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REVIEW

Lower body problems and injury in cycling

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Exercise;
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Knee

Summary Cycling is generally regarded as a low impact sport. It has a range of skills and disciplines, but the majority of cyclists are usually involved in the endurance aspect of the sport. The low impact nature, however, does not preclude cyclists from injury and musculoskeletal problems. Apart from the obvious trauma and sequelae involved in a fall from the bike, the prolonged postural adaptations combined with the repetitive limb movement from spending hours cycling seem to be one of the main reasons for lower limb and lower body problems. Those intending to become involved in the diagnosis and treatment of such problems should be aware of the plethora of mechanical and biomechanical issues when assessing an injured cyclist. This review of lower body problems in cycling highlights the typical patterns of injury and points out that to obtain a diagnosis for a cycling related problem a practitioner must evaluate faults in the bicycle as well as the cyclist. It also highlights that, despite some useful biomechanical input, there is a disturbing lack of evidence base for the treatment of some musculoskeletal complaints. This is unhelpful to those seeking more evidence-based practice, and may encourage an anecdotal approach to treatment for cyclists. All practitioners who are involved in the care of these sports people should continue to press for good quality studies so that cycling injuries of the lower limb may treated more efficaciously in the future.
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Introduction

In the last decade, British cycling as an elite sport has seen unprecedented success with a host of world and Olympic champions. Despite this success on the world stage, road cycling, track cycling or mountain biking remain, to all intents and purposes, minority sports in Great Britain and most other countries outside mainland Europe.

British success is due in part to the technical and physiological advances in coaching, which have been matched by similar 'upgrades' in the knowledge, diagnosis and treatment of cycling related injuries by both medical and physiotherapy practitioners, as well as other appropriately trained health care providers. This advancement has always been hindered somewhat by a powerful subculture of unqualified practitioners and advisors who distribute advice and treatments based mainly on anecdote and hearsay.

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Despite this (or because of it) we still have to question if medical and physiotherapy practitioners are any further advanced in their care of cycling sportsmen and women. This article highlights some of the common musculoskeletal problems that afflict cyclists and investigates the treatment strategies used and their evidence base.

Techniques and strategies for the prevention of injury

The role of the physiotherapist (and other appropriately trained health care providers) in cycling, as with other sports, revolves around the areas of injury care, injury prevention and optimal performance.

Injury prevention is inevitably linked to stretching, which has always been an important component of most programmes aimed at preventing sporting injuries. These programmes have proved difficult to implement mainly because acute muscle tears or strains rarely happen in cycling and cyclists consider themselves as low risk for this type of injury. This is not due to a lack of muscular effort, but probably because of the controlled linear pedalling action that prevents sudden muscle stretch and the minimum amount of eccentric contractions (Shrier, 1999). Ensuring that the stretching programme has a solid evidence base is not helped by most recommendations being clouded by misconceptions and conflicting evidence (Chaitow, 2003). Evidence from critical and systematic reviews concluded that although a stretching programme alone may possibly have enhanced the performance of a muscle, it did not reduce the risk of overuse or acute injuries (Shrier, 1999) and does not confer protection from muscle soreness (Herbert and Gabriel, 2002).

Nevertheless, based more on intuitive biomechanics than scientific evidence, cyclists are encouraged to undertake stretching programmes mainly to counter muscle and tendon shortening that may result from the prolonged positions of flexion and aide a better body position. Cyclists involved with endurance cycling adopt an unusual, prolonged, flexed posture (see Fig. 1) and a stretching programme has been recommended to achieve a degree of flexibility needed for pain free cycling. At present there have not been any studies examining the effect of flexibility on body position, biomechanical parameters or injury rate in cycling. Studies looking at the effects of body position on respiratory performance (Ashe et al., 2003) and on power production (Too, 1994) concluded that periods of adaptation to and training for unusual aerodynamics cycling postures is needed before their benefits are manifest.

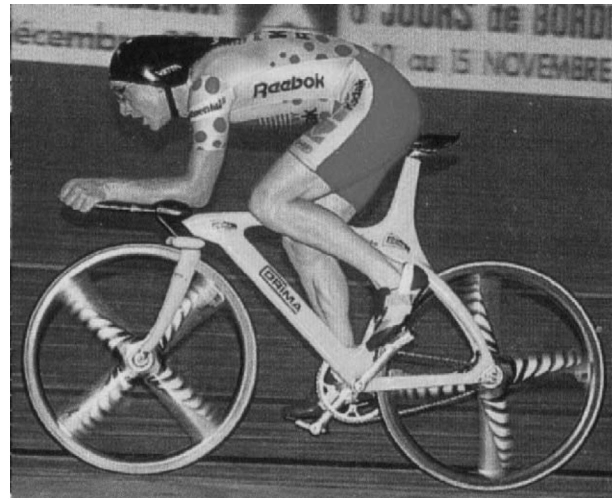

Figure 1 In order to increase power output and reduce drag cyclists can adopt prolonged and unusual postures.

Techniques and strategies for the treatment of injuries

Cyclists usually acquire injury in two distinct ways. The first is due to tissue macrotrauma usually associated with direct trauma after a crash or fall from the bicycle. The second is tissue microtrauma that can be as a result of overuse injury that does not overtly involve such direct trauma. It is the latter that presents a more challenging diagnostic process, especially when the cyclist may have acquired the microtrauma injury as a result of subtle abnormalities such as a leg length discrepancy or abnormal foot posture.

The knee

Like most sports, the knee is a commonly reported problem area for cyclists. The difference in cycling is that most knee problems result from overuse repetitive injuries and occur anteriorly, usually involving the patellofemoral joint (PFJ). Collateral and cruciate ligament and meniscal injuries are regarded as a rarity (Weiss, 1985) and such diagnoses should be considered carefully. Traumatic knee injuries invariably result from a fall or crash (Dannenberg et al., 1996) and can result in bony and soft tissue contusion to the lower limb and knee or in the worst cases a fracture, with the patella being a particularly prone structure. A small amount of data has been gathered over the years regarding the incidence of knee pain in cyclists. Weiss (1985) evaluated 132 amateur cyclists in a 500 mile 8 day tour. Some degree of knee pain was reported by 35% of riders with 21% having significant pain in this area. These findings nicely illustrate the common pattern of overuse knee pain, because anterior knee pain (attributed to the PFJ) was the most common finding (33%), and lateral knee pain (attributed to iliotibial band syndrome (ITBS)) the second most common (7%). None of the riders had evidence of a knee joint effusion, meniscal or ligament instability thus confirming the rare occurrence of internal derangement or ligament problems. Dannenberg et al. (1996) found that of those 1638 recreational cyclists taking part in a 339 mile 6 day tour, 76 riders sought treatment for overuse injuries and 43% of these were knee related. Wilber et al. (1995) attempted to analyse overuse injuries amongst male and female recreational cyclists in California by sending 2500 mail questionnaires. From the 518 replies, they reported that the knee (41.7%) was the second most common overuse injury (after the neck), although no differentiation was made for the precise origin of their knee pain and almost half the cyclists with knee problems reported the discomfort as 'mild'. In elite cyclists, Callaghan and Jarvis (1996) found knee problems accounted for 33% of all self reported injuries, although, once again, no distinction was made between pain at different areas or structures of the knee. Holmes et al. (1991) retrospectively analysed a series of over 300 cyclists of either an elite, competitive or recreational standard. At all ability levels, anterior knee pain (defined as 'chondromalacia patellae') had the highest percentage of overuse knee injuries (37%) with iliotibial band problems the second highest (14%). Interestingly, their data seemed to indicate that it was the 'competitive' riders rather than the 'elite' or 'recreational' who suffered the most knee injuries. Therefore, even from these limited data it seems that problems at the PFJ and the iliotibial band feature consistently and so need further consideration.

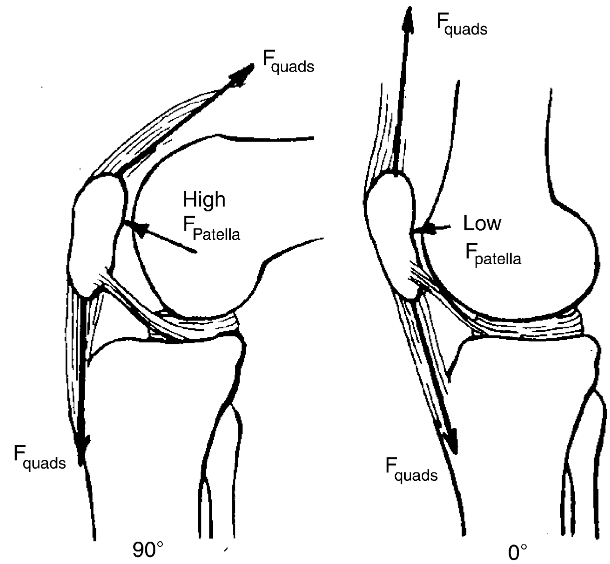

Figure 2 PFJRForce (from high tech cycling). Reproduced with permission from Human Kinetics.

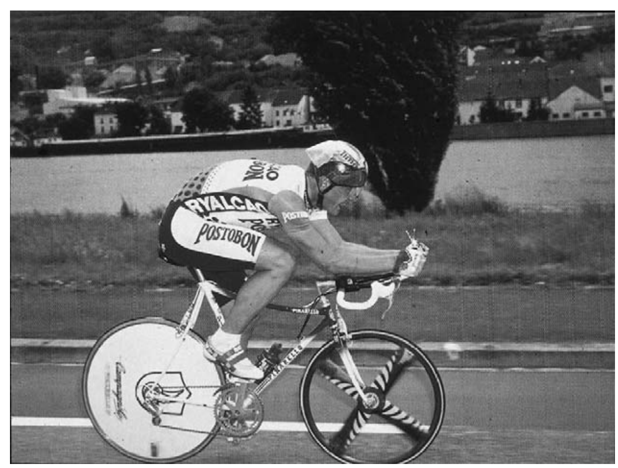

Figure 3 Cyclist at the commencement of downstroke generating high PRJRForce.

Patellofemoral pain

Problems of the PFJ are so common in cycling that this problem has been labelled 'biker's knee'(Mellion, 1991) or 'cyclist's knee' (Sanner and O'Halloran, 2000). One of the aspects of this condition that hinders our understanding of its causes in cyclists is that a considerable body of our knowledge on aetiology, risk factors and treatment is based on running data. The reason for the predominance of patellofemoral problems in cycling is the force that the riders generate at their PFJs. The quadriceps femoris muscle group has a large cross sectional area transmitted through the quadriceps and patellar tendons (Hull and Ruby, 1996). A large reaction force develops at the PFJ surface that is made even greater by the amount of knee flexion achievable by a cyclist at the beginning of a downstroke which is approximately 111° (Timmer, 1991). This is particularly so when in a time trial aerodynamic position (see Figs. 2 and 3). There is still debate surrounding the cause of PFJ pain. It has been clear for some time that many patients

Table 1 Problems caused by incorrect saddle position.

Author	Bike problem	Body problem
Asplund and St Pierre (2004)	Saddle too high	ITB pain, PF loading posterior knee pain
Holmes et al. (1993)	Saddle too high ($>30^{\circ}$ Knee flexion)	ITB pain
Holmes et al. (1994)	Saddle too high	ITB pain, biceps femoris tendonitis
Timmer (1991)	Saddle too high	ACL strain
Farrell et al. (2003)	Saddle too high	ITB pain
Burke and Pruitt (1996)	Saddle too high	Posterior knee pain
Fleming et al. (1998)	Saddle too high	Increased ACL strain
McLean and Blanch (1993)	Saddle too high	Increased extensor torque
Kronisch (1998)[a]	Saddle too high	Hamstrings tendonitis, PES anserine bursitis, patellar tendonitis, PFJ pain, ITB pain quadriceps tendonitis
Holmes et al. (1991)	Saddle too high	Posterior capsule strain biceps femoris strain
Burke and Pruitt (1996)	Saddle too low	Anterior knee pain
Mellion (1991)	Saddle too low	Patellofemoral pain
Sanner and O'Halloran (2000)	Saddle too low	Patellofemoral pain
Salai et al. (1999)	Saddle tilted anterior/ posterior	Low back pain

[a]Mountain bikes.

with PF pain are wrongly attributed as having chondromalacia patellae (Lindberg et al., 1986; Radin, 1985). Yet several cycling texts specifically state that 'chondromalacia' is a cycling related problem without making a distinction between this pathological condition and the clinical condition of PF pain (Asplund and St Pierre, 2004; Holmes et al., 1994; Hull and Ruby, 1996; Gregor and Wheeler, 1994; Sanner and O'Halloran, 2000). This confusion is unhelpful to the clinician and needs to be reconsidered as it implies that all cyclists have PF pain due to chondromalacia patellae. Although arthroscopy studies of the general population suggest that this is not always true (Casscells, 1979), there has not been any epidemiological study to examine specifically this relationship in the cycling population.

Training errors such as pedalling too high (i.e. too hard) a gear, or prolonged hill climbing seem to be major culprits for PFJ pain and indeed for some professional cyclists early retirement has been attributed to prolonged mileage pedalling with huge gear ratios resulting in greater PFJ forces than the periarticular and intraarticular tissues could cope with.

PFJ pain can be exacerbated by lowering the saddle height and alleviated somewhat by being higher (see Table 1). McLean and Blanch (1993) summarized the work of biomechanists looking at a basic cycling error of inappropriate saddle height and its effect on the knee joint loading. Firstly, they stated that a higher saddle decreased the extensor torque at the knee because the amount of knee flexion was less. Secondly, changing the saddle height may have affected quadriceps muscle activation patterns. They concluded, based on previous work (McConnell, 1986), that alterations in vastus medialis and vastus lateralis activity contributed to the PFJ pain that besets many cyclists. Unfortunately, as the role of medial and lateral vastii muscle activity in PFJ pain has been and continues to be the subject of much debate; this is still an area of conjecture rather than of definite conclusions (Kasman et al., 1998).

Iliotibial band syndrome

Some authors state that this problem is the second most frequent of knee injuries in cycling (Holmes et al., 1991, 1993; Weiss, 1985). The features of ITBS are no different in the sport of cycling than in other sports, i.e. lateral knee discomfort or tenderness close to the lateral femoral condyle. Sometimes this is accompanied by a snapping sensation and a positive Ober's test.

The aetiology is thought to be due to repetitive friction of the distal iliotibial band posterior fibres against the lateral femoral condyle that is particularly susceptible at 30° of knee flexion (Holmes et al., 1993). This is just within the usual range of knee motion for a cyclist of 30° to 110° (see (Timmer, 1991) for a review of joint excursions in cycling). This area of friction has been described as the 'impingement zone' (Farrell et al., 2003). A myriad of reasons have been proposed to explain why cyclists are prone to this condition that can be summed up as 'improper cycle fit' (Holmes et al., 1993; Gregor and Wheeler, 1994). Consequently, a considerable amount of advice has been given to correct the bicycle and correct the cyclist's body that is not specific and applies the 'scatter-gun approach' to treatment. The only study to collect instrumented data on this condition gave new information as to why cyclists seem to have more incidence ITBS than runners. Although the runners spent more time than cyclists in the 'impingement zone' (75 versus 38 ms) they calculated that a runner's knee will be in the impingement zone 4800 times in a 10 km (6 miles) run. A cyclist, by comparison, will hit the impingement zone 6600 times for the same distance. It was concluded that repetition of knee flexion rather than pedal force was the likely contributor to ITBS along with anatomical differences (such as leg length), the seat height affecting riding position and training changes (Farrell et al., 2003). This study supports the theories of other authors (Asplund and St Pierre, 2004; Holmes et al., 1994). As many cyclists' journeys, in the form of training or competition, can last several hours a considerable amount of repetitive movement can take place with the smallest abnormality causing dysfunction and impaired performance.

Vascular and neurological problems in cycling

There are several issues concerning the vascular and neural structures in the leg and around the perineum that are problematic in cycling and are thought to be related to the unique, prolonged seating posture adopted by cyclists. For example, one area in which progress has been made is in the diagnosis of vascular problems in cycling, especially those that may masquerade as referred pain from the lumbar spine or the sacroiliac joint. Unfortunately, for many years doctors, physiotherapists and many other practitioners involved in examining and treating cyclists frequently missed the diagnosis of vascular pathology simply because they were unacquainted with the problem (Schep et al., 1999). Consequently, cyclists were thought to have a neurological cause for their symptoms even though the neurological examination was normal (Abraham et al., 1997) and sought inappropriate treatments, in some cases for several years, before the correct diagnosis was made (Scavèe et al., 2003). We now appreciate that such a presentation represents a vascular dysfunction due to a stenotic thickening in the external iliac artery (Taylor et al., 1997) (Fig. 4) that constitutes about 90% of intravascular lesions (Schep et al., 1999). Cyclists with this condition (although it is not exclusive to cyclists) present with symptoms similar to intermittent claudication such as paraesthesia and a loss of power in part of or throughout the whole lower limb, brought on particularly by extreme maximal effort in racing or training (Taylor et al., 1997).

The causes for this condition are thought to be a mixture of prolonged, repetitive hip flexion causing trauma to the external iliac artery in combination with high cardiac output and high blood flow to the lower limbs causing arterial hypertension (Schep et al., 2002; Mosimann et al., 1985). There may also be an element of anatomical variation such as extra arterial branches, excessive arterial lengthening, a hypertrophic psoas muscle (Pils et al., 1990) or associated metabolic disorders such as diabetes mellitus (Wright et al., 1997).

The diagnosis is one of exclusion and the key is taking a careful history and if possible trying to perform a maximal exercise test to reproduce the symptoms. None-invasive equipment to measure the ankle/brachial pressure index during provocative exercise tests has been reported and have been proven to be useful in aiding an early diagnosis (Taylor and George, 2001). Further investigations would usually involve angiography, magnetic resonance angiography, arteriography or echo Doppler ultrasound scanning (Schep et al., 1999).

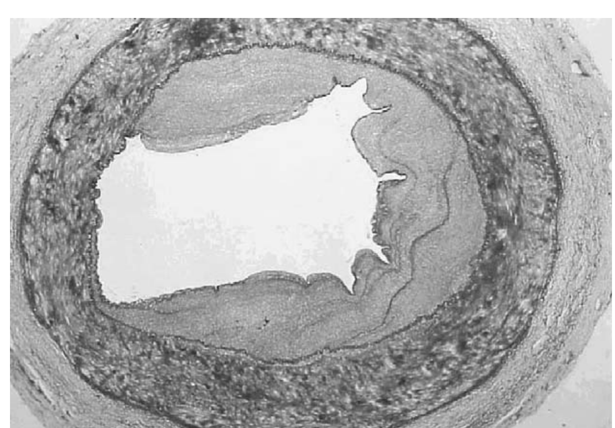

Figure 4 Thickened intima of the external iliac artery (from Taylor et al., 1997, p. 256).

If the cyclist wishes to compete at the elite level, or if the symptoms are worsening to such an extent that activities such as stair climbing reproduce the symptoms, then vascular reconstruction is usually the treatment option although there are reports of the condition being alleviated by physiotherapy in the form of stretching and changing the pattern of lower limb movement (Pils et al., 1990).

Surgery may involve either dilation of the stenotic artery or in more severe cases, a resection and end to end anastomosis or intravascular stent. However, these procedures are not without risk and some controversy remains as to the gold standard treatment and diagnostic procedure (Schep et al., 2002).

Another area concerns that of perineal numbness that is a frequent complaint of cyclists of both sexes whilst keen male cyclists also report penile numbness and in some cases erectile dysfunction (Marceau et al., 2001; Andersen and Bovim, 1997). These complaints are thought to be due to a transient ischaemia from pressure on the perineal neurovasculature as a result of frequent cycling. This theory was given some scientific credence when (Ricchiuti et al., 1999) provided EMG evidence of chronic pudendal nerve injury in one keen, male cyclist with transient, dorsal penile numbness. One (underpowered) study found that in males just over 50 years of age, cycling for longer than 3 h per week may have been associated with erectile dysfunction (Marceau et al., 2001).

The two commonly cited treatment strategies are to severely curtail cycling and to change saddle design. There are reports that have documented a resolution of symptoms associated with the pudendal nerve injury once cycling has ceased (Ricchiuti et al., 1999). The second is to adjust the saddle position or design along with an alteration in riding technique (Silbert et al., 1991). Correcting saddle position is an obvious starting point, but there is contradictory advice in the popular cycling press regarding not only the optimum angle but also the direction of tilt. A low handlebars position is also believed to be a contributing factor due to the associated forward body rotation increasing the pressure on the perineum. Similarly, increased perineal pressure will result if the rider's position is overly stretched due to a long top tube (crossbar) or handlebar stem.

Saddle designs now include a cutaway seat, in which a gap in the middle of the saddle reduces perineal pressure, and a gel saddle in which problems are eased by the cushioning effect of the gel. Although various websites provide riders with ideas of saddle design, personal preference and trial and error are still the practice today in the absence of definitive biomechanical evidence of the optimum design.

Treatment of atraumatic knee injury

In cycling, the treatment of atraumatic knee injuries should be directed to the cyclist's body as well as to the cyclist's bicycle. These two factors have been described as intrinsic and extrinsic factors respectively (Asplund and St Pierre, 2004). Indeed, Holmes et al. (1991) stated that treatment of the injured area would be ineffective if associated biomechanical problems were not also corrected.

Unfortunately, the barrage of treatment to the body and for bike adjustment to alleviate knee and back problems tends, yet again, to be of a 'scattergun' approach which although ensuring that at least something might be helpful, hinders a properly tailored treatment plan.

Correction of intrinsic factors

There are several important intrinsic factors to assess intrinsic factors that can lead to cycling injuries. For example, it is recommended that the body is checked for leg length shortening. Holmes et al. (1993), without any accompanying data, stated that length discrepancies of 1/4 of an inch (6.4 mm) or more should be 'considered significant'. This was said to cause a stretch of soft tissues resulting in posterior-medial or posterior-lateral knee pain. Suggested treatment strategies revolved around ensuring that the bicycle was fitted to the longer leg and then correcting the short leg by building up the space between the cycling shoe and the pedal (Holmes et al., 1994). Additionally, tibial internal or external rotation of $>20^{\circ}$ can contribute to PF pain whilst tibial internal rotation combined with thigh adduction, usually as a result of excessive foot pronation, is regarded as a possible cause of medial knee pain (Hull and Ruby, 1996).

A stretching routine to counter tightness of the soft tissues such as tendons around the knee is advocated in virtually every text written about cycling injuries. However, this is based on clinical experience and good intuition rather than good evidence as there has never been a prospective controlled clinical trial looking at soft tissue tightness and its relationship to cycling overuse injury. Certainly with the extreme positions adopted by some riders and the resultant combination of lumbar posterior lengthening and anterior shortening, it is intriguing to know why some riders cycle pain free without a stretching programme and why some depend on such a regime to keep them asymptomatic.

Correction of extrinsic factors

The practitioner treating cyclists has to be aware of the myriad of extrinsic problems that can contribute to pain and the technical issues involved with cycling. Almost any piece of equipment on a bicycle can be faulty and therefore would need checking. As an illustration of this problem the following takes the example of the saddle correction (Table 1):

The saddle may be too high thus putting the rider at increased risk of ITBS (Asplund and St Pierre, 2004; Farrell et al., 2003; Holmes et al., 1994; McLean and Blanch, 1993). Or too low increasing the tendency to PFJ pain (Asplund and St Pierre, 2004) (see Table 1). The saddle may be too far forward increasing the likelihood of anterior knee pain (Asplund and St Pierre, 2004; Holmes et al., 1994) or too far back increasing the risk of neck pain (Mellion, 1994). If the saddle has been forward tilted, with the front of the saddle pointing down, this is thought to increase perineal pressure with short term perineal numbness and male penile numbness and long-term chronic pudendal nerve injury. The definition of what constitutes 'too high, low, forward, or backward' will depend on the type of bike being ridden, and the anthropometry of the individual cyclist.

Of all the modifications and corrections that can be made to the bicycle, the pedal has received most attention probably as it is the main area of interface between bike and rider and the place where energy is transferred from the rider to the bicycle (Broker and Gregor, 1996). The commonly accepted position for the foot relative to the pedal is to align the 1st metatarsal head to the pedal spindle (Ruby et al., 1992) (see Fig. 5). Cyclists are often advised to change their pedal system or foot position if knee pain and injury persist as proper shoe/cleat alignment is considered a critical factor in the management and prevention of overuse knee injuries (Wheeler et al., 1995); usually these corrections are made by trial and error. It has been helpful that several clinicians and biomechanists have attempted to remove some of the guesswork about equipment correction by utilising kinetic analysis via force-plates in the pedals and kinematic analysis via video to investigate the effect of foot and lower limb position on the knee.

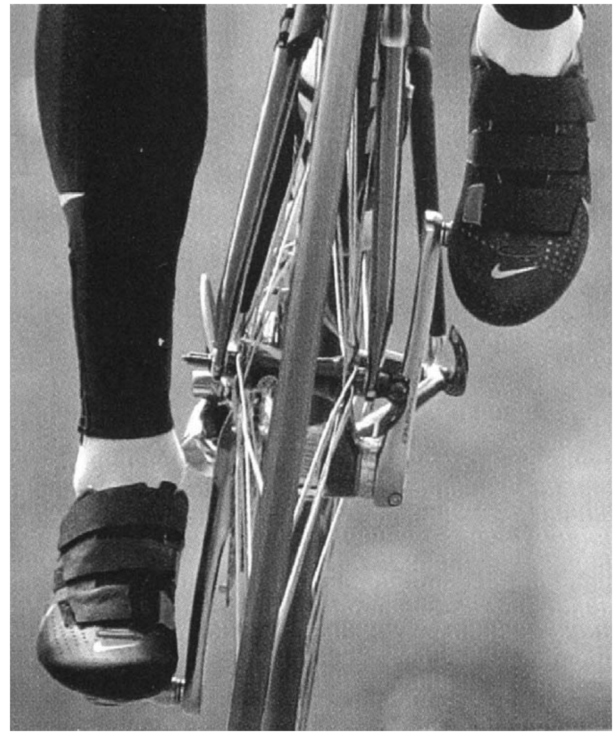

Figure 5 Alignment of the metatarsal head in relation to the pedal spindle.

Ericson et al. (1984) found that the predominant load on the knee during stationary cycling is a varus load, putting strain on the lateral structures of the knee. They then showed that simply putting more pressure on different parts of the foot would ease the varus knee load moment. This was confirmed years later by Ruby et al. (1992).

The development of the pedals from the traditional clips and straps to the so-called 'clipless' systems was not embraced enthusiastically by all cyclists due to the belief that the rigid foot position of the clipless system only had to be minutely out of the correct position to place undue stresses on the knee. A clipless system which allowed a small amount of rotation (moving the heel towards and away from the bike) was designed to satisfy the requirements of fixation and cause less knee strain and this became known as the 'floating' system. It has only been since the development of reliable, instrumented pedal systems that our understanding of the biomechanical processes has improved (Wheeler et al., 1995). These biomechanists were able to provide quantitative data to show that the torque applied through the pedal was highest during the power phase of the cycle and could be reduced by using a 'floating' clipless system. In actual fact they also revealed that the greatest reduction in pedal torque was with the traditional clip and straps system but it was unlikely that many cyclists would ever revert to their use. They also had a small amount of data on cyclists with knee pain and found that they had much larger internal knee moments. The implication for injury was that a decrease in the pedal moment during the power phase of the pedal stroke may be desirable by using rotation of the foot with a 'floating' clipless pedal system.

Hannaford et al. (1986) used a 2-dimensional video to analyse frontal and transverse plane deviations of the knee when the tibial tuberosities were marked. A specially constructed and self adjustable 'Biopedal™' altered foot positions in 3 planes allowing the foot to tilt side to side, to move the heel in and out and also to lift, thus compensating for leg length discrepancies. Once an optimum position in the frontal and transverse planes was found, the riders' own shoes and pedals were adapted. Unfortunately only 8 cyclists' knee pain was evaluated by a follow up questionnaire, 5 of whom originally had overuse knee pain and attributed their symptomatic improvement to the alterations and modifications of their pedalling technique from the kinematic analysis. Although the Biopedal™ was never developed commercially (Millslagle, personal communication, 2004) it still remains a useful research tool for biomechanists and has been used recently to study the effect of pedal–foot position on maximal oxygen uptake (Millslagle et al., 2004).

The alleviation of patellofemoral pain was hinted at by Schwellnus et al. (1996) who reported in abstract form that alteration in the cycle shoe cleats or the use of orthotics could correct abnormal patterns of movement at the lower limb.

Similarly, Hull and his co-researchers considered that the high cyclical loads involved in cycling may be due to malalignment of the 'bike/rider interface' (i.e. the pedal) and that this could result in chronic knee injuries. Using similar processes as Hannaford et al. (1986) a 3 planer motion pedal was used to collect kinetic data and simultaneously collect 3D kinematic data (see Figs. 6 and 7). Firstly they found that, viewed from the front, the knee does not move straight up and down, but has a clockwise circular motion. In other words, when pushing down on the pedal the knee is adducted and then abducts when the pedal returns to the top. They also calculated intersegmental knee loads and found, theoretically, that higher loads would cause knee pain. They found that twisting the foot in and out reduced anterior and lateral knee forces, and when the foot tilted from side to side posterior and lateral knee forces were also reduced (Ruby and Hull, 1993). This experiment helped to explain the importance of having knowledge of the effect of simple methods of adjustments and precisely which adjustments were more likely to ease loads on the knee.

Figure 6 Kinetic analysis with a 6 load pedal dynamometer.

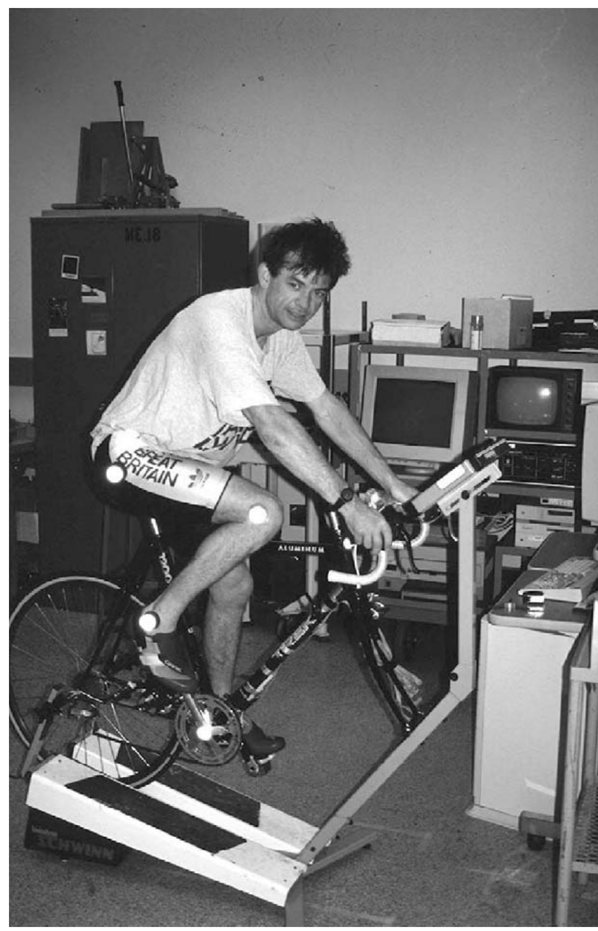

Figure 7 Kinematic analysis of the knee using static cycle.

The role of orthotics in cycling

There is some debate and confusion about the role of foot orthotics in cycling. This is due to the fact that most evidence of the effectiveness for foot orthotics to correct lower limb alignment problems is extrapolated from running data (Sanderson et al., 1994). As Hannaford et al. (1986) pointed out almost 20 years ago, full length or rearfoot orthotics are often inappropriate in cycling as they are incapable of preventing abnormal knee motion at high forces. This is because in the frontal plane, the force from pedalling when using a rigid cycling shoe has two distinct pressure points at the medial forefoot, i.e. the 1st metatarsal head and hallux (the 1st ray) and the 5th metatarsal head (Sanderson and Cavanagh, 1987). The contribution from these points increases as the power output increases. This is less so at the other metatarsal heads, the midfoot and rearfoot regions (Fig. 8) (Hennig and Sanderson, 1995). In the coronal plane, pressure distribution through the foot/pedal interface is greatest through the forefoot particularly the metatarsal heads and much less through the rearfoot (Fig. 9). Despite this, several texts have recommended the use of orthotics to help knee problems (Mellion, 1991; Holmes et al., 1994), and

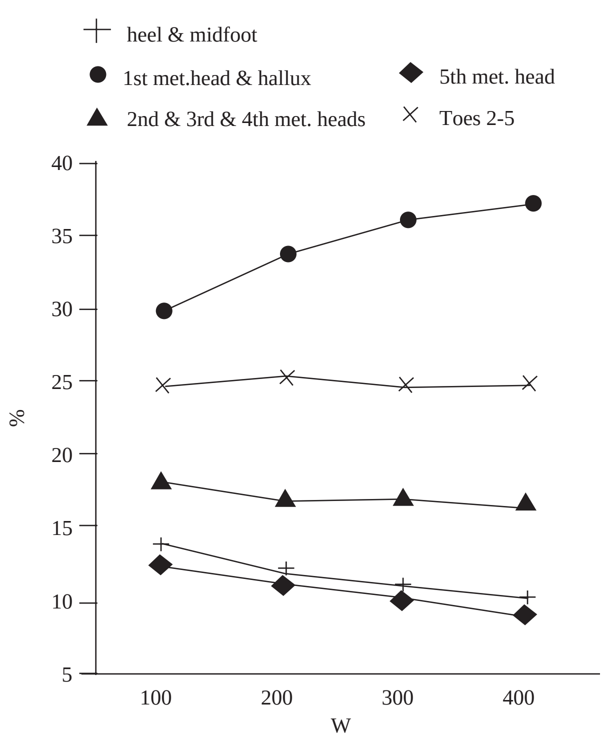

Figure 8 Relative loads under the areas of the foot when cycling at various power outputs (from Hennig and Sanderson, 1995, p. 76, Fig. 5). Reproduced with permission from Human Kinetics.

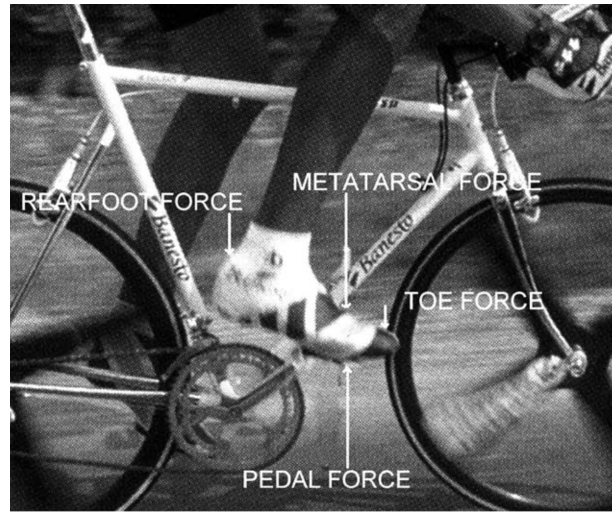

Figure 9 Foot force distribution through the foot/pedal interface.

reduce foot pronation (Sanner and O'Halloran, 2000) although Asplund and St Pierre (2004) do at least make a distinction between the different characteristics needed between running and cycling orthotics. Schwellnus et al. (1996) recommended soft orthotics which they maintained could alter abnormal knee movement patterns and reduce PFJ pain.

Sanderson et al. (1994) investigated wedges of 10° valgus (forcing the foot into pronation) and 10° varus (forcing it into supination) inserted between the foot and pedal in 13 cyclists. Using kinematic data in the coronal plane they found that there were no significant differences between the neutral, valgus and varus wedges in terms of the pattern of motion on the knee. This study also highlighted the large variation in data between the cyclists and hinted that individual analysis and tailored treatment would be more important than trying to find a normal value. In addition, this study did not allow an adaptation period, in contrast to Joganich and Martin (1991) who allowed a 2 week adaptation for nine cyclists with knee pain. Kinetic and kinematic data however still did not significant alter any of the dependent variables such as tibial rotation or medial knee position. Interestingly, five of the nine subjects reported a decrease in their knee pain. This final example illustrates the conundrum with orthotics that the decrease in pain does not seem to be related to a change in musculoskeletal alignment or an alteration in the objective biomechanical data. One explanation may lie in the fact that the measurement devices as they presently exist are not sensitive enough to pick up subtle alterations to knee, lower limb or patella position after an intervention such as foot orthotics. The subtle changes that occur after the insertion of orthotics may be sufficient to alter soft tissue stresses and alleviate discomfort without being aggressive enough to alter skeletal position and biomechanics. A second explanation is that an orthotic is effective by a providing proprioceptive input to the lower limb. This alternative explanation of the mechanisms of orthotics comes from biomechanists and gait researchers who suggest that, rather than changing skeletal alignment, an orthotic works by supporting a preferred movement path of the lower limb and affecting muscle activity (Nigg, 2001; Ball and Afheldt, 2002). This proposed new paradigm for the effectiveness of in-shoe orthotics is worth considering from the podiatric literature and may lead to a better understanding by all clinicians as to the rationale for this common treatment modality.

Summary

Cycling is a sport that generally has lower impact forces than running but cyclists still suffer from a considerable number of injuries, the most common of which seem to be at the knee. Although various tips for treatment are available in the descriptive literature, there is a dearth of prospective controlled trials which can help treating clinicians to be more certain of the cause and effect of injury and tailor their treatment accordingly. Sadly, the treatment of musculoskeletal problems in cyclists is predominantly an evidence based free zone.

Some sophisticated kinetic and kinematic data has given insights into the way in which forces, especially at the knee, can be altered for the better, but it seems we are no nearer being able to describe normative data for treatment options such as orthotics, pedal alignment and seat height. Therefore, although these studies can give guidance as to the direction of treatment and bike modification, these adjustments are still very much based on trial and error to suit the individual cyclist.

Nevertheless, all practitioners involved in treating cyclists should be aware of the various modifications available both to the cyclist's body and the bicycle itself in order to alleviate or prevent these injuries.

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