.

While coaches have long been the leaders in developing strategies to maximise performance, a surprising number of advances in molecular exercise physiology mean that, for the first time, basic researchers are beginning to understand how best to train simultaneously for strength and endurance.

Enzymes and exercise training

Before we can discuss how to train for strength and endurance together, it is necessary to understand a little about the basic process of how our muscles build strength and endurance. To do this, we will have to talk about two **enzymes** that play an important role in the effect of training on muscle. The first is the 'AMP-activated protein kinase' (AMPK) and the second is the mammalian 'target of rapamycin complex 1' (mTORC1).

AMPK and endurance – As the name suggests, adenosine monophosphate (AMP) activates AMPK. AMP is a molecule formed in muscles when large amounts of ATP are needed to power exercise. Basically, ATP is broken down into adenosine disphosphate (ADP), inorganic phosphate, and energy. It is this energy that we use to power our bodies. In order to rapidly make new ATP, two ADP molecules can be combined by an enzyme called myokinase, to produce a new ATP plus a molecule of AMP. It is this AMP that turns on AMPK during exercise.

During exercise, this enzyme increases the rate of sugar uptake and fat oxidation, allowing us to make more energy aerobically. But AMPK also has other important roles in muscle. Along with the short-term increase in metabolism, AMPK is involved in the control of a number of genes that give muscles more endurance.

Using drugs and different models of muscle, molecular exercise physiologists have shown that repeatedly activating AMPK in muscle results in many of the adaptations that occur following endurance exercise. This includes the improved transport of fat and sugars into muscle, and the increase in **mitochondrial** mass, resulting in greater endurance. From these data, it is now widely believed that, within muscle, one of the primary goals of endurance training is to activate AMPK.

In an elegant study by Shin Terada, we learned that while long-duration exercise increases AMPK activity, repeated short high-intensity sprints produce a greater effect on AMPK (*see figure 1*). This tells us that, as far as muscle is concerned, the best type of exercise for improving endurance is repeated high-intensity sprint exercise.

Jargonbuster

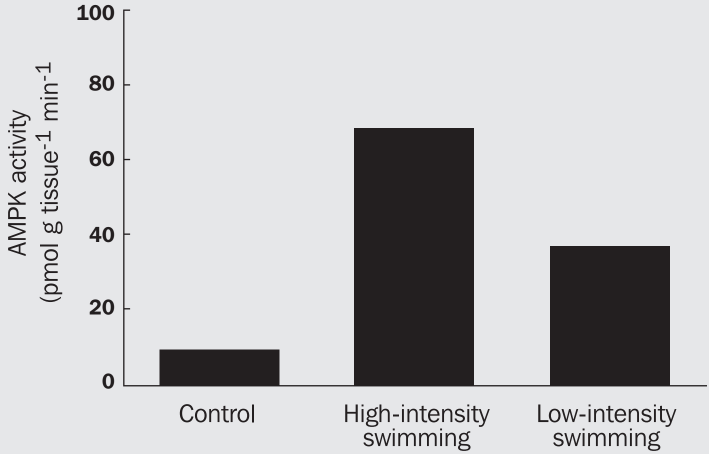
Enzymes – large protein molecules synthesised in the body that speed up biochemical reactions that would otherwise occur either too slowly or not at all

ATP – adenosine triphosphate, a crucial molecule that acts as 'universal energy currency' in the body

Collagen – the major component of the tendon and the extracellular matrix of muscle

Mitochondria – small structures in the cell that produce energy for it

Figure 1: Exercise intensity and the activation of AMPK (adapted from [1])

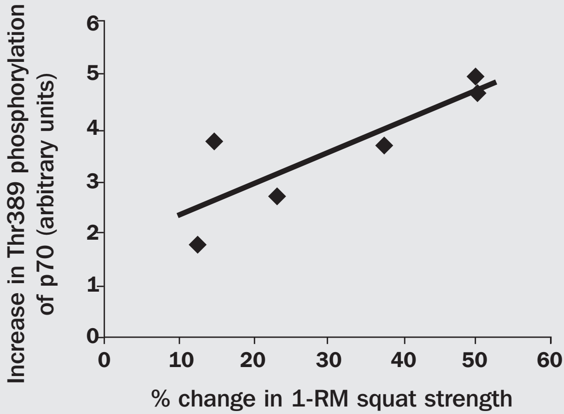


Activation of AMPK following either long-duration exercise or repeated sprint exercise. All exercise produces a metabolic stress that results in the activation of AMPK. However, high-intensity exercise results in significantly greater activation of AMPK than low-intensity exercise.

However, this does not mean that purely repeated sprint training is the best way to improve whole-body endurance performance, since a number of other tissues – including the heart, the circulatory system, and the connective tissue – must also adapt in order to translate endurance training into improved performance. But as far as muscle is concerned, the higher the intensity, the higher the AMPK activity and hence the better the subsequent endurance adaptation.

mTORC1 and strength – Unlike AMPK, mTORC1 is not activated by endurance exercise. Instead, this enzyme is turned on following resistance exercise. In fact, the activity of this enzyme is the best marker for muscle growth and strength improvement discovered to date. In every animal tested, from mice to humans, mTORC1 activity following a single bout of exercise is the best predictor of muscle hypertrophy and

Figure 2: mTORC1 and strength gains (adapted from[2])



The correlation between mTORC1 activity (determined by the phosphorylation of S6K1) 30 minutes after a bout of resistance exercise, and the increase in strength following 14 weeks of resistance training. Note the strong correlation between mTORC1 activity and strength gains.

improved strength (*figure 2*). Not only does the activity of mTORC1 correlate with improved strength – when this enzyme is blocked by the drug **rapamycin**, muscle doesn't grow in response to a normal growth stimulus.

So, we know that mTORC1 is required for muscle growth and increased strength, but you are probably now wondering what it does. In order for our muscles to grow bigger and stronger, we need to increase how much protein we make within our muscles. This is where mTORC1 comes in. This enzyme controls muscle size and strength by regulating protein synthesis. Following resistance exercise, mTORC1 activity is increased and as a result there is an increase in protein synthesis that makes muscles bigger and stronger. From these data, strength coaches should have as their goal maximal activation of mTORC1 when looking to improve an athlete's strength.

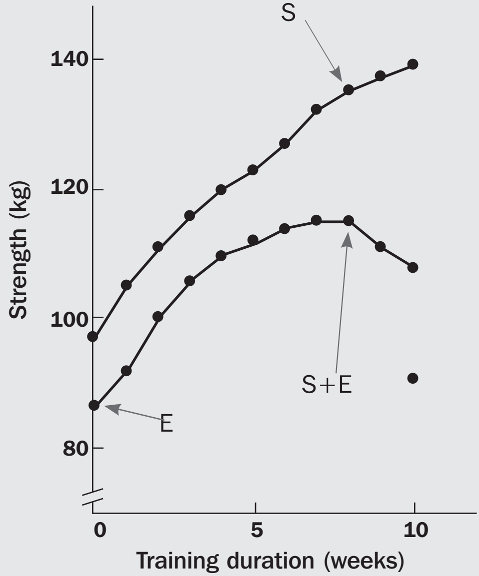
Many strength coaches and athletes are already doing this unwittingly, by taking **amino acids**. The reason that this helps

Jargonbuster

Rapamycin – a drug that is used to prevent rejection following organ transplant; it specifically inhibits mTORC1

Amino acids – building blocks that are used to make proteins

Figure 3: Concurrent training effect (adapted from[3])



The effect of endurance (E), strength (S) or concurrent training (S+E) on squat weight lifted. The endurance-training-only group was tested initially and following the 10-week training programme. The strength-training-only group improved their squat performance by 40%, while the strength-plus-endurance group showed only a 25% improvement in squat performance and the endurance-only group did not show a change in squat strength.

increase strength is that, like resistance exercise, amino acids – especially the branched-chain amino acids, such as leucine – activate mTORC1. Consequently, coordinating amino-acid supplementation and resistance exercise results in greater mTORC1 activation and therefore greater improvements in strength.

If amino acids can increase muscle size and strength, why not take supplements to maintain high amino acids at all time? The reason that this doesn't work is that mTORC1 has a self-braking mechanism. What this means is that if amino acids are sustained at high levels in the blood for too long, mTORC1 and protein synthesis are shut off. Therefore, it is the timing of the amino acids and not the total amount that is the key.

Another way to activate mTORC1 is through growth factors like insulin and insulin-like growth factor (IGF-1). Insulin and IGF-1 can both directly activate mTORC1 and indirectly activate mTORC1 by increasing the uptake of amino acids. This is why the IOC has banned insulin and IGF-1 as performance-enhancing drugs. However, diet can be used to legally increase insulin, simply by adding some carbohydrate to any amino-acid supplement that an athlete takes. Coordinating this supplement with resistance exercise can increase mTORC1 activation and, as a result, strength.

The concurrent training effect

Many athletes and coaches will tell you that if you train for endurance and strength together improvements in performance are slower than if you train for one alone. This phenomenon is called the 'concurrent training effect' (*see figure 3*). It is here that molecular exercise physiologists are beginning to contribute to training efficiency.

As we have already discussed, AMPK leads to improved endurance and mTORC1 increases strength. So you might be asking: if two *different* enzymes have evolved to enhance two different aspects of fitness, why is it difficult to increase both simultaneously? The answer lies in the fact that AMPK can block the activation of mTORC1. What this means is that, in our genes, there is a block to improving both our endurance and our muscle mass and strength at the same time. This will come as no surprise to many coaches and athletes who already know that endurance training tends to prevent strength gains.

This genetic interaction almost certainly developed hundreds of thousands of years ago as we evolved to move over great distances to hunt for food. These long trips not only found the food that kept us alive, but also decreased the amount of muscle we had and, as a result, the amount of fuel we needed to consume. Today, when having enough food is not a concern, we are still fighting against the way we evolved eons ago.

'In our genes, there is a block to improving both our endurance and our muscle mass and strength at the same time. This will come as no surprise to many coaches and athletes who already know that endurance training tends to prevent strength gains'

Dynamics of enzyme activation

In order to overcome this genetic limitation and train for both endurance and strength, we need to understand a little more about how the two enzymes in question work. As described above, AMPK is turned on during exercise, but it is rapidly turned off when we refuel. This is because it senses the amount of glycogen in the muscle, as well as the metabolic state of the muscle. When these return to normal, AMPK turns off.

On the other hand, mTORC1 isn't turned on during exercise, but rather during the recovery phase from resistance exercise. The maximal activation of this enzyme occurs between 30 minutes and six hours, but can be maintained a full 24 hours, after a single bout of resistance exercise. The correlation between mTORC1 and strength gains occurs both at 30 minutes and six hours after training, suggesting that it is important to have mTORC1 active for a long time, in order for it to influence muscle strength.

Training for endurance and strength

From the information above, it becomes more obvious how we can maximise both endurance and strength. The key aspects of any programme aiming to do this are the timing of the exercise and the use of diet. The basic rules are:

1. Perform endurance training first and strength training last;
2. Add intensity to your endurance;
3. Take food with your weights;
4. Keep your strength sessions short;
5. Use negative repetitions.

The whys behind the rules

1. Endurance first – strength last: AMPK is rapidly turned off after exercise, but mTORC1 needs to be high for as long as possible for maximum effect – and AMPK turns off mTORC1. Therefore, if endurance exercise is performed first, early in the day, and glycogen is reloaded, then AMPK will be low later in the day (when the strength exercises are performed) and will not interfere with mTORC1. Training for strength at the end of the day (5–6pm) allows mTORC1 to be high for the rest of the evening and while the athlete is sleeping. When the athlete wakes, they will have at least 12 hours with high mTORC1, promoting muscle growth and improved strength before their next session of endurance exercise turns on AMPK and turns off the strength signal.

'The best way to add high intensity is to follow a long endurance session with some high-intensity intervals'

2. Add intensity to your endurance: AMPK is turned on by all exercise – but, since it responds to metabolic stress, the higher the intensity, the higher the metabolic stress and, therefore, the higher the AMPK activity. The best way to add high intensity is to follow a long endurance session with some high-intensity intervals. The long, slow exercise depletes muscle glycogen and this makes the high-intensity work even more of a metabolic stress than if the high intensity is performed while the athlete is fresh. This is because, as already mentioned, AMPK senses muscle glycogen levels. Therefore, depleting muscle glycogen before high-intensity exercise is optimal for activating AMPK and improving muscle endurance.

3. Take food with your weights: Diet is the most overlooked aspect of training and, when training for both endurance and strength, diet becomes even more important. Eating a high-carbohydrate meal or snack an hour after your endurance training will help to turn off AMPK and replenish muscle glycogen. Taking a drink or snack that delivers 6-8g of protein before strength training helps deliver amino acids to the working muscles. Since blood flow is increased to these muscles, they will see more amino acids than the non-working muscles and this, together with the activation of mTORC1 by the strength training, will result in maximal strength gains. Also, adding a protein- and carbohydrate-rich meal soon after completing training (around one hour) will increase insulin and amino acids in the muscle, thus supporting the training session.

4. Keep your strength sessions short: Make sure that your strength exercises don't last more than 60 seconds. Six to eight reps, performed properly, minimises the metabolic stress of the exercise. Energy for less than 60 seconds can be supplied from muscle stores. Stored ATP, **phosphocreatine** and glucose can provide all of the energy required to work hard for less than a minute. This keeps the metabolic stress of the exercise low, minimising AMPK activity and therefore maximising mTORC1. Taking twice the active time (*ie*, resting for around two minutes between sets) to recover those stores will also help keep the metabolic stress low.

5. Use negatives: Negatives (slow, lengthening contractions) put the maximal load on the muscle for the minimal metabolic cost. Muscle is around 1.8 times stronger when lengthening under load than when contracting. More importantly, muscle consumes much less ATP during lengthening contractions than it does during shortening contractions. This means that the body needs less ATP to lower a weight than to lift it. Besides that, we can handle a heavier weight with lengthening contractions. The result is more weight and less ATP used, and this translates into more mTORC1 activity and stronger muscles.

Summary

Most modern sports and games put a huge emphasis on developing both strength and endurance. For almost 30 years, we have known that training for both is not as efficient as training for either one individually. As molecular exercise physiologists, we are beginning to understand why this is, and that we can use diet and intensity of exercise to create training programmes that will simultaneously improve both strength and endurance. However, even when applying the rules proposed here, the genetic limitations mean that training for both strength and endurance will never be as effective as training for either individually. As a result, those of us who study concurrent training will continue to marvel at the great decathletes and always consider them the 'World's Greatest Athlete'!

Practical implications

- The order and nature of training are important when trying to build endurance and strength simultaneously;
- Endurance training should be intense and carried out before strength training;
- Strength sessions should be kept short with plenty of recovery before more endurance training takes place.

References

1. Acta Physiol Scand. 2005 184: 59-65
2. Eur J Appl Physiol. 2008 102: 145-52
3. Eur J Appl Physiol Occup Physiol. 1980 45: 255-63
4. Am J Physiol. 1999 276: C120-7

All together now: how to implement simultaneous strength and endurance training in practice

At a glance

- The concept of concurrent training is introduced and previous research is discussed;
- New research demonstrating the benefits of concurrent training is presented and practical advice given for those wishing to try it as part of their own training routine.

Many sports require high levels of upper and lower body strength, muscular endurance and flexibility, yet the prevailing wisdom is that you can't train all these aspects of fitness simultaneously. However, according to James Marshall, new research suggests that concurrent training can deliver the goods.

Prevailing wisdom says that by training on one area you automatically interfere with the development of another. In this article, we'll look at recent research from the University of California that shows how a method of training can improve all these factors at once [1,2].

Many sports require explosive actions to be performed in quick succession with limited or no recovery time. This scenario may then be repeated, for example over 5-30 seconds of a tennis rally, 1-2 minute periods of play in a rugby match, or 2-5 minute rounds in combat sports, and then carried on over the duration of the match.

Box 1: Endurance and strength

Strength is usually improved by coordination of the motor units within the muscle, the rate of firing of motor neurons within the muscle spindles and an increase in cross sectional area of the muscle. Endurance is improved by the ability to take up more oxygen (VO_2max) through central processes such as an increase in stroke volume (blood volume pumped with each heartbeat) as well as at the cellular level through an increase in capillarisation (the network of tiny blood vessels that supply working muscles) and the number and size of mitochondria (energy producing factories) within the cell. Endurance training on its own has not been shown to improve strength training and strength training on its own has not been shown to improve oxygen uptake.

'Rarely does a sportsman or woman use strength or endurance in isolation'

Explosive movements require a strength base, while throwing, striking and hitting actions also require strength. Players who are leaner have less weight to carry around and so (all other things being equal) experience less fatigue. Players who have a greater VO_2max (maximum oxygen uptake capacity) can recover more quickly between these repeated bouts of work.

Rarely does a sportsman or woman use either strength or endurance in isolation; if you become stronger, but can't do as much overall work because you have poor endurance, you will be less effective. Conversely if you run around and get to a lot of positions but can't then execute effectively because you're too weak, that's no good either!

Given the above, it makes sense that training for a particular sport should (at least some of the time) reflect the demands of that sport and that means working on endurance, strength, and muscular endurance at the same time. **Concurrent training** is the integration of aerobic type work and resistance type work in the same session. This is a very time-efficient method of training, allowing a lot of activity in different formats to be performed in a short space of time.

Coaches have known this for a long time; go to most combat sport gyms and you will see fighters working on bags, followed by circuit type exercises, followed by sparring or combinations of all three. Rugby League players often play small games, which require running around, followed by some partner resistance work or tackling bags or getting up and down off the floor, followed by more games.

However, some research has shown that trying to work on strength and endurance concurrently can interfere with muscle power or strength adaptations [(3)]. This is also commonly stated in physiology textbooks and so sports science undergraduates are taught this, too [(4)]. This leads to a situation where coaches who are training athletes see results, but sports scientists who are measuring physiological parameters come up with different answers from the coaches.

Whether you think the coach or scientist is right can depend on the research that you look at. The nature of research and publishing normally means that you have to look at one specific area, test it, apply a training principle and then retest it. In order to eliminate all other variables, researchers often limit their study to one specific area, and study that in detail (*see box 2*). Unfortunately this approach doesn't always transfer to the real world because the body (and the athlete) may not respond the same way to events and stimuli in isolation. Most athletes have to work on technical and tactical aspects of their sport for most of the year. Many of these sessions will be having at least some conditioning effect, so one aspect of training cannot be isolated.

Overtraining

Another possible reason why some studies have found concurrent training ineffective is that they were conducted without following periodised plans, which may have led to overtraining. The study by Hickson consisted of ten weeks' continuous progressive exercise, with strength lessening in the last two weeks [(9)]. If an athlete starts a programme with residual fatigue, he or she will not be able to adapt to an increase in stimulus and instead suffer a drop in performance, or a plateau.

Jargonbuster

Concurrent/ combination training
Training strength and endurance in the same training cycle, or working on strength and endurance within the same session

Serial training
Doing a block of resistance training immediately followed by a block of endurance training

Box 2: Concurrent training – effective or ineffective?

There are a number of reasons why some previous studies have shown concurrent training to be ineffective. Among these are:

Protein interference: After strength training, protein synthesis is essential in order to repair and rebuild the muscle. Endurance training has been shown to reduce the rate of protein synthesis in the hours after exercise, so combining the two incorrectly could limit the strength gains [5];

Neural interference: More a hypothesis than proven, the theory is that endurance training weakens the ability to produce explosive strength by reducing the rate of firing of the motor units within muscles[6];

Glycogen depletion: Both endurance and resistance training result in the depletion of glycogen stores (glycogen is the muscles' premium fuel grade fuel for high-intensity exercise). Performing two-a-day sessions or daily sessions may not allow enough time for muscle carbohydrate stores to be replenished adequately. Low glycogen levels have been shown to reduce the intra-cell signaling after resistance exercise, which may inhibit strength adaptations [7];

Changes in muscle fibre type: Intense endurance training can cause a reduction in the number of Type II fibres within the muscle, and also the rate of firing of those muscles [8]. And it's the type II fibres that respond most to hypertrophy stimuli and increase strength gains. If there are fewer of these fibres, and those that are left do not fire as quickly, then strength gains are potentially lessened.

Meanwhile, some studies looking at concurrent training and which showed interference (ie concurrent training ineffective) used untrained subjects [10,11]. The studies that have shown no interference and improved both endurance and strength have used well trained subjects [12,13,14]. It may well be, therefore, that untrained subjects do not have the capability to adapt to the combined training load.

Also, a lot of the research has looked at concurrent training where strength and endurance work were performed in different sessions in the same week or where basic concepts of periodisation weren't applied. One of the first studies looking at concurrent training was by Hickson, back in 1980[9]. The study used three groups of subjects:

- An endurance group, who alternated between interval training using six 5-minute sets with 2 minutes' rest on a cycle ergometer three days a week, and a running programme of 30 minutes in week one, 35 minutes in week 2 and 40 minutes thereafter;
- A strength group who trained three days a week on five sets of 5 parallel squats, with three sets of 5 reps on knee extensions and knee flexions; and two days a week on three sets of 5 reps on leg press and three sets of 20 reps on calf raises, with additional deadlifts and sit ups;
- A combined group who did both training protocols with a 2-hour rest between the endurance and strength sessions.

The results were as follows:

- The endurance group improved their endurance with no change in strength;
- The strength group improved their strength with no change in endurance;
- The combined group improved their endurance as much as the endurance-only group and also, for the first seven weeks, their strength. The strength gains leveled off, however, between the 7th and 8th weeks and then decreased during the 9th and 10th weeks of training.

This last result is not surprising; the subjects had not done any training for months prior to the study and it's likely they adapted for seven weeks and then predictably got tired. If the study had stopped at eight weeks, the combined group would have shown gains in both strength and endurance. After ten weeks of continuous training, it's possible that the subjects were overreaching (*see box 2*), especially at the loads and intensities set. Yet this study is often cited as 'proof' that concurrent training limits strength adaptations.

Researchers in California recognised these problems and

Jargonbuster

Integrated training
Preceding each set of resistance training with brief periods of aerobic work

Muscle perfusion
The flow into and from the muscle cells of nutrients and waste products

1 repetition maximum (1RM)
The maximum amount of weight that can be lifted in a given exercise for one repetition

Cardio acceleration
A brief period of 30-60 seconds of intense aerobic work designed to elevate the heart rate

Systolic blood pressure
Blood pressure when the heart is contracting

Diastolic blood pressure
The minimum blood pressure during relaxation of the heart

designed two comprehensive studies that utilised concurrent training within the same session and measured several performance outcomes [1,2]. The first study used 28 female soccer and volleyball college athletes as subjects and measured the following:

- **1 repetition maximum** (1RM) of three lower body and five upper body exercises;
- Muscular endurance of the legs using leg press and upper body on five different exercises;
- Body fat percentage and fat free mass;
- Upper and lower body flexibility.

The second study used the same female athletes and also 20 male athletes and measured **systolic and diastolic blood pressure** and VO_2max on a graded treadmill running test. Both studies were conducted over 11 weeks with the subjects training three times a week for an hour and 50 minutes each session. The subjects were split into two groups who performed the following:

Serial training group

- Aerobic warm up - five minutes;
- Alternating sets of resistance exercise with brief rest periods – 60 minutes;
- Aerobic exercise – 30 minutes;
- Range of motion cool down – 15 minutes;

Integral training group

- Aerobic warm up – 20 minutes;
- Alternating sets of resistance exercise with brief aerobic **cardioacceleration** – 75 minutes;
- Range of motion cool down – 15 minutes.

In the resistance section of the workout, both groups did three sets of 8-12 repetitions of nine different exercises, starting with a load of 50%1RM. The difference was that in the serial group the heart rate was deliberately kept low (107.9bpm) by sitting

Table 1: percentage change in tests between beginning and end of study		
	Serial	Integrated
1 RM Upper body	19%	17.8%
1 RM Lower body	17.2%	23.3%
Muscular endurance legs	18.2%	27.8%
Muscular endurance upper body	9.6%	5.2%
Body fat percentage	-1.1%	-5.7%
Fat free mass	1.8%	3.3%
Lower body flexibility	6.5%	8.4%
Diastolic blood pressure	-14%	-12.6%
Systolic blood pressure	-8.7%	-13.2%
VO_2max	18.9%	22.9%

down between sets whereas the integrated group performed 30-60 seconds of vigorous aerobic exercise (usually treadmill running) to elevate their heart rate (151.1bpm) between sets. The serial group performed their aerobic exercise after their resistance training. Both groups did exactly the same amount of work; it was just the sequencing of the exercises that was different. Both groups then finished their workout with 15 minutes of range of motion exercises.

There were three hypotheses in this study:
1. Serial training is as effective as training in either strength or endurance alone, producing similar gains;
2. Integrated training produces training effects that are greater than single mode training alone;
3. Integrated training produces greater training effects than serial concurrent training.

The results (*see table 1*) showed that all three hypotheses were correct (the authors did not have control groups who performed the single mode of exercise alone; instead they compared their results with those produced from other studies that did only use single modes of exercise). The two main points here are that

'Integrated training may also help the heart (which is of course a muscle itself) become stronger and more efficient by repeatedly challenging the vascular pump within the heart and by increasing muscle perfusion within the cardiac muscle'

there was no apparent interference effect from combining strength and endurance training; and that simply changing the sequencing of exercises can have a very big impact on results. In fact, apart from the upper body strength and muscular endurance, all parameters measured in the study were improved more in the integrated than serial group.

Explanation

The authors of the Californian study above suggested that in integrated training there is actually a synergy between strength and resistance training, and the results seem to support this. It could be that by elevating the heart rate and increasing blood flow to the muscles prior to strength training, the movement of hormones such as insulin and nutrient delivery to muscles is enhanced, leading to greater recovery and adaptation. This same mechanism also assists in delivery of oxygen and removal of waste products, which would assist local muscular endurance.

Integrated training may also help the heart (which is of course a muscle itself) become stronger and more efficient by repeatedly challenging the vascular pump within the heart and by increasing muscle perfusion within the cardiac muscle. This repeated stimulus may be a better way of working the heart muscle than a single block of aerobic work after the resistance training.

In practice

Taking information from one study and trying to apply it wholesale isn't always wise. For starters, an hour and 50 minutes (as used above) is a long time to work out. In my experience an hour is pretty much the longest you can train while still maintaining intensity and concentration. Also, the subjects in this study were not playing any sport at the time, which means they didn't have to do technical/tactical sessions, play matches or to nurse the bumps and bruises associated with competition!

Having said that, there are some important take-home points. Firstly, the sequencing of the exercises does seem to have a major impact on the results, even when the same amount of work is performed, and integrated training appears more effective than serial training. This means preceding weight-training sets with a brief period of 30-60 seconds of aerobic work throughout the session.

Secondly, the concept of hard/easy days isn't new and allows recovery of glycogen and adequate protein synthesis to take place. This could be the key difference between this study and others (which did not provide adequate recovery for their subjects) that showed an interference effect, and should be a principle in your training, too.

Thirdly, studies that have shown an interference effect have been conducted on untrained subjects, so if you are new to training, or returning from injury, it may be best to separate the two modes of training first – ie perform serial rather than integrated training. However, if you are well conditioned, then integrated sessions could be for you, as long as you allow adequate recovery between your sessions.

Practical implications

- For well conditioned athletes, concurrent training may well be as effective as conventional training; this could be especially useful when time for training is limited;
- Because concurrent training is physically demanding, athletes should always ensure adequate recovery when employing this type of strength/endurance regime.

References

1. *Journal of Strength and Conditioning Research, 22(5), p1487-1502, (2008)*
2. *JSCR 22(5), p1503-1514 (2008))*
3. *European Journal of Applied Physiology, 92, p376-384 (2004)*
4. *Essentials of Exercise Physiology, p494. MCKardle, Katch and Katch, Philadelphia: Lippincott Williams and Wilkins (2006)*
5. *Annual Review of Nutrition 20, p 457:483 (2000)*

6. Eur. J. Appl. Physiol. 89:42–52, (2003).
7. Journal of Applied Physiology. 99:950–956, 2005
8. Journal of Applied Sports Science Research. 4:55–60, 1990
9. European Journal of Applied Physiology 45, p255-263 (1980)
10. Eur. J. Appl. Physio 92, p376-384 (2004)
11. Medicine and Science In Sports and Exercise, 348-356 (1990)
12. JSCR 15, p172-177 (2001)
13. JSCR 20, p541-546 (2006)
14. JSCR 17 p393-401 (2003)

Power and the glory – building power for winning performance!

At a glance:

- The importance of power in sport and the distinction between power and strength is explained;
- Research into optimal loadings for developing power in the weights room is discussed;
- The issue of fixed versus free weight training for power is addressed;
- The benefits of ‘power-combination’ training in power development are explained.

Although power and strength are intimately connected, they’re not the same thing. And, as John Shepherd explains, training for power in sports requires a significantly different approach to traditional conventional strength-training methods.

Although strength is important for the majority of sports, it’s invariably the most *powerful* athlete who is blessed with superior performance. The 2007 Rugby World Cup provided a case in point. The power of some of the tackles made for a truly awesome spectacle. The athletes demonstrated incredible power – that is they were able to overcome resistance as quickly as possible. And with a high power to weight ratio, they showed that they could move themselves or an object (such as an opponent!) very quickly, in split seconds. This contrasts with gross strength, which is about developing the ability to lift as heavy a weight, or overcome as much resistance as possible regardless of the speed of the movement – but usually slowly!

Weight training and strength versus power

As touched upon previously, strength is defined for the purposes of this article as the ability to lift as heavy a load or overcome as much resistance as possible. This is normally achieved in the weights room by lifting weights in excess of 75% of **1 repetition maximum** (1RM). Low repetitions (1-6) are normally used to achieve this goal.

In comparison, power is defined as the ability to overcome resistance as fast as possible. In terms of weight training, it's normally developed by lifting weights in the region of 60-75% of 1RM, as fast as possible, but safely with control (6-12 repetitions would normally be used). However, as we shall see, this may not actually be the optimum load for achieving the greatest power gains – particularly when it comes to improving acceleration, jumping ability and hitting, for example.

Developing sports-specific power in the weights room

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

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

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

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

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

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

Weight training protocols, strength type and muscle fibre adaptation

The theme of the previous research was reflected in another study performed by a team from Ohio[3]. They specifically

Jargonbuster

Hang pull
A truncated power clean with the bar being driven to the shoulders from a hanging position in front of the shins (it's not pulled from the floor)

1 repetition maximum (1RM)
The maximum amount of weight that an athlete can lift on one attempt

EMG
Electromyography, measures electrical activity in muscles; the more there is the greater the muscle stimulation

considered the number of repetitions performed and the effect they had on muscle fibre adaptation, maximal strength (1RM), local muscular endurance (maximal number of repetitions performed with 60% of 1RM), and various cardio-respiratory measures (for example, maximum oxygen consumption, maximal aerobic power and time to exhaustion).

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

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

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

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

All three major fibre types (types I, IIA, and IIB)

Jargonbuster

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

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

Potentiation
Increased stimulation of fast-twitch muscle fibre, thought to be the result of increased neural activity

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

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

'Although fast twitch, "intermediate" type IIA fibres are not as adept at producing out and out power as their IIB counterparts'

Fixed path versus free-form weight training

What about the way athletes lift weights? Athletes may use different types of weight training equipment across the training year. Will one method be the same as another? Is, for example, a 75kg bench the same on a Smith machine as performed on a bench using free weights? Researchers from Iowa considered this[5]. Smith machine exercises were termed 'fixed path' and the lifts performed outside of the Smith machine 'free-form path'. Specifically, the team wanted to compare muscle force production using a 1RM for the parallel back squat and bench press. From this they then wanted to predict the 1RM for one mode from 1RM on the other mode.

Sixteen men and 16 women alternately completed 1RM testing for squat and bench press using Smith machine and free weight methods. The team discovered a 'significant difference'

Combining weight training with plyometric exercises for an enhanced power output

Although the prime focus of this article is on gaining power through the use of weight training exercises, it would be remiss not to consider the potential that combining plyometrics (jumping-type exercises) and weight-training exercises in the same workout has on boosting muscular power outputs. This is called 'power combination training'. Coach/athlete should select exercises that work the same muscle groups, for example, the jump squat and the squat, the split jump and the lunge and the plyometric press-up and the press-up. Combining these in a workout can be achieved in two ways.

Contrast power combination method – The athlete performs a set of plyometric exercises (or a set of weights exercises) and then a set of weights (or plyometric) exercises. They continue their workout in this alternate fashion.

Complex power combination method – The athlete performs all their sets of the plyometric exercise (or weights exercise) first, before completing all their sets of the weights (or plyometric) exercise – these are known as the complexes.

Power combination training is seen to boost the power output of fast-twitch muscle fibres above and beyond that achieved by either method (plyometrics or weights) alone. The weight used for the weights exercises is usually recommended to be about 75% of 1RM (akin to the weight training methodology*). This is thought to be as a result of **potentiation**.

Although, research does exist that questions the validity of power combination training[6], other research indicates that it does work especially with experienced strength trained athletes. For example, a team from Greece indicated this and found that pre-squatting significantly enhanced the vertical jumping ability of their survey's stronger participants by 4.01% and that of the weaker group by 0.45%[7]. It would thus appear prudent for the athlete looking to increase their muscular power output to power combination train, once they have developed high strength gains over a number of years.

between bench press and squat 1RMs for each mode of equipment for all participants. Specifically:
- Squat 1RM was greater for the Smith machine than for free weights;
- Bench 1RM was greater for free weights than the Smith machine.

This is slightly surprising, as it might seem intuitive that exercises performed using a Smith machine would permit greater force production, due to the safety aspect and crucially the confined/guided path that the bar has to follow. Free weight exercises on the other hand, require balance and greater control to be imparted on the bar throughout the movement – using numerous additional stabilising muscles. Although it could be argued that these muscles could assist the movement of the weight, the inherent instability created by the unconfined lift channels their input away from directly overcoming the resistance, instead providing balance.

It is possible that, had experienced weight trainers/athletes been involved in the study, the Smith machine protocol would have resulted in higher power outputs, as they would have had the ability to recruit more muscle fibre. The fixed path would have facilitated their use of their strength.

'Athletes may derive greater benefits from using free weights to develop sports-specific power due to the additional balance requirements associated with free weights'

When the researchers broke down the findings by gender they found:
- The bench 1RM for free weights was greater than Smith machine for men and women;
- The squat 1RM was greater for Smith machine than free weights for women only.

Not surprisingly the 1RM on one mode of equipment was the best predictor of 1RM for the other mode. This enabled the researchers to formulate an equation that can be used to predict performances on each mode of weight lifting for these lifts (*see box overleaf*):

These findings are useful as they allow coaches to prescribe

Formulae relating Smith machine 1 RM to free weight 1RM

For both sexes: Smith machine bench 1RM (kgs) = -6.76 + 0.95 (free weights bench 1RM)

For women only: Smith machine squat 1RM (kgs) = 28.3 + 0.73 (free weights squat 1RM)

‘Athletes may derive greater benefits from using free weights to develop sports-specific power due to the additional balance requirements associated with free weights’

similar ‘effect’ weight training programmes across different methods of weight training although, of course, the weight lifting experience of the athletes might become a determining factor. Having said that, many athletes may derive greater benefits from using free weights to develop sports-specific power due to the additional balance requirements associated with free weights. That’s because in nearly all sports, movements are performed in an ‘open’ environment where balance is an important factor in the muscular actions of that sport – for example, a football striker leaping off balance to attempt a header on goal!

Summary

Developing power in the weights room is a complex area with so many variables. I have deliberately steered clear of the ‘Olympic lifting debate’, which, depending on your perspective and research, is or is not beneficial for sports performance, or the hormonal effects of weight training to focus on more specific forms of weight training and equipment use. The information presented here should enable coach/athlete to construct a power-developing programme opposed to a strength developing one. The key recommendations are as follows:

- Use 30% of 1RM loads when performing dynamic weight-training exercises, such as jump squats;
- Use circa 75% of 1RM loads when standard weight lifting (preferably free weights);

● Finally, include some power combination training in your routine!

Practical implications

● Where power development is critical, lighter loads (around 30% of 1RM) and faster movements should be employed as a starting point in strength programmes;

● Where outright strength is more important, heavier loadings and lower reps should be used;

● Power combination training using plyomterics should also be considered as a training mode.

References

1. J Strength Cond Res 2007; 21(2):336-42
2. J Strength Cond Res 2002; 16(1):75-82
3. Eur J Appl Physiol 2002; 88(1-2):50-60 Epub 2002 Aug 15
4. Sports Med 2001; 31(15):1063-82
5. J Strength Cond Res 2005; 19(1):169-76
6. J Strength Cond Res 2003; 17(4):694-700
7. J Strength Cond Res 2003; 17(2):342-4

Explosive strength training – can it blow away conventional methods?

At a glance

● The conventional approach to strength training using 'task failure' protocols is summarised;
● The use of explosive contractions for achieving maximum muscle activation is discussed;
● New research on explosive strength training is presented, including potential advantages over conventional approaches.

The traditional resistance training wisdom is that performing two or three sets to failure is the best way to achieve rapid strength gains. But new research suggests that less could be more. John Sampson explains…

Athletic performance in many sports demands the development of muscle strength, which is required for other performance related characteristics, notably speed and power. Muscle strength is routinely developed through prolonged participation in a structured resistance exercise programmes. Yet despite extensive research in the area, the adaptive mechanisms contributing to maximal strength adaptation are not yet fully understood.

Skeletal muscle is an extremely sensitive and highly adaptive tissue; consequently almost any overload applied to the muscle will result in some form of adaptation (ie strength gain). In the case of athletes, even sub-optimal resistance training programmes can result in some positive adaptations. However, long-term adherence to such a resistance training programme

Box 1: Brain and muscle contractions

Muscle contractions are ultimately controlled and regulated by the brain. Muscles are controlled by motor units, and when a motor unit is activated, it causes the group of muscle fibres it controls to contract. This is often referred to as the 'neural control of force' and is predominantly a function of the number of active motor units and the rate at which they fire. The level of motor unit activity is directly proportional to the level of force required to complete a task.

is unlikely to result in optimal strength gains and in some cases may even lead to reduced performance capabilities and an increased risk of injury.

A number of key principles are applied during resistance exercise programmes. Legend suggests Greek athlete Milo of Croton lifted and carried a calf on his shoulders each day from birth until it became fully grown; as the animal grew in size so did his strength. This legend clearly demonstrates the importance of applying a progressively increasing external load!

The mechanical loading of muscle as a consequence of the external load is perhaps the most important consideration of any resistance-training programme. Research has consistently indicated that moderate to heavy loads are required in order to gain an increase in muscle size, muscle activity and muscle strength. Correspondingly, an extensive review of the literature and current guidelines published by the American College of Sports Medicine (ACSM) suggest relatively heavy loads that equal, or are in advance of 80% of a one-repetition maximum (1RM) are required in order to achieve optimal strength gains [1].

Resistance exercise programmes can be modified not only by the external load, but also by the speed of contraction, and level of induced fatigue. Altering resistance exercise programmes in just one of these ways will induce a distinct skeletal muscle response. However, the combined effects of adjusting training in two or more of these areas simultaneously will result in more complex physiological interactions that may either hinder or improve training related strength gains. Unfortunately, we still have insufficient evidence to fully understand the complex interactions between load, movement speed and the extent of muscular exhaustion induced by the level of work (eg completed number of sets and repetitions).

Optimum strength training protocol

Everybody knows that a structured resistance training programme results in increased muscle size (hypertrophy), and that a larger muscle has the potential to produce greater levels of force. When first starting out in resistance training you may have noticed increases in your muscular strength, but no increase in the size of your muscles. Strength gains without muscle size increase are generally attributed to an increased level of 'muscle activation' – ie better recruitment of motor units that 'fire' muscle fibres (*see box 1*).

Maximal activation of muscle fibres during resistance exercise is essential for maximal strength gains. When completing a set of resistance exercises, you'll no doubt be aware of an increase in the difficulty of exercise as you complete an increased number of repetitions. This is because motor units fatigue and in an attempt to maintain the desired force output, more motor units are recruited. Consequently the level of muscle activity increases as the muscle attempts to maintain the required force to overcome the load. This explains why training to the point of repetition failure is seen as an important consideration in resistance training program design.

Repetition maximum loading regimes were first credited by Delorme [2] and later Delorme and Watkins [3] who conducted a series of investigations examining the effect of progressive-resistance training in exercise rehabilitation. This research proposed the completion of 10 repetitions using a load which was consequently heavy enough to result in 'task failure' (muscular exhaustion) on the 10th repetition. This loading technique was termed a 10-repetition maximum (10RM). Some 60 years later, repetition maximum loading regimes remain the dominant resistance-training model utilised across

Jargonbuster

One-repetition maximum (1RM)
The maximal load you can lift one time only unassisted through the complete range of motion

Motor units
Function to transport information from the central nervous system to muscle fibres. A single motor unit consists of a motor neuron and all of the muscle fibres it innervates

Box 2: Exercise efficiency

Human movement results in an energy cost as a consequence of the mechanical work performed. Thus if the same amount of work can be completed at a lower energy cost, the movement can be considered more efficient. For resistance training to be successful, we expect certain adaptations to occur (ie increased strength and muscle size). Therefore, if one training programme demands a lower energy cost, but results in the same adaptations as a second, the first programme can be considered as more efficient.

research literature and in gyms across the world. Task failure has therefore become closely affiliated with maximal strength adaptation and most resistance exercise programmes advocated by coaches and fitness trainers result in high levels of muscular exhaustion.

However, research into the necessity for such high levels of induced fatigue is far from conclusive. Most resistance trainers apply the use of multiple sets in order to achieve maximal strength gains, yet there's conflicting evidence surrounding the use of multiple versus single set strength training programmes. The concept of high levels of workload and induced fatigue as a prerequisite for strength adaptation is thus far from proven.

Increasing the number of sets performed in a resistance training session is not the only way to influence the level of muscular exhaustion. Research has compared the effects of allowing brief inter-repetition rest periods within a resistance exercise programme. Two of the studies in this area have again produced conflicting evidence [4,5].

Each of these studies examined two resistance exercise protocols that were performed against a relatively heavy external resistance:

- One protocol induced high levels of fatigue by directing participants to complete repetitions without rest, to the point of task failure (muscular exhaustion);
- The other protocol had participants performing the same

Box 3: Explosive contractions and limb movement

The attempt to perform an explosive contraction is regarded as an effective method of improving high-speed muscle adaptations, even when contractions are performed in the absence of limb movement, against an isometric resistance. Thus, it appears the intent to contract rapidly is more important than the actual movement of the limb [8].

number of repetitions but with a 30 second inter-repetition rest period, thus allowing time for recovery in between repetitions.

The strength gains resulting from this 'high fatigue' exercise regime were compared to those undergoing the lower fatigue protocol. One of the studies found that those in the high fatigue group achieved greater strength gains, while the other study observed no difference between the groups. This poses a dilemma; one set of results proposes an important role for high levels of muscle fatigue, yet the other suggests this is not necessary!

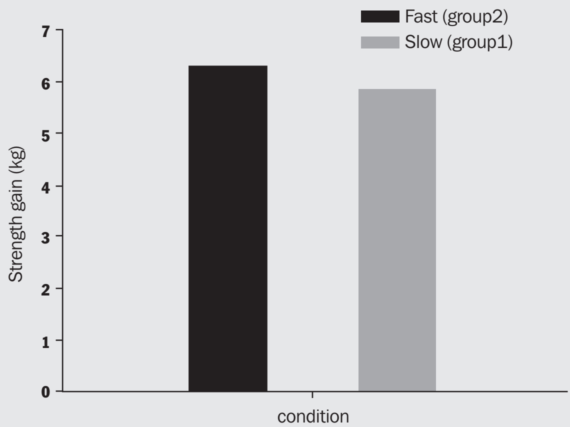
'Explosive muscle contractions result in the rapid generation of force, increase the rate of motor unit firing and reduce motor unit recruitment thresholds'

Repetition failure

The necessity of repetition failure has also been questioned. A study [6], compared the strength gains achieved in a group performing exercise sets to the point of repetition failure and those of a second group who performed the same total number of repetitions but over a greater number of sets (*ie* where repetition failure wasn't induced). This research again suggested similar strength gains were achieved in both groups despite a less exhaustive stimulus applied in the group performing a greater number of sets.

A number of research studies have therefore suggested similar strength gains can be achieved despite a reduction in the level of induced fatigue. An important point to make here however is that all groups ultimately performed the same relative amount of work, thus the efficiency of exercise was no different between groups (*see box 2*).

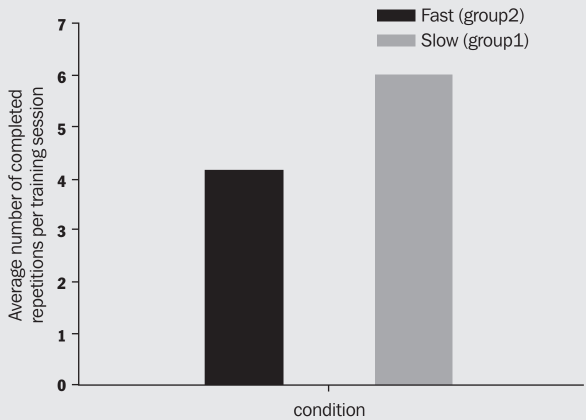
Figure 1: Shows the similar strength gains achieved by the conventionally trained (group 1) and the fast, explosively trained (group 2) subjects



Some researchers have advocated the use of single set training programmes, which they believe increases exercise efficiency without compromising strength gain but this is an area of much contention. However, an important interaction between repetition speed and the level of induced fatigue may exist. Repetitions can be performed quickly or slowly and both methods have been used across research in the area.

A review of purposefully 'slow training' discussed the mechanical effects of such training [7]. In short, the researchers highlighted that repetitions performed slowly increase the time it takes to complete each muscle contraction over any given range of motion (effectively increasing the time a muscle is subjected to tension). However, they also pointed out that as a function of increasing the time under tension, the load must decrease. Considering the well defined relationship between external loading and muscular adaptation, this appears to directly contradict the well accepted notion that associated resistance training adaptations are proportional to load.

Figure 2: Shows the difference in work volume performed by the two groups. Note how the fast, explosively trained subjects (group 2) performed around 30% fewer reps than subjects in group 1 yet still achieved similar strength gains



Increasing the time spent performing a muscular contraction is not the only way to increase total time a muscle is under tension. The same effects can be achieved by increasing the number of completed repetitions. Both methods increase the level of muscular exhaustion and will eventually lead to task failure. However, neither effectively increases the efficiency of resistance exercise.

Explosive contractions

In contrast to purposefully slow training, repetitions can also be performed as fast as possible. Such training is often termed as 'explosive' or 'ballistic'. Remember, in order to stimulate muscle and achieve maximal strength gains during resistance exercise, you need to achieve maximal muscle activation. Explosive muscle contractions result in the rapid generation of force, increase the rate of motor unit firing and reduce motor unit recruitment thresholds.

Explosive muscle contraction can lead to superior activation

'The idea that 'heavy load, explosive contraction' resistance exercise can increase the efficiency of exercise has also been supported by research'

of muscle. However, in order to perform an explosive movement, the external load needs to be reduced and (as we have discussed) a relatively heavy external load is required in order to gain maximal strength adaptation. Proponents of purposefully slow training have claimed that this makes explosive training less efficient.

It is, however, possible to attempt an explosive contraction against a heavy external load. High levels of force production are required whenever you attempt to initiate a high-speed movement. This is due to inertia; if you attempt to accelerate a mass very rapidly, much more force must be generated to overcome inertia compared to a slower movement with less acceleration.

Performing explosive contractions against relatively heavy loads is also likely to increase power related performance characteristics, while resulting in equal strength related adaptations as performing contractions against the same load at lower speeds (9).

The combination of a heavy external load combined with maximum contraction speed has also found favour in one-set resistance exercise training programmes. For example, researchers in Australia examined the effect of one and three sets of resistance exercise performed at either fast or slow speeds on maximal strength adaptation over a six-week resistance exercise programme with each set resulting in task failure (10). The results of this research highlighted that one set of heavy load exercise performed at fast speeds resulted in similar strength gains as three sets of exercise performed at slower speeds. Furthermore, no additional benefit was observed from performing three sets at the faster speeds. Thus a 'heavy load, explosive contraction' may be a key performance related variable in this area.

New research

The idea that 'heavy load, explosive contraction' resistance exercise can increase the efficiency of exercise has also been supported by research from our laboratory at the University of

Summary

Our research suggests that the efficiency of a strength training programme can be improved by selecting a relatively heavy load and attempting to complete fewer repetitions but using explosive muscle contractions. These findings have beneficial implications for athletes:

- Increasing the efficiency of resistance training reduces the time required for resistance work for a given gain in strength, freeing up time to complete other aspects of training;
- Not having to work to failure (which can be very exhausting) also provides the athlete with faster recovery and more energy for subsequent training;
- Most sports and athletic events demand the use of explosive movements; if explosive resistance training is equally effective at building strength as conventional training, the athlete can benefit from both the specificity of explosive training as well as the strength gains produced

A note of caution is required however. Heavy load explosive resistance exercise training may place the muscle and/or joint at an increased risk of injury because of the forces generated when attempting to rapidly accelerate and move loads at high speeds. Having said that, in the resistance exercise model used by ourselves, we believe that the lower levels of induced fatigue resulting from fewer completed repetitions may actually reduce the risk of injury, despite the attempts to complete an explosive contraction.

Wollongong, Australia. We manipulated the level of completed work (and thus the level of induced muscle fatigue) and the speed at which repetitions were performed.

One exercise group performed four sets of resistance exercise using a relatively heavy external load, resulting in repetition failure after approximately six repetitions. Meanwhile, a second group were also asked to perform four sets of exercise against the same relatively heavy external load, but we imposed a work reduction on this group by asking them to perform only four repetitions. We also asked this group to complete repetitions as fast as possible (ie explosively), whilst repetition speed in the first (task failure) group was controlled to a four-second cadence; a two-second muscle-shortening phase (normally associated with lifting a weight) and a two-second muscle-lengthening phase (normally associated with lowering a weight).

After 12 weeks of resistance exercise, we found similar strength gains in both groups. These findings are significant; not only did the second (explosive) group performed 30% less total work than the first, they also achieved the same strength gains without working to failure (*see figures 1 and 2*). Moreover, the similar gains in strength between groups were also accompanied by similar increases in muscle size and muscle activity, suggesting no benefit in any area of strength adaptation from a more exhaustive exercise routine performed by the first group.

Practical implications

- Athletes and coaches should be aware that while most conventional strength training programmes can produce strength gains, they may not provide the most efficient route;
- Those whose sports include explosive type movements may wish to consider explosive strength training as research suggests it's not only very time and energy-efficient, it also replicates muscle recruitment pattern specificity.

References:

1. Med Sci Sp Ex (2002) 34, 364-380
2. J. Bone Joint Surg (1945) 27, 645-667
3. Arch Phys Med (1948) 29, 263-273
4. Br J Sp Med (2002) 36 370-375
5. Med Sci Sp Ex (1994) 26, 1160-1164
6. J Appl Physiol (2006) 100, 1647-1656
7. J Sp Sci Med (2008), 7, 299-304
8. J Appl Physiol (1993), 74, 359-368
9. J Am Geriatr Soc (2002), 50, 655-662
10. Med Sci Sp Ex (2005) 37, 1622-1626

Is GABA the 'next creatine' for strength athletes?

At a glance

- The role and different types of growth hormone in the body are explained;
- The nutritional link between GABA and growth hormone is outlined;
- New research on the potential benefits of GABA supplementation is presented and recommendations are made.

The naturally occurring amino acid known as GABA has long been know to function as an inhibitory neurotransmitter in the brain, and as such, is popular as an 'anti-anxiety' supplement. However, exciting new research suggests that it may also stimulate the natural release of growth hormone, which could yield benefits such as enhanced muscle growth, strength gains and fat loss. Andrew Hamilton explains

Back in the 90s, the use of creatine as a strength-building supplement revolutionised sports nutrition, because unlike most other supplements out there, it actually did what it claimed on the tin! Since then, a number of would-be pretenders to the throne have appeared on the market, but none has matched creatine for its sheer efficacy.

Creatine is able to produce strength gains because it enhances the short-term, high-intensity energy pathway in muscles known as the 'phospho-creatine (PC) system'. An enhanced PC energy pathway allows muscle fibres to contract vigorously for longer, thus producing more intense loading and fatigue. This in turn produces a greater repair and growth stimulus, and in the longer term, with adequate rest and nutrition, greater strength gains.

The role of growth hormone

One of the key players in muscle repair and growth following exercise is a substance called 'growth hormone' or GH for short. GH is a large protein molecule that is synthesised, stored, and secreted by specialised cells within anterior pituitary gland in the brain (*see box 1 below*).

In the body, GH has a number of biological functions, but of particular interest to athletes is the fact that it increases protein synthesis and promotes fat burning[1], increases calcium retention and therefore strengthens and increases bone mineralisation, and it also stimulates the immune system.

In adults, GH is not secreted steadily, but instead in discrete bursts resulting in about five large pulses or peaks of GH release each day. These peaks last from about 10-30 minutes and the most predictable of these peaks occurs roughly an hour after the onset of sleep[2]. However, another

Box 1: GH in the body – irGH and ifGH

GH exists in several forms in the body, only some of which are biologically active. To produce its biological effects, GH must bind to GH receptors on cell surfaces in a kind of 'lock and key' reaction.

There are two specific regions of the GH molecule that can bind to these receptors and thus switch on the chain of biological reactions that follow; if a GH molecule contains both of these regions, it is assumed to be biologically active. This 'active' form of GH is sometimes referred to as 'immunofunctional GH' or ifGH. By contrast, 'immunoreactive GH' refers to a measure of total GH present (*ie* all of the forms of GH, both biologically active and inactive).

Although rises and falls in irGH levels are normally mirrored by similar changes in ifGH levels, the ideal measurement of GH levels in research studies is ifGH, because this is guaranteed to be the fraction of GH that is active in the body.

Box 2: Neurotransmitters

Neurotransmitters are chemicals (often simple amino acids) that are used to relay, amplify and control signals between a nerve cell and other cells. Neurotransmitters are synthesised and stored in the nerve cells and only exert their specific actions if they're secreted in sufficient quantities and can bind to the target cells via specific receptors.

Some examples of naturally occurring neurotransmitters include:

- Acetylcholine – regulates voluntary movement of the muscles;
- Norepinephrine – regulates wakefulness or arousal;
- Dopamine – regulates voluntary movement and motivation, 'wanting' and pleasure associated with addiction and love;
- Serotonin – regulates memory, emotions, wakefulness, sleep and temperature;
- GABA (gamma aminobutyric acid) – regulates the inhibition of motor neurons;
- Glycine – regulates spinal reflexes and motor behaviour.

Some examples of artificial (drug) neurotransmitters include:

- Cocaine – blocks the reuptake (breakdown) of dopamine, allowing dopamine neurotransmitters to exert their effects for longer;
- Prozac – a selective serotonin reuptake inhibitor (SSRI) anti-depressant drug, which effectively potentiates the effect of naturally released serotonin;
- AMPT – prevents the conversion of tyrosine to L-DOPA, the precursor to dopamine, which results in lower dopamine levels.

extremely powerful GH release stimulus is exercise, particularly high-intensity exercise such as resistance training or high-intensity anaerobic training[3-6].

Given that GH promotes muscular growth and repair, and also stimulates fat burning, it's not surprising that some athletes have been tempted to resort to GH abuse in order to accelerate recovery from training, increase strength and maintain low body fat levels. However, not only is this illegal, GH abuse is a potentially risky business, leading to potential health

Jargonbuster

Metabolite
A molecule that results from a subsequent biochemical transformation of the target molecule

Blood-brain barrier
A membranic structure that acts primarily to protect the brain from chemicals in the blood, while still allowing essential metabolic function

Anxiolytic
A substance (usually medication) that reduces anxiety

Precursor
A molecule used in the synthesis of the target molecule

Circadian variability
Rhythmic fluctuations that occur naturally as a result of the body's internal 24-hour clock

complications such as high blood pressure and heart damage[7].

The GABA-GH connection

If you want to maximise natural GH release and create an anabolic environment, intense exercise and adequate sleep are vital. But are there any nutritional tricks you can use to further enhance GH secretion? Given that GH is secreted from the brain, the obvious question to then ask is whether there are any nutrients that could in some way influence brain function.

As it happens, there are a large number of biologically active compounds that are involved in regulating brain chemistry and the central nervous system (CNS), and which are synthesised from simple constituents of foods. These compounds are collectively known as neurotransmitters, which control and regulate brain and CNS activity by acting on specific receptors within those regions (*see box 2*).

The neurotransmitter/diet link

Many key neurotransmitters are actually simple amino acids (AA) or **metabolites** of amino acids. Examples include the AAs glycine and gamma amino butyric acid (GABA), which regulate spinal reflexes/motor behaviour and inhibition of motor neurons respectively, and serotonin, which is synthesised from the AA tryptophan in the body[8].

‘The irGH response after exercise–GABA was approximately 200% greater than exercise–placebo at 30 minutes after exercise’

At this point eagle-eyed readers may be wondering whether and how protein in the diet (which is built of AA building blocks) can influence neurotransmitter synthesis and subsequent brain function. The answer is that ingesting AAs can affect neurotransmitter levels and/or synthesis, but not as a result of normal dietary protein consumption – an AA neurotransmitter will only be significantly boosted via diet in the brain when large amounts of that AA enter the brain relative to others.

The problem is that virtually all dietary protein contains 20 or more AAs; in order to enter the brain after digestion, these AAs have to compete with each other to cross the ‘**blood-brain barrier**’. The net result is that no one single AA can dominate over the others, meaning that there’s no large increase in the brain levels of any single AA over the others. And while it's true that some sources of protein contain a relative abundance of one particular AA compared to others (*eg* cottage cheese, which is very rich in tyrosine), the presence of other, competing AAs means that even eating these foods in isolation has a minimal impact on subsequent brain levels of that AA.

However, things are very different with single AA supplements taken away from food. With no other AAs around to compete for absorption across the blood brain barrier, even small doses of a single AA can have a significant effect. A good example of this is the increasingly popular use of the AA supplement tryptophan, which is a **precursor** to serotonin, low levels of which are strongly associated with depression and other disorders of brain chemistry. Studies show that taking tyrptophan away from other proteins produces a significant rise in brain serotonin[9].

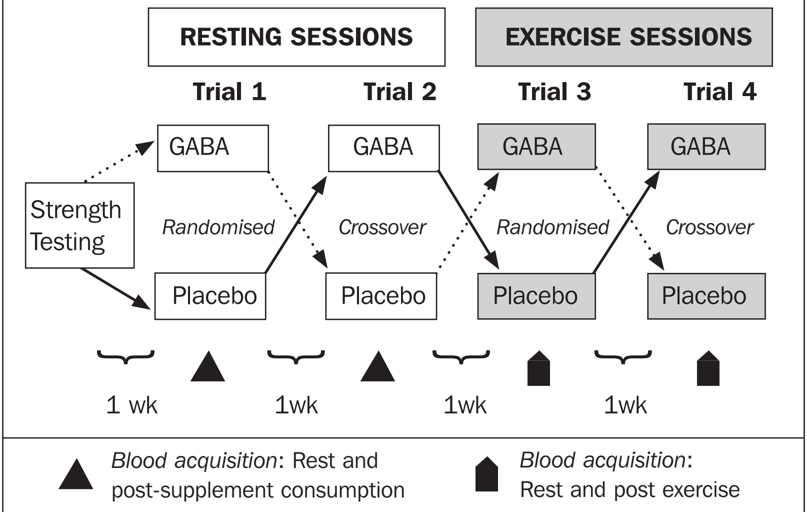
The role of GABA in brain chemistry

Gamma amino butyric acid (more commonly known as GABA) is a naturally occurring AA present in small amounts in the body. Although it's not present in muscle tissue or in food (unlike most other AAs), it can be synthesised in the body from the AA L-glutamine[10] and is found in the CNS, pancreatic islet cells and kidney.

In the CNS, GABA is the chief inhibitory neurotransmitter, tending to decrease the electrochemical activity and therefore excitability of nerve cells. This explains why the administration of GABA can produce anti-anxiety and anti-convulsant effects and why much research into **anxiolytic** and anticonvulsant medication has focused around slowing down the breakdown of GABA in the CNS.

All well and good, but what can GABA offer to athletes? Well, it just so happens that GABA supplementation while at rest seems to directly stimulate GH secretion in the brain via centrally mediated mechanisms[11,12]. However, until recently, there was no research available to show whether this effect is significant; *ie* does supplementation boost ifGH (the active

Figure 1: Experimental design of GABA/resistance training study[13]



form) and how relevant is this compared to the effect of GH release as a result of exercise?

More importantly, what is the effect of combining both resistance exercise and supplemented GABA on irGH and ifGH?

GABA and resistance training for GH release

Until recently the answers to the questions above were unknown, but a fascinating recent study carried out by US scientists at the University of Florida makes for truly intriguing reading[13]. The researchers hypothesised that GABA ingestion would increase circulating irGH and ifGH concentrations at rest, and that oral GABA administration would augment the irGH/ifGH response to resistance exercise (*ie* result in a larger release of GH) – ideal for athletes for all the reasons given earlier.

The study was designed as a randomised, double-blind, placebo-controlled, crossover study – *ie* to be as rigorous and as accurate as possible. In the study, 11 healthy, resistance-trained males (average age 23.6yrs, average weight 87.5kgs) were investigated to see what effects 3 grams of GABA supplementation had on subsequent irGH and ifGH release followed by either a period of rest, or a session of resistance training.

The study consisted of four trials, each separated by a week; in trial 1, the subjects were given either 3 grams of GABA or capsules containing inert sucrose (table sugar) of the same calorific value. After taking GABA or placebo they then rested and measurements were made. In trial 2, exactly the same protocol was followed but those who had taken placebo now took GABA and vice-versa. Trials 3 and 4 mirrored trials 1 and 2, except that now, after taking the GABA/placebo supplements, the subjects performed an intense 15-minute resistance routine, which included the following exercises: chest press, lat pulldown, chest fly, seated row, shoulder press, biceps curl, triceps extension, leg press, leg curl, leg extension, and calf raise. Figure 1 shows a schematic representation of the overall experimental design.

Before each trial, blood was collected and then again afterwards at 15, 30, 45, 60, 75, and 90 minutes in the 'rest' trials and after 1, 15, 30, 45, 60, 75 minutes in the 'exercise' trials. These blood samples were analysed for subsequent irGH and ifGH concentrations. The researchers also timed the trials and blood collections so that they all took place between 07.00h and 09.00h in order to minimise any **circadian variability** (GH secretion tends to rise and fall naturally at different times of the day).

Results of GABA supplementation

The results obtained by the team were as follows:

- Exercise performance – there was no difference in exercise performance between those subjects taking GABA and those taking placebo (as expected – GABA would not be expected to exert a direct effect at the muscular level);
- irGH and ifGH secretion – as might be expected, compared

Results of the GABA/resistance training study

Figure 2: Changes in irGH and ifGH blood concentrations over time

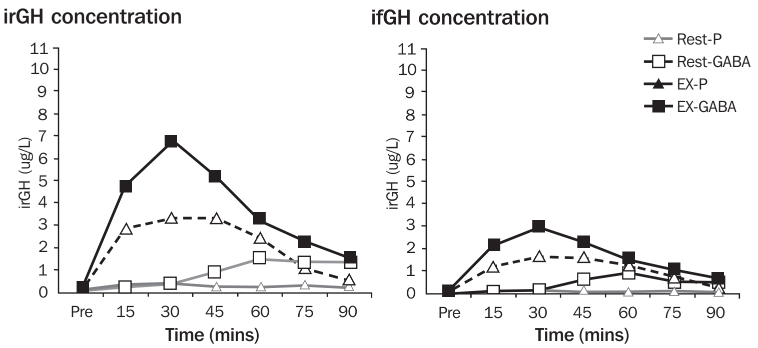


Figure 3: irGH and ifGH AUC secretions

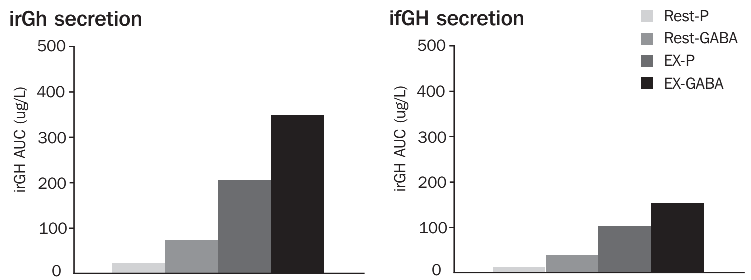
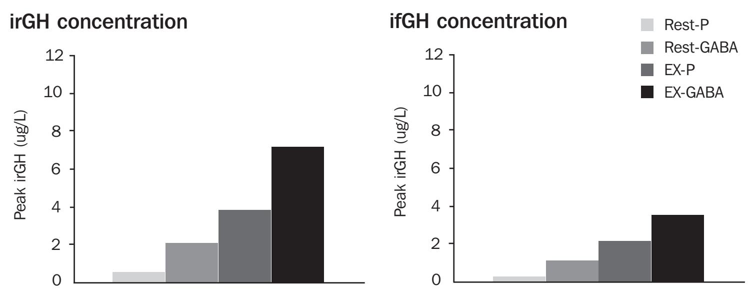


Figure 4: Peak irGH and ifGH blood concentrations



to the equivalent resting trials, those with resistance training resulted in significantly higher levels (up to 18-fold) of irGH and ifGH (we already know that exercise is a powerful stimulator of GH release);

- GH release at rest – GABA ingestion produced significantly elevated levels of both irGH and ifGH regardless of whether exercise was performed – up to 15-fold!
- Effects of GABA plus exercise – the fact that GABA can enhance GH release is encouraging enough, but even more impressive was that GABA plus exercise produced significantly higher levels of irGH and ifGH than exercise plus placebo, both at various time points after administration and in terms of total amounts secreted (area under curve – AUC). For example, the irGH response after exercise-GABA was approximately 200% greater than exercise-placebo at 30 minutes after exercise cessation. Likewise, the ifGH response after exercise-GABA was 175% greater than exercise-placebo at 30 minutes after exercise. The same trends were noted for peak concentrations of both irGH and ifGH.

Figures 2, 3 and 4 (left) illustrate these results.

What does this mean for athletes?

The two key findings from this study are that, firstly, GABA supplementation at rest dramatically enhances the release of ifGH. This is important because it's the first study that shows GABA supplementation at rest increases ifGH – the portion of GH that's known to be biologically active. This increase is significant; compared to rest-placebo, ingestion of GABA produced three to four times as much total secretion. Similarly, GABA ingestion combined with rest produced peak concentrations of ifGH that were over four times higher than without GABA.

However, even more interesting is the combined GABA-exercise effects on GH; looking at the figures given above, you can see how, compared to exercise alone (*ie* plus placebo), taking GABA boosted the GH response significantly: 200% more irGH and 175% more of the biologically active ifGH at 30 minutes after exercise following GABA ingestion is not to be sneezed at! Moreover, compared to placebo-GABA, the same trends were observed for total units of irGH and ifGH released (AUC) when GABA and exercise were combined.

For athletes seeking to gain strength, lose fat and recover rapidly, this seems like a win-win situation; for the same degree of exercise intensity (remember the GABA in itself does not directly improve exercise performance), the magnitude of the subsequent GH release is nearly doubled. Even GABA taken on its own raised levels of both irGH and ifGH, which opens up the intriguing possibility that it could also be used to augment the natural peak of GH production that occurs during the early hours of sleep.

However, before we get too excited, there are important caveats to add. The first is that there's still little understanding of how ingested GABA is able to produce this GH-boosting effect. As any exercise biochemist will tell you, when mechanisms are poorly understood, caution is the by-word.

The second is that despite everything we know about GH, exactly how the administration of GABA to boost exercise-induced GH might affect subsequent growth and recovery in athletes has yet to be determined. Until long-term studies have been conducted to investigate this, we can't be sure if these theoretical benefits will actually translate into improved performance. As the researchers themselves put it, 'Although GABA-induced irGH/ifGH secretion may alter substrate metabolism and/or enhance the skeletal muscle responses to resistance training, this still remains to be determined.'

Despite these caveats, GABA is considered a safe supplement with low toxicity and is relatively cheap: for example, 200g (66 servings) typically costs around $20-30 in the US and £15-20 in the UK. Those who wish to experiment with it as an adjunct to resistance training therefore, may have little to lose. However, this of course presupposes that the emphasis remains firmly intelligent training and good general nutrition – no supplement can ever be a magic bullet. That said, while the jury's still out, the research on GABA to date is promising and it remains an area to watch.

Practical implications

- The ingestion of GABA appears to naturally boost growth hormone production in the body; when combined with appropriate training, this should in theory enhance muscle growth and adaptation;
- Athletes wishing to try GABA have little to lose but should not neglect the fundamentals of training and recovery nutrition!

References

1. Clin Chim Acta 2006; 364: 77-81
2. Clin Invest 1968; 47 (9): 2079-90
3. J Sci Med Sport 2003; 6:295-306
4. J Appl Physiol 2001; 91:163-72
5. Growth Horm IGF Res 2000; 10:99-103
6. Am J Physiol Regul Integr Comp Physiol 2006; 291:R1749-55
7. Nat Clin Practice Endocrin & Metab 2007; 3, 198-199
8. Pharmacol Rev 1980; 32(4): 315-35
9. Int J Neurosci 1992; 67(1-4): 127-44
10. Neuroscientist 2002; 8: 562-73.
11. J Clin Endocrinol Metab 1980; 51: 789-92.
12. Acta Endocrinol (Copenh) 1980; 93: 149-54
13. Med Sc Sports Exerc 2008; 40(1): 104-110

Notes

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