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PEAK PERFORMANCE

The research newsletter on stamina, strength and fitness

NUTRITION

Spit or swallow?

At a glance

This article:
- Provides an overview of carbohydrate supplementation and performance;
- Looks at new evidence on 'carbohydrate rinsing' for performance enhancement in short endurance events;
- Explains why carbohydrate rinsing works and makes practical recommendations.

Everyone knows that carbohydrate drinks can enhance performance. But as Asker Jeukendrup explains, new research suggests that actually swallowing your favourite sports drink might not be necessary. Bizarre as it sounds, you can rinse your mouth, spit the drink out on the ground and still be faster!

During the 1980s, carbohydrate CHO supplementation received a lot of attention and a large number of studies demonstrated that fatigue was delayed and performance was improved when exercise lasted two hours or longer. These studies are summarised in recent reviews[1,2]. The reason for the improved performance may be the prevention of hypoglycaemia. However, probably more important is the maintenance of higher rates of carbohydrate oxidation. These high rates of carbohydrate oxidation allow higher work rates to be maintained.

The optimal carbohydrate dose is still open to debate, as dose-response studies have not given clear answers. Some studies have shown a dose response relationship and concluded that more carbohydrate is better. However, a larger number of studies have found no relationship [1,2]. A recent ACSM position statement recommended athletes take 30-60 grams of carbohydrate per hour [3]. This is partly based on the finding that ingested carbohydrate cannot be oxidised at rates higher than 60 grams per hour[1,2]. But these guidelines may be out of date already, especially for exercise lasting three hours or longer.

Recently it was demonstrated that when a combination of carbohydrates is ingested that use sugars with different intestinal transporters (*ie* glucose:fructose) this can result in very high ingested carbohydrate oxidation rates – as much as high as 105 grams per hour [4]. When this glucose: fructose drink (2:1) was compared with a glucose drink and performance was measured during a

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In this issue

FROM THE EDITOR

Wash your mouth out

They say that science fact is stranger than fiction and this issue's lead article certainly seems to bear that out. After all, can it really be possible that merely rinsing your mouth with carbohydrate drink and then spitting it out boosts performance? Asker Jeukendrup reveals all in a fascinating article that turns some of our previous thinking on carbohydrate nutrition upside down.

Meanwhile, Alicia Filley takes at look at new findings on back health for athletes and explains how cyclists can minimise their risk of back pain by careful saddle positioning. If you're a seasoned cyclist, you might be surprised at what the latest research recommends!

Consistency might be an overrated virtue in the eyes of some, but when it comes to sporting excellence, it's indispensable. With that in mind, regular *PP* contributor Andy Lane explores what makes for consistent performance and how athletes can train their minds to achieve increased consistency.

In our fourth article, James Marshall revisits the topic of plyometric training. In this two-part article, James begins by looking at new research showing which of the most common exercises are most effective and why. In part 2, he'll go on to explain how you can tailor a plyometrics programme to work for you.

Rounding up the issue we report on new findings hot off the press in our What The Papers Say, including HICA and lean muscle mass gain, how chain ring shape affects cycling efficiency, and the role of joint stiffness in back pain.

Regular readers will also notice a change to the format of *PP* this month, with four main articles per issue instead of three. This allows us to increase the range and variety of topics covered in a single issue, while maintaining the rigorous standards and comprehensive discussion about the latest findings in sport science that *PP* readers have come to expect. As always, we welcome your feedback, so please don't hesitate to contact me with any comments or suggestions that you may have. Enjoy this issue and we'll see you next month.

Andrew Hamilton BSc MRSC *editor*

Carbohydrate supplementation pioneers

It's long been known that carbohydrate feeding can improve endurance performance. One of the earliest reports came from the Boston marathon in 1923 and 1924(5). A group of researchers measured blood glucose in some of the participants of the 1923 Boston Marathon and observed that in most runners, glucose concentrations markedly declined after the race. These investigators suggested that low blood glucose levels were a cause of fatigue.

To test that hypothesis, they encouraged several participants of the same marathon one year later to consume carbohydrates (candy) during the race. This practice, in combination with a high-carbohydrate diet before the race, prevented hypoglycaemia (low blood glucose), and the runners also improved their times. Of course this study had severe methodological issues and would not stand up to the rigour of today's scientific scrutiny. However, it was the first study to suggest that carbohydrate intake during exercise might affect performance.

The importance of carbohydrate for improving exercise capacity was further demonstrated in the 1930s. Investigators let their dogs (Joe and Sally) run without feeding them carbohydrates(6). The dogs became hypoglycemic and fatigued after 4 to 6 hours. When the test was repeated but with carbohydrates during exercise, the dogs ran for 17 hours to 23 hours!

3-hour cycling trial, it appeared that the glucose:fructose drink improved performance by 8% compared with glucose and 17% compared with a placebo(7).

These data suggest that higher exogenous oxidation rates may result in better performance, at least during very prolonged exercise. These effects are only seen when large amounts of carbohydrate are ingested (*ie* 90 grams per hour). The potential benefits of glucose/fructose drinks were discussed in *Peak Performance* issue 233 and an overview of up to date recommendations is given in table 1 below.

Carbohydrate and short duration exercise

Twelve years ago, we discovered that carbohydrate feeding can also improve performance during shorter duration exercise of higher intensity(8). We studied cyclists who performed a 40km time-trial with or without carbohydrate and on average, they were 1 minute faster with carbohydrate. This was a large and unexpected effect for which we did not have an explanation at the time.

'The results were remarkable: performance was improved with the carbohydrate mouth rinse compared with a placebo'

During exercise of one hour or less duration, hypoglycaemia does not develop and blood glucose concentrations may even rise. Also, it takes time before any ingested carbohydrate is absorbed, transported to and used by the muscles, so we calculated that only a small percentage of the carbohydrate ingested during these time trials was actually used as a fuel. This amount was thought to be too small to provide additional fuel and result in a beneficial effect.

In order to further study the potential role of carbohydrate as a fuel during this type of exercise, we asked cyclists to perform a 40km time-trial. On one occasion we infused them with a glucose solution, and on another occasion we infused saline (salty water)(9). The cyclists did not know what they were getting on each occasion.

We observed that when glucose was infused blood glucose concentrations were twice as high and glucose was taken up into the muscle at high rates. However, even though this glucose was going into the muscle and was probably utilised, there was no effect on performance. This tells us that providing fuel during this type of exercise is not that important and other factors determine performance. But if carbohydrate does not exert its effects through being used as additional fuel, how can we explain the performance benefits during a 40km time trial?

Mouth-brain connection

An alternative explanation could be that the carbohydrate somehow influences the brain. For example, there is evidence that taste influences mood and it may also influence the perception of effort. An interesting observation provides support for a central nervous system effect. When you are hypoglycaemic after a long ride or run without food and you are feeling weak and dizzy, all you have to do is bite into a chocolate bar to feel better. Almost instantly the feelings of weakness and dizziness are reduced, and you feel better long before the carbohydrate has reached the blood circulation and the brain. This means that there must be connections from the mouth directly to the brain.

This may also explain why we found improved performance during a 40km time trial. In the following study, we asked cyclists to repeat the 40km time trial but only rinse their mouth with a carbohydrate solution without swallowing any of

Table 1: Recommended carbohydrate intake during exercise in order to optimise performance

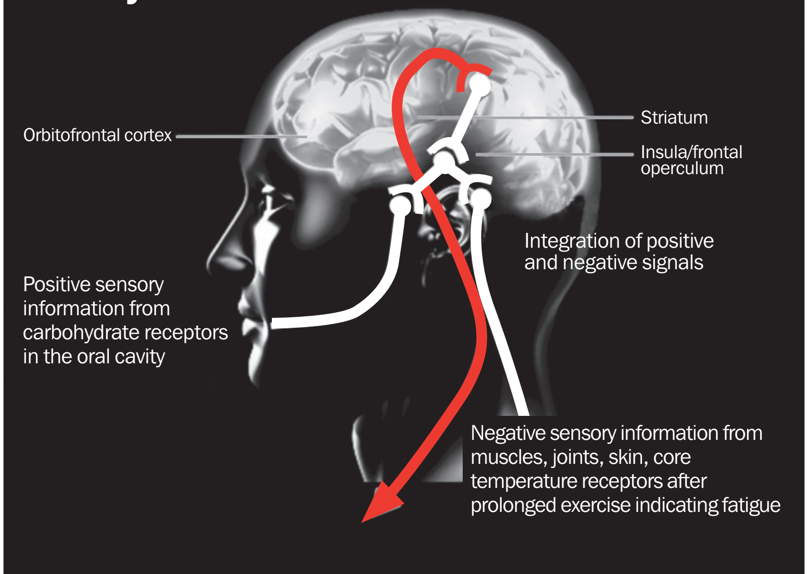
Exercise duration	CHO needed	CHO intake	Comments
15-45 min	Very small amounts of CHO		
45 min-2h	Small amounts of CHO	Up to 30g/h	Can be achieved with most forms of CHO
1.5-3h	Moderate amounts of CHO	Up to 60g/h	Can be achieved with CHO that are rapidly oxidised (glucose, maltodextrins)
>2.5h	Large amounts of CHO	Up to 90g/h	Can only be achieved by intakes of multiple transportable CHO (glucose:fructose; maltodextrin:fructose)

NB – Some of these time periods overlap because individual tolerance differences need to be taken into account.

it[10]. The carbohydrate used in this study was a non-sweet maltodextrin solution, containing carbohydrate, but tasteless. The rinsing protocol was standardised. Subjects would rinse their mouth for 5 seconds with the drink and then spit the drink out into a bowl. They were not allowed to swallow any of the drink.

The results were remarkable: performance was improved with the carbohydrate mouth rinse compared with placebo and the magnitude of the effect was the same as the effect we had seen in the early study with carbohydrate ingestion! They were about 1 minute faster, even though none of the carbohydrate had actually entered the body (no carbohydrate is absorbed in the mouth). Perhaps the carbohydrate in the mouth rinse had connected with a receptor in the mouth that subsequently sent a signal to the brain. This signal probably informed the brain that food was on its way and this reduced the perception of effort, making the exercise task easier. These results were reproduced in studies that followed, although not all studies have found these effects (see discussion below).

Figure 1: A simplified model of the actions of a carbohydrate mouth rinse



Carbohydrate receptors in the mouth send positive signals to three main areas in the brain (insula/frontal operculum, the orbitofrontal cortex and the striatum). These signals are integrated with negative signals from the periphery and an appropriate motor output is generated.

Brain imaging

In follow-up studies conducted at the University of Birmingham, brain scans using a technique known as fMRI were used to see if there was increased activity in certain areas of the brain with a carbohydrate mouth rinse that was not present with a placebo mouth rinse[11]. Indeed the study revealed that with a carbohydrate mouth rinse, certain areas of the brain such as the reward centre and areas involved in motor control were activated. The areas investigated included the insula/frontal operculum, orbitofrontal cortex and striatum (*see figure 1*).

During strenuous exercise many incoming signals arising from muscle, joints, lungs, skin and core temperature receptors are sent to the brain. Over time, these signals will be perceived as unpleasant and consciously or unconsciously this will lead to an inhibition of motor output. This is often called 'central fatigue'.

Athletes tend to regulate their physical activity to keep their levels of discomfort within acceptable limits. It is not clear exactly which pathways are involved in this inhibitory activity but it seems plausible that the signals arising from the carbohydrate receptors in the mouth are counteracting some of these negative signals. Perhaps the sensors are telling the brain that: 'you have nothing to worry about, because energy is on its way!' The exact nature of the communication is unknown but the studies clearly show that there is a huge amount of communication between mouth and brain, even before any carbohydrate is delivered.

Sweetness or carbohydrate

Another question that arises is whether it's the carbohydrate that has this effect or the sweetness or taste of the drink? Interestingly, the brain centres that responded to a carbohydrate mouth rinse did not respond to sweetness. When a drink with artificial sweetener was used to rinse the mouth no activation of these areas occurred. However, when a maltodextrin solution, which is a carbohydrate that is not sweet and has virtually no taste, was used, these areas of the brain were equally activated to glucose.

Together, these findings suggest that there are receptors in the mouth that detect carbohydrate and that these receptors are separate from the receptor that detects sweetness. However, such 'carbohydrate receptors' have not yet been identified in humans. These findings are also in agreement with some of the performance studies we conducted. When we compared a sweet and a non-sweet carbohydrate and asked cyclists to perform another 40km time trial we observed similar performance improvements [12].

'These findings suggest that there are receptors in the mouth that detect carbohydrate and that these receptors are separate from those that detects sweetness'

During what type of exercise does mouth rinsing work?

Carbohydrate ingestion seems to work when the exercise is longer than 30 minutes. Exercise shorter than that does not seem to benefit from carbohydrate intake [13]. Recently a study showed that mouth rinsing with a CHO solution increased total distance covered during a self-selected 30-minute run in comparison with mouth rinsing with a colour and taste-matched placebo [14]. Similar results were obtained during a 60-minute self-paced run [15].

In another study, the influence of ingestion and mouth rinsing with a carbohydrate solution on the performance during a high-intensity time trial

Table 2: Summary of studies currently in the literature that have investigated the effects of a carbohydrate mouth rinse on performance

Authors	Exercise	Effect (+ is enhancing)	Performance effect
Carter et al	~1h cycling	+2.9%	Improved
Pottier et al	~1h cycling	+3.7%	Improved
Rollo et al	30 mins running	+2.0%	Improved
Rollo et al	1h running	+2.0%	Improved
Chambers et al	~1h cycling	+1.9%	Improved
Beelen et al	~1h cycling	+0.5% (ns)	No effect
Witham et al	~1h running	-0.3%	No effect

NB: 'ns' = non-significant effect

(~1h) was investigated in trained subjects [16]. Subjects either rinsed around the mouth or ingested a 6% carbohydrate solution or placebo before and throughout a time trial. In the mouth rinse conditions, time to complete the test was shorter with the carbohydrate mouth rinse (61.7 minutes) than with placebo (64.1 minutes). Interestingly in this study, when drinks were swallowed and not rinsed, there was no difference between the placebo and carbohydrate drinks.

Also, in another study at the University of Birmingham, a 1.9% improvement in time-trial performance was observed with a carbohydrate mouth rinse compared with placebo. In two other studies no effect was observed when subjects ingested a breakfast before the time trial[17] or during running [18]. So overall, the effect of a carbohydrate mouth rinse is convincing and seems to be significant for exercise lasting 30-60 minutes. It is not clear whether shorter exercise can benefit and it is unlikely that the mouth rinse effect can override some of the other factors that cause fatigue during more prolonged exercise.

'The effect of a carbohydrate mouth rinse is convincing and seems to be significant for exercise lasting 30-60 minutes'

In practice

So what does all this mean in terms of practical advice? Well, it appears that it's not necessary to take on board large amounts of carbohydrate during exercise lasting approximately 30 minutes to one hour. Simply rinsing your mouth with carbohydrate may be sufficient. I have often seen athletes with lollypops and little sweets in their mouth before and during competition. Maybe that's a practical solution?

It must also be said that in most conditions, the performance effects with the mouth rinse were similar to ingesting the drink, so there does not seem to be a disadvantage in taking the drink (although occasionally athletes may complain of gastro-intestinal distress when taking on board too much fluid). Of course when the exercise is more prolonged (two hours or more), carbohydrate becomes a very important fuel and it is essential to take it on board.

We will see what the future holds but it's not difficult to imagine some messy feed zones with athletes taking sports drinks and then spitting them out on other athlete's shoes. A final word of caution however; if you use this practice in Singapore you may be fined $500!

Asker Jeukendrup is professor of exercise metabolism at the University of Birmingham, has published over 150 research papers and books on exercise metabolism and nutrition and is also consultant to many elite athletes

References

1. *Nutrition 20, 669-677, 2004*
2. *European Journal of Sport Science 8, 77-86, 2008*
3. *Med Sci Sports Exerc 39, 377-390, 2007*
4. *Br J Nutr 93, 485-492, 2005*
5. *JAMA 82: 1778-1779, 1924*
6. *Am J Physiol 108: 203-209, 1934*
7. *Med Sci Sports Exerc 40, 275-281, 2008*
8. *Int J Sports Med 18(2): 125-9, 1997*
9. *Med Sci Sports Exerc 36(9): 1543-50, 2004*
10. *Med Sci Sports Exerc 36(12): 2107-11, 2004*
11. *J Physiol 587, 1779-1794, 2009*
12. *Can J Appl Physiol 30(4): 379-91, 2005*
13. *Eur J Appl Physiol 104, 831-837, 2008*
14. *Int J Sport Nutr Exerc Metab 18, 585-600, 2008*
15. *Med Sci Sports Exerc 41 (5), p 21 (abstract), 2009*
16. *Scand J Med Sci Sports, 2008*
17. *Int J Sport Nutr Exerc Metab 19, 400-409, 2009*
18. *J Sports Sci 25, 1385-1392, 2007*

Practical implications

- Rinsing your mouth with carbohydrate during exercise can improve exercise performance in events lasting 30-60 minutes, even when carbohydrate is not ingested;
- To use this technique, the mouth should be rinsed with a carbohydrate solution every 10 mins or so;
- A lollypop or sweets can also be used but care should be taken to ensure you don't swallow it or choke on it!;
- Carbohydrate drinks used for rinsing should be higher than 6% concentration (6 grams per 100ml) and it is probably more effective to use a 10-20% solution (10-20 grams per 100ml);
- It is okay to drink the carbohydrate as well but this is not needed to get the beneficial effect. If you drink it make sure your don't drink amounts that would cause gastro-intestinal distress;
- Be aware that a keeping a carbohydrate solution in your mouth and swirling it around your teeth can be detrimental to dental health.

Back health – don't get saddled with injury!

At a glance

This article
- Explains the causes of low back pain and the related injuries that many athletes suffer;
- Helps you to determine which injuries are likely respond to conservative treatment and when you can return to activity;
- Shows how you can evaluate your cycling position to improve performance and decrease the strain on your low back.

In the last issue of *PP*, we looked at rehabilitation from back injury. But as the saying goes, 'an ounce of prevention is worth a pound of cure' and with this in mind, Alicia Filley looks at how to keep your back in top condition, paying special attention to the demands of cycling

Studies reveal that 60% to 80% of the general population experiences low back (lumbar) pain at some point in their lifetime[1]. Despite their level of fitness, athletes are no exception and even elite cyclists show an incidence of back pain similar to the general population[2].

The structure of the spine arises from a set of stacked bones running from the skull to the pelvis, called vertebrae. These stacks of bone have a hole in the centre of them through which passes the spinal cord. Nerve roots branch off of the spinal cord between the bones and send a network of nerves throughout the body. Filling the spaces between those stacked bones are gelatinous discs that cushion the vertebral bones and absorb the forces that travel along the spine (*see figure 1*). Connecting the vertebrae are many tiny ligaments, muscles and tendons. The larger muscles of the back attach to the vertebrae and span to the scapula ribs and pelvis.

There are four basic origins of dysfunction that athletes with back pain should consider: pathology, musculoskeletal strain/sprain, injury to the disc, and **spondylolysis** or **spondylolisthesis**. Pathological causes of back pain include tumour, infection and fracture. Any back pain accompanied by fever, chills, weight loss, a history of trauma, or neurological symptoms (numbness or loss of bowel or bladder control) should be evaluated by a physician.

Jargonbuster

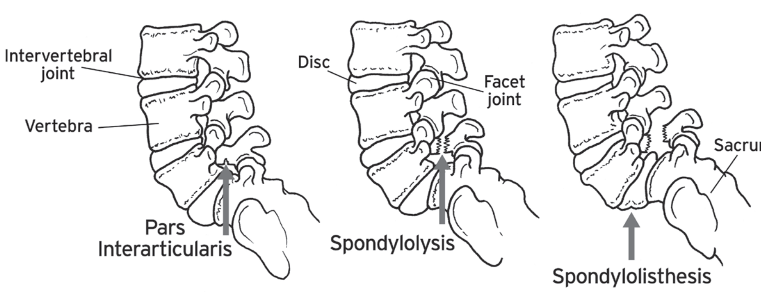
Spondylolysis
A stress fracture in one of the vertebral bones of the lower spine that is common in adolescent athletes

Spondylolisthesis
the forward slipping of one vertebra upon another, due to fracture or joint degeneration

Fluoroscopy
a radiographic study, similar to an X-ray, that evaluates moving body structures

Perineum
the area between the legs that bears the pressure while sitting on a bicycle saddle, usually defined as between the pubic bone and the tailbone

Figure 1: Anatomy of the spine



Fracture of a vertebra (usually the 5th lumbar vertebra) at the pars interarticularis results in spondylolysis. When the unstable vertebra slips forward onto the one below it, spondylolisthesis results.

Oh, my aching back

The most common cause of back pain in athletes however is lumbar strain or sprain. Any of the tiny ligaments (sprain) and muscle tendons (strain) that connect the vertebrae can be injured through acute trauma or by overtraining. Usually the athlete recalls some traumatic event (lifting something heavy, a fall, or an unanticipated tackle) that triggered the pain, however, there may have been underlying weakness or prolonged stress that made the area vulnerable. Pain and stiffness (muscle spasm) result, and are usually worse the following day.

When there is pain, a cycle of immobility begins. Even if you continue your sporting activity, you develop compensations to avoid using painful muscles. Weakness and muscle wasting in these muscles result from lack of use. A muscle imbalance occurs, leading to further compensations, weakness, and increased risk for further injury.

Most low-back strains/sprains improve within two weeks, and 90% of patients are pain free within two months[3]. The key to the management of lumbar strain/sprain is pain control. Over-the-counter, non-steroidal, anti-inflammatory drugs (NSAIDS) relieve pain and decrease inflammation. Prescription muscle relaxants help if there is significant spasm.

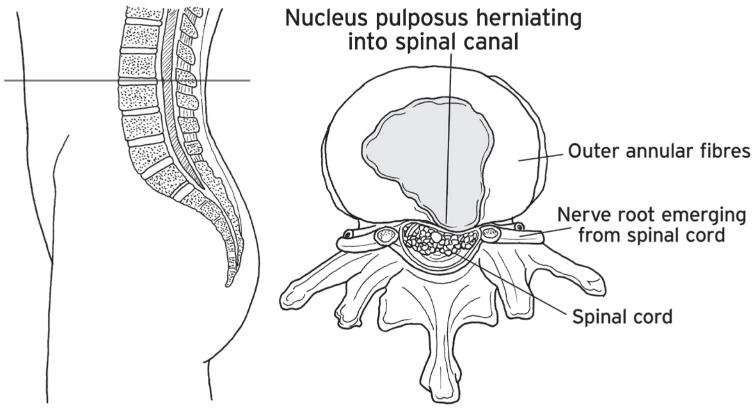
Physiotherapy modalities such as ice, heat, and ultrasound improve the pain and allow early initiation of therapeutic exercise. Early return to light activity is advised, since taking more than two days of rest results in muscle atrophy. An athlete can return to full activity once he or she demonstrates pain-free, full range of motion. A further evaluation is necessary if pain and function do not improve with conservative treatment within two to three weeks.

The slippery disc

The discs between the vertebrae cushion the bones of the spinal column and absorb the shock of movement. The outer rings of the disc are composed of cartilaginous fibres that provide stiffness and form to the inner jelly-like substance. The outer rings are innervated by pain receptors that generate pain when the inner disc is forcibly squashed against them, as in forceful flexion and rotation movements.

Continued stress to the disc may result in a tear of the outer fibres (*see figure 2, overleaf*). As you can see, the disc does not actually 'slip', but rather herniates or leaks through the outer fibres into the

Figure 2: Anatomy of the spine at the vertebral level, showing a herniating disc



space occupied by the spinal cord or its nerve roots, causing a radiating pain to the hips and legs. The irritation caused by this intrusion is more evident upon trunk flexion (bending forwards) as the disc is forced against the sensitive nerves. Diagnosis of a herniated disc is achieved by clinical exam and magnetic resonance imaging (MRI).

Again, pain control is achieved through NSAIDS and physiotherapy. Most people respond well to conservative treatment, consisting of limited rest and initiation of a therapeutic exercise programme under the supervision of a physiotherapist. Surgery may be required for those who do not. A discectomy, or excision of the offending protruding disc, is performed via small incisions in the back (called a percutaneous discectomy) or through a traditional open incision. For either procedure, the return to play for the typical athlete with a single level disc protrusion is two to three months[3]. For those who have disc protrusions at multiple spinal levels and for whom a spinal fusion is indicated, the return to play for non-contact sports can be a year or more.

Cycling and back pain

The British Cycling Federation reported the frequency of injuries for over 500 elite cyclists who were evaluated by squad medics[2]. Sixty percent of the injuries reported were in the low back. Further analysis revealed that the distribution of injuries were equal among track riders, road riders, and those who did both, indicating that actual hours in the saddle may not be a contributing factor to low back pain in cyclists.

So why do so many cyclists experience back pain? Physicians at the Eisenhower Army Medical Centre in Georgia believe the primary cause is lower back weakness[5]. In cycling, the low back is the powerhouse for generating forward momentum and controlling the bike. If the back is not well conditioned, fatigue sets in quickly and muscles are strained. This repetitive strain begins an inflammatory process that damages local tissue. Over time weakness, loss of flexibility, and pain become more prominent. What might seem like an acute backache brought on by moving some furniture may actually be the result of chronic stress from overuse.

Finding the right fit

Overuse injuries result primarily from using faulty equipment or progressing a training schedule too quickly. Often something as simple as a minor adjustment to the riding position can ameliorate the problem. The total reach of the rider from the seat to the handlebars is called the virtual top tube length. Getting this distance right is the most important factor for preventing low back pain. Unfortunately, there is no set formula for finding the magic fit for every rider. There are however, a few general guidelines:

Riders find proper reach when they can't see the front hub (because it is obscured from view beneath the handle bars) while riding in the drop handlebars. In this position, elbows should be bent 65° to 70°. The distance from the elbows to the

Recommended exercises for healthy backs

No matter how fit you are, you may experience back pain during your athletic career. Whether it's due to lack of core strength, decreased range of motion, faulty technique, or overtraining, back pain usually responds to a conservative treatment of pain management and exercise. The following exercises isolate the core muscles of the trunk. Conditioned athletes may be able to substitute larger muscles to perform more advanced balance manoeuvres, yet struggle with the exercises below.

Pelvic clock

Lie on your back with feet supported on a chair and hips and knees each at 90°. Imagine the face of a clock on your abdomen. Six o'clock is toward your pubic bone; 12 o'clock is toward your nose. Pull your pelvis down toward six o'clock in an anterior pelvic tilt and hold for five seconds. Now pull your navel toward your nose, using only your abdominal muscles, in a posterior pelvic tilt. Hold for five seconds. You may need to place your hands on your thighs to keep the muscles in your legs relaxed. Repeat the sequence five times. Progress to holding each contraction for 10 seconds.

Heel touch

Lie on your back with your knees bent and feet on the floor. Press your navel to the floor. Keeping that position, bring both knees to your chest. Continue to press the small of your back against the floor as you slowly straighten one hip, keeping the knee bent, and lightly touch your heel to the floor. Return that leg to the starting position. Keep your chin tucked, but head on the floor as you repeat with the opposite leg. Repeat slowly, three times on each leg, for three sets. When you reach eight to ten reps without fatigue, begin to perform the exercise while straightening the knee until it is fully extended.

Superman

Lying on your stomach, stretch your arms forwards of your head. Begin with floating each arm, then each leg upward, and holding each for five seconds. Progress to lifting the opposite arm and leg simultaneously and holding for five seconds. When ready, add difficulty by lifting arms and legs together, keeping face down and neck long, and hold for eight seconds. Do 10 reps of each exercise.

knees should be two and a half to five centimetres at the top of each pedal stoke. With hands comfortably placed on the brake hoods, a plumb line dropped from the nose should intersect the bicycle stem. Most importantly, forward lean should come from the pelvis rotating at the hip, rather than bending the back, which should remain as straight as possible.

Handlebar height plays a role in rider comfort as well. Handlebar height should be even with, or just slightly lower than, that of the seat. Setting the handlebars lower than four centimetres below the seat places increased pressure on the low back unless the rider is extremely flexible and able to rotate his or her pelvis forward.

While tilting the pelvis forward at the hips rather than flexing the lumbar spine decreases the strain to the low back, it increases the pressure on the **perineum**. Researchers at Utah State University hypothesised that if female cyclists could achieve a greater pelvic tilt while riding, without increasing pressure on the perineum, their incidence of low back pain would decrease[6].

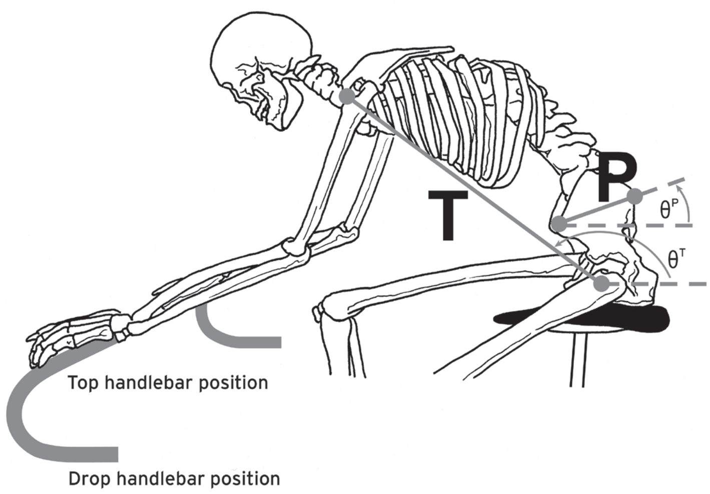
To test this hypothesis, 20 female volunteers rode a stationary bicycle ergometer using three different saddles: standard, partial cutout design and complete cutout design. The pelvic angle and trunk angle were recorded while on each saddle (*see figure 3*). Subjects rode on each saddle for four minutes with their hands on the tops of the handlebars and four minutes with hands in the drops.

The results showed a greater pelvic angle with the partial and complete cutout design than the standard saddle; however, the complete cutout design also slightly increased the overall trunk flexion angle. The majority of the subjects found the partial cutout saddle to be the most comfortable. Both cutout designs decrease pressure on the perineum while allowing an increased pelvic angle.

Investigators at the Chaim Sheba Medical Centre in Israel found that an increased pelvic angle could also be achieved by tilting the saddle angle forward 10° to 15° from horizontal[7]. Using **fluoroscopy**, they evaluated 10 healthy adults on different types of bicycles using different seat angles. They found that tilting the seat angle 10° to 15° increased the pelvic angle and decreased the forces at the lumbar spine and pelvis.

They then adjusted the seats of 40 volunteers from a local cycling club who reported low back pain. Follow up after using the new saddle position for six months revealed that 72% of the cyclists no longer had back pain, and 20% reported a significantly decreased incidence and intensity of pain. The limitations of this study are the small sample size and the fact that most back pain resolves within two to three months anyway. However, the fluoroscopic results cannot be ignored; cyclists with low back pain should consider experimenting with a slightly forward saddle angle to achieve a better back position.

Figure 3: Diagram of conventions used to specify angular displacements (θ) about the pelvis (P) and the trunk (T)[7]



‘Researchers found that tilting the seat angle 10° to 15° increased the pelvic angle and decreased the forces at the lumbar spine and pelvis’

You can also improve your pelvic angle by increasing your flexibility. Try adding yoga or Pilates to your cross training to increase both pelvic flexibility and core strength. Remember to use any flexibility you acquire and change your habitual riding posture. If you don't have a coach or riding club, have a friend video tape you on a trainer. Evaluate your posture and work to increase the bend at the hips and flatten the low back. Minor adjustments to your bike, your training and your posture can have big payoffs in your comfort and performance.

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References

1. *Curr Sports Med Rep, 2004 Feb;3(1):35-40*
2. *Br J Sports Med, 1996;30:349-353*
3. *Clin Sports Med, 2004 Jul;23(3):367-79*
4. *Arch Pediatr Adolesc Med, 1995;149:15-18*
5. *Curr Sports Med Rep, 2005;4(5):271-4.*
6. *Med Sci Sports Exerc, 2003 Feb;35(2):327-32*
7. *Br J Sports Med, 1993;33:398-400*

Practical implications

- Regardless of the source, back pain usually responds to conservative treatment and most athletes can expect to return to their prior level of play;
- Specific trunk strengthening exercises are needed to condition your core and help prevent back injury;
- Cyclists with low back pain should evaluate the fit of their bike and consider using a saddle with a partial cutout, angled forward 10° to 15°.

Consistency: keep it together under pressure

At a glance

This article:
- Explains why inconsistent performance is associated with attempting to achieve peak performance;
- Discusses the psychological states associated with peak performance and how to achieve them in regular practice sessions;
- Encourages athletes to develop positive attitudes to performance and to enjoy the pressure of competition.

Oscar Wilde once said that 'consistency is the last refuge of the unimaginative'! However, it's an irrefutable fact that consistency in sport is essential for long-term success. Andy Lane explains how you can increase your consistency for better sport performance

Imagine the scene; it's the World Cup final and England will win if Steven Gerrard scores the final penalty in the shootout. If Gerrard performs consistently, past form indicates it's highly likely he will score. However, if he does, it bucks the trend; the English football team has lost their last three penalty shoot-outs in major competitions.

Public uproar followed exit from the 2006 World Cup on penalties after defeat by Portugal and questions such as: 'Why can't the England players take penalties in major competitions?' and 'Do English penalty takers have the nerve for major competition?' followed. Successful penalty taking for professional players is about maintaining consistency. Penalties are missed when performance dips, and dips to catastrophic levels.

Variable performance

Addressing the issue of why performance varies is a common reason for athletes seeking support from a sport psychologist. If we begin asking: 'To what extent does your performance in training vary?' athletes tend to say 'Not by much' and if performance improves or deteriorates, they can often provide a good reason why.

For example, if an athlete can bench press five sets of 10 repetitions at 70kg, and performs this session three times per week, its possible he/she can repeat this performance. He or she might perform worse if they have had trained hard already that day, or is stressed from the pressures of work, but in general, athletes confidently estimate that they produce non-maximal performance repeatedly, and this relates strongly with actual performance. The key point is that athletes are highly confident about being capable of delivering a sub-maximal performance. However, this level of consistency changes when athletes want to produce peak performance at key times.

'Athletes are highly confident about being capable of delivering a sub-maximal performance. However, this level of consistency changes when athletes want to produce peak performance at key times'

Of the variables susceptible to change, a plethora of studies provide convincing evidence of the transient nature of emotions [1]. Emotions can come on rapidly, invading our consciousness and disturbing the normal flow of thoughts and actions during competition [2]. Emotion can usurp performance routines of even the most able athletes.

The effects of emotion on performance are most apparent when people are asked to perform a routine skill under pressure, such as walking a rope ladder 20 metres above ground[3]. It's the same skill as walking on the ground, but once the person becomes nervous and starts thinking about performance, they inhibit performance. Extending this logic to sport, it is not surprising that intense emotions represent the most plausible explanation on why soccer players miss penalties in competition, but rarely miss in practice (to the extent that many argue that practising penalties is not a productive strategy).

A great deal of research has demonstrated links between emotions and performance [2]. Research indicates that athletes develop beliefs on which emotions help performance and which emotions hinder performance. Research has indicated that emotional intelligence, defined as the ability as to identify, regulate and utilise emotional states to bring about peak performance is an important variable for sport psychologists to work with[4]. Furthermore, it has been proposed that consistent performance is brought about by frequent usage of psychological skills such as imagery, self-talk, goal-setting and relaxation training to manage the stresses and strains of competition[5].

Practising performance under pressure

Athletes spend relatively little time performing under pressure. When the critical moment arrives therefore, they have had relatively little exposure to the pressures involved so perhaps it's not so surprising that performance can vary. In short, skills learned in non-pressure situations will not necessarily transfer to pressure situations.

One useful strategy for learning to perform under pressure is to simulate the demands of competition using imagery. A recent development in imagery research is the PETTLEP (Physical, Environment, Task, Timing, Learning, Emotion and Perspective) model – see table 1[6]. PETTLEP aims to closely replicate the sporting situation through imagery, including physical and emotional sensations associated with performance. Research demonstrates that imagery is associated with enhanced performance in pressure situations [7].

Athletes should learn to see themselves

Table 1: The PETTLEP model of conducting imagery	
PETTLEP model	Applied to sport
Physical – the athlete's physical responses in the sporting situation	Examples include holding the correct stance, holding any implements that would usually be held, and wearing the correct clothing.
Environment – replicate the actual performing environment	Imagining the performance should be as similar as possible to the actual performing environment. If a similar environment is not possible, photographs of the venue or audio tapes of crowd noise can be used.
Task – replicate the skill or set of moves performed in competition	Examples include; taking a penalty, running up a hill, a particularly phase of play.
Timing – the pace at which the imagery is completed	Use a stopwatch to record the actual time it takes to complete the task, and then perform the imagery at the same speed.
Learning – the adaptation of the imagery content in relation to the rate of learning.	For example, a soccer player who learns that effective penalty taking involves placing the ball down, taking seven steps backwards, and then focusing on kicking through the centre of the ball so that it is directed to the chosen spot in the goal.
Emotion – simulate those emotions experienced in competition	For example, if the athlete felt nervous at the start of competition, then up-regulate emotions to feel nervous before starting imaging a task from the competition.
Perspective – imagery can be internal (first person) or external (third person). Internal perspective refers to the view that an athlete would have when he was actually performing, whereas external perspective would be like watching yourself performing on a video tape. Internal imagery is preferable as it more closely approximates the athlete's view when performing.	Eg, watch performance as though you are the camera.

performing successfully in pressure situations, but should not underestimate the demands of the task. It's important to perform well and condition positive emotions, but it's also important not to create a false scenario that under-represents how difficult the task will be. The greater the clarity of the imagery and the extent to which this accurately replicates the demands of peak performance, the greater its potential benefits will be. Once these images have been developed, the athlete should incorporate imagery into his or her training programme and not just save it for use in competition The more often the athlete performs imagery, the greater will be the simulated exposure to the stresses of competition [7].

Manage your mind habits

Emotional conditioning or reprogramming your mind habits involves challenging the habits associated with negative thinking. The performance sapping effects of unpleasant emotions are often built on a habit negative thinking [8]. People have conditioned themselves to be susceptible to experiencing such emotions through negative thinking habits, and as such, these habits need breaking. The key is to reprogramme your mind to replace these negative habits with positive thoughts and images. Eventually these new positive thoughts will become habitual and performance will become more consistent.

'If-then' plans have been found to be an effective method of changing thought processes (see table 2)[9]. If-then plans work by putting the barrier to poor performance alongside the solution. By putting barriers and solutions side by side, the process of implementing the solution can become automated. During the learning stages, people repeat the if-then plan daily until it becomes ingrained. If-then plans can re-structure negative thoughts and turn them into positive thoughts by having pre-prepared structured statements.

Table 2: If-Then plans for penalty takers	
If (barrier to performance)	Then (solution to the barrier)
If I notice my heart rate pounding as I place the ball down	Then I will take a deep breath and focus on the word 'relax' as I breathe out
If I hear the crowd screaming	Then I will focus all my attention on the centre of the ball
If I think about changing my mind where the ball is going	Then I will remind myself of my penalty-shot routine and say 'concentrate on kicking through the centre of the ball'

Summary

With practice, you can become more aware of your emotions and able to use psychological strategies to manage performance. You also need to know what each emotion means and the appropriate response to deal with it. Practising sport skills using competition imagery and if-then strategies combined with PETTLEP can help you deal with these emotions. With practice, you can learn to manage your negative emotions until it becomes a habit!

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References

1. *Psych of Sport & Exerc, 8(1): p. 47-72 2007*
2. *Mood and human performance: Conceptual, measurement, and applied issues, Hauppauge, NY: Nova Science 2007*
3. *Cyber Psych & Behavior, 4(3): p. 335-339 2001*
4. *Emotional intelligence in sport: conceptual, methodological, and applied issues. In A.M. Lane, Editor. 2007, Nova Science: Hauppauge, NY. p. 131-154*
5. *Social Behav and Persony: An International Journal, 37: p. 195-202 2009*
6. *J Applied Sport Psych, 13(1): p. 60-83 2001*
7. *Sport and Exercise Psychology: Topics in Applied Psychology, A.M. Lane, Editor. 2008, Hodder-Stoughton, UK. p. 139-150*
8. *Person and Social Psych Review, 11(2): p. 167-203 2007*
9. *J Person and Social Psych. 96(1): p. 11-31. 2009*

Plyometrics: make it work for you

At a glance

This article:
- Explains why plyometrics can enhance sport performance over and above simple resistance training;
- Looks at new research on how athletes can maximise the benefits of plyometrics training.

Plyometrics is a topic that has been covered before in *Peak Performance*, but a number of questions remain about which exercises are best, how much, how often, and to which population should they be given. In this two-part article, James Marshall looks at the latest evidence, and comes up with some practical answers

Figure 1:
Depth jump step-off

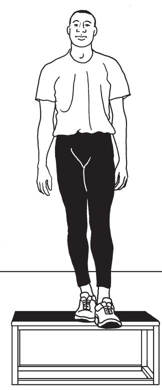


Figure 2:
Depth jump landing

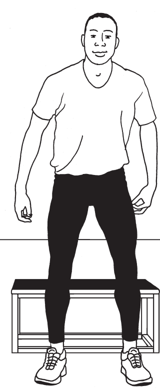
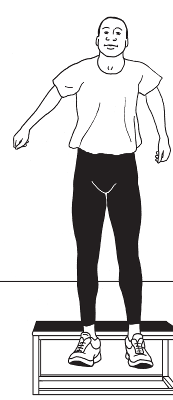


Figure 3:
Depth jump rebound



Why do plyometrics?

During the early stages of an athlete's career, running, jumping and throwing can all be improved by improvements in strength. A weak athlete who is good technically may simply improve their jump by increasing leg strength. However, there is a law of diminishing returns and this is due to the limits of recruiting muscle fibres at speed.

Most sporting actions occur in fractions of a second, and the ability to reproduce maximal strength may take longer than this. Zatsiorsky uses the example of a shot putter who is weak compared to other shot putters [1]. The delivery part of the shot put lasts between 0.15 and 0.18 seconds, and elite shot putters can produce a force of 60kg in that time. If a shot putter can bench press a maximum of 220-240kg, this equates to 110-120kg per arm; in the put described above therefore, our shot putter is only using 50% of maximum strength.

By contrast, a beginner shot putter who could only bench press 50kg would definitely improve performance by being able to bench press 150kg, because he or she would be able to produce more force during the put. However as the putter's maximal strength increases, so does the time it takes to recruit all these muscle fibres. The clear implication is that after a certain point, it's explosive strength that needs to be developed, and this is where plyometrics comes in. After all, what good is maximal strength if it can't be used within the short time frame of an explosive action?

Another example is the high jump where the force production to propel the body upwards occurs in just 0.2 seconds on take off. Once a certain level of strength has been reached, doing slow squats will not help the ability to produce force in the legs in that short time. Instead, faster, lighter squats or squat jumps plus unloaded plyometric activities will help train the reactivity needed to increase the speed of the takeoff.

Plyometrics help train explosive strength by shortening the time taken to switch from an eccentric action (such as landing) to the concentric action (such as jumping). You are basically training the muscle fibres and motor neurons to work more quickly and in synchronisation with each other. It follows therefore that the jumps and drills you should use are those that train the actions and timings required in your sport.

However, research in individual sports is limited and study design varies, so analysing what is the most effective jumping programme is difficult. Most studies seem to look at outcomes of 10m speed and vertical jump height, or similar measurements. These are quite useful, but both are linear in nature, not multidirectional (the sort of movements that characterise sport actions) and do not require reactive ability. With those limitations in mind we can look at the best way to improve vertical jump.

How to jump higher

A key question is how to make the jump training specific for your sport. A recent meta-analysis (a study that pools the data from a number of previous studies) of many different plyometric studies has looked at this issue and provides some interesting answers [2]. The Spanish researchers looked at 56 different plyometric jump programmes to see which type best increased vertical jump (VJ) height.

The programmes included in the meta-analysis varied in their design and length, but all incorporated lower body plyometrics of some description (*see box*). A meta-analysis is useful in this respect because it eliminates some of the minor variables that can cause variability in results between different studies. This can help to paint a more accurate overall picture than when just one individual study is used.

The meta-study looked at studies that were varied in their approach, and used both experienced and inexperienced subjects from different sporting backgrounds such as track and field, volleyball, basketball, bodybuilding, rowing, swimming and football. Some of the major findings were as follows:
- The greatest gains were found in athletes who were at international level (*ie* elite) rather than at regional or national level;
- Men demonstrated greater gains than women;
- The gains were similar for groups from different sporting backgrounds;
- VJ height improvement was no greater when plyometrics were combined with different types of exercise compared with when plyometrics were used alone (*eg* combining resistance training with the plyometric programme didn't yield greater gains).

Although the international athletes showed the greatest gains, all groups showed improvements,

What are plyometrics?

Plyometrics are any exercises that help develop the stretch shortening cycle (SSC) of movement. They start with the stretching of a muscle, an amortisation phase (the period of time from the beginning of the lengthening phase to the beginning of the take-off phase) and then a muscle contraction phase. The faster the stretching phase, the faster the contraction phase. It's akin to an elastic band being stretched and then released, rather than just thrown. The actions should be explosive in order to train the SSC, rather than heavy and slow. The exercises can involve some sort of jumping or landing for the lower body, or some sort of throwing for the upper body. The three main jumps are:

Drop (or depth) jump (DJ)
Here the athlete steps or jumps off a bench or step, lands on one or two feet and then jumps up as high as possible. This is a fast jump and one of the fundamental plyometric exercises (see *figures 1-3*).

Countermovement jump (CMJ)
The athlete starts in a vertical position, lowers their body by bending the knees and then jumps up, usually with an arm swing. This is a slower jump, although it does result in greater height than the squat jump (see below).

Squat jump (SJ)
Here the athlete jumps up from a squatting position. The depth of the squat does not matter and is related to personal preference. This is a concentric-only jump and therefore not strictly speaking a plyometric action as there is no pre-stretching involved. However, some gains can be made from increasing maximal strength but these should be done in conjunction with the jump training.

Once the basic landing and jumping techniques have been learned and can be performed effectively, the correct mechanics for that sport should be taught and rehearsed in situations that require decision making. This requires sound coaching, but it should make it more interesting and effective for the athlete.

including beginners. Plyometric training improves both the elastic tendencies of the muscles and tendons involved in jumping, together with neurological response. It is not surprising therefore that more advanced athletes who have better coordination patterns to begin with improved more, but the study shows that there does not need to be a training base before starting a programme.

When looking at what type of training was done, many of the individual studies did not detail the jumping and landing technique used, so it is not known how much of a factor the technical and coaching aspects were. The variety of jumps incorporated did make a difference, with a combination of squat jumps, depth jumps and countermovement jumps proving most beneficial.

The depth jump height did not appear to be a factor in how effective the depth jump was, and the authors recommended a maximum height of 20cm to jump from; the reduced intensity of a modest jump height allows more repetitions to be performed with reduced risk of injury and a potentially greater neurological response. Some programmes used 'weighted jumps' (wearing a weighted vest or holding dumbbells) but they did not appear to add any extra benefit to the programme.

Although some shorter-term studies did show improvements, overall it was the duration and volume of work that seemed to improve jump height the most. A programme lasting 10 weeks minimum, with two sessions a week and 50 jumps a session was recommended. It's worth adding that if you're conducting a session, 50 repetitions don't last long, so this can easily be incorporated into a field or technical session. However, if you're doing a line out session in rugby or another sport drill that requires jumping, this may already include repeated jumps, so you need to take this into account.

In part two, James looks at how to tailor a plyometric programme to the needs of specific sports, with the emphasis on younger athletes

References

1. Zatiorsky, VM, Science and Practice of Strength Training, Champaign, Il: Human Kinetics. 1995
2. JSCR 23 (2), p 495-506 2009

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WHAT THE PAPERS SAY

Reports by Andrew Hamilton BSc Hons MRSC ACSM

Chain ring shape in cycling

Bikes have traditionally used circular chain rings to drive the chain and turn the rear wheel. Over the years however, there's been a continual interest in the use of slightly non-circular chain rings (containing a very slight ellipse), which some have claimed to be better suited to the biomechanical requirements of pedalling, resulting in more force delivered to the crank for less perceived effort from the rider.

To look at this in more detail, Norwegian scientists have been studying the effects on force development and pedalling rate of using a non-circular (Biopace) chain ring compared to a conventional circular chain wheel. Ten trained cyclists (average VO_2max of 61.7mls/kg/min, average age 27 years) cycled with a Biopace and a circular chain wheel at 180 watts power output at 65 and 90rpm, during which their crank torque profiles were measured. They also pedalled using both chain ring types at their freely chosen pedal rate where metabolic responses were monitored, including oxygen uptake and blood lactate concentration.

The researchers discovered that crank torque profiles were similar between the two chain wheels during cycling at the preset pedal rates of 65 and 90rpm. They also found that the freely chosen pedal rate was not dependent on chain ring type, averaging 93rpm in both cases. Interestingly however, blood lactate concentration was significantly different between the two types of chain rings being on average 0.2mmol per litre lower with the Biopace rings compared to the conventional circular rings.

The researchers then carried out a musculoskeletal simulation model. This seemed to support the idea that a contributing factor to the observed difference in blood lactate concentration could be the slightly reduced muscle activity observed where peak crank torque occurred during each crank rotation when using the

Biopace rings. The researchers concluded that this slightly lower observed muscle activity might result from larger transfer of energy from the legs to the crank when the Biopace rings were used. This study then provides some evidence to support the anecdotal observations of some cyclists that pedalling using non-circular chain rings feels easier for a given pace compared to conventional rings.
J Physiol Anthropol. 2009 Nov;28(6):261-7

HICA and lean muscle gain

Regular *PP* readers may be aware of the importance of the amino acid building block called leucine on muscle growth and metabolism. Alpha-hydroxyisocaproic acid (HICA) is closely related to leucine; HICA is an end product of leucine metabolism in human tissues such as muscle and connective tissue, and according to clinical and experimental studies, HICA appears to act as an 'anti-catabolic' substance. Now a new study by Finnish scientists has been looking at the effects of HICA supplementation on body composition, delayed onset muscle soreness (DOMS) and performance in athletes.

In this four-week, double blind study, 15 healthy male football players (average age 22 years) were divided into two groups; subjects in the HICA group received 500mg of HICA mixed with liquid three times a day for four weeks while the placebo group received an equivalent amount of an inert substance (maltodextrin) mixed with liquid three times a day for the same period.

The subjects in both groups underwent football training 3-4 times a week, performed strength training 1-2 times a week, and played one football game during the study. The subjects were also required to keep diaries on training, nutrition, and their symptoms of DOMS following training. Body composition was evaluated with an accurate technique known as 'DXA' before and after the four-week period, while muscle strength and running speeds were measured with field tests.

The results were fascinating. Those taking HICA very significantly increased their total body weight while maintaining a constant level of body fat (*ie* the gains in weight were from lean tissue such as muscle mass). Moreover, when they analysed the lean body mass of lower limbs, the researchers observed an average gain of 0.4kg in the HICA group but a loss of 0.15kg in the placebo group. Moreover, HICA supplementation decreased the whole body DOMS symptoms in the fourth week of the treatment compared to placebo.

It's important not to read too much into just one study, but if confirmed, these results suggest that HICA supplementation could offer significant benefits for athletes who are either trying to add lean muscle mass or prevent lean tissue loss – eg following an injury or layoff.
J Int Soc Sports Nutr. 2010 Jan 5;7(1):1. [Epub ahead of print]

Joint stiffness and back pain'

Some researchers have hypothesised that lower limb joint stiffness can be a contributing factor to low back pain because it alters running biomechanics, placing additional loading on the back.

To test this theory, US researchers have investigated lower extremity joint stiffness in runners with and without low back pain. To do this, they compared data from three groups of runners:
- Those with current low back pain (LBP);
- Those with resolved low back pain (RES).

Subjects ran at 8.5mph on a 'force treadmill' – a specially adapted treadmill designed to measure the vertical, horizontal and lateral components of the ground-reaction impact forces during running. Data on these forces were collected during running and joint stiffness was determined from the joint moment/angle profiles.

The results showed no differences in ankle or hip joint stiffness; however, in the group with lower back pain, knee stiffness was significantly higher. Increased knee joint stiffness is associated with less 'give' on each foot strike; the researchers surmised that their findings suggest that the LBP group of runners were not able to attenuate the foot-ground impact to the same level as the other groups and that this decreased attenuation could increase the level of the shock to the low back region, thus potentially increasing the load on the low back.
Res Sports Med. 2009;17(4):260-73

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