OVERUSE INJURIES IN CYCLING

THE WHEEL IS TURNING TOWARDS EVIDENCE-BASED PRACTICE

– Written by Paul Visentini, Australia and Ben Clarsen, Norway

Cycling is an activity with high levels of participation and is growing in popularity. In recent times it has gone from an elite European sport to a worldwide, mass-participation sport. Population statistics show that those who ride one to three times per week or more number 10 and 4 million in Great Britain[1] and Australia[2], respectively. There is a worldwide push to increase cycling participation with the inherent health, environmental and transport benefits being key drivers. The benefits of cycling must be appraised against potential costs such as injury. Surprisingly there is a paucity of research in the area of cycling overuse injury, leaving cycling injury managers very much in the dark when clinical decision-making is required.

EPIDEMIOLOGY OF CYCLING INJURY

Overuse injuries in cycling are related to monotonous loading and maintenance of static postures for extended periods[3], most commonly associated with traditional road cycling. The injury profile of other cycling disciplines vary greatly, with BMX and track sprint cycling requiring maximal effort over a short duration, riders from these disciplines are more likely to suffer injuries related to strength and power training, such as weightlifting and plyometrics.

The distribution of overuse versus traumatic cycling injury seems to be consistent over a range of studies, and between professional and recreational cyclists, with overuse injuries shown to represent 50 to 60% of cycling injury presentation. One may argue that overuse injuries are under-represented when injuries are counted only when defined as time-loss injuries[4] or medical consultation injuries[5]. Overuse injury or pain rarely precludes the cyclist from riding, but likely limits their comfort and performance. In one study, 67% of recreational riders with high levels of pain continued to ride[5]. When pain or injury is defined by athlete self-report, there is a high representation of overuse injury described in cyclists. For example, of the 518 cyclists surveyed by Wilbur 440 overuse injuries or pain over a 1 year period were identified[6]. In the Clarsen et al study of 109 cyclists, elite level cyclists suffered mostly lumbar spine pain, while knee pain led to the most time loss[7].

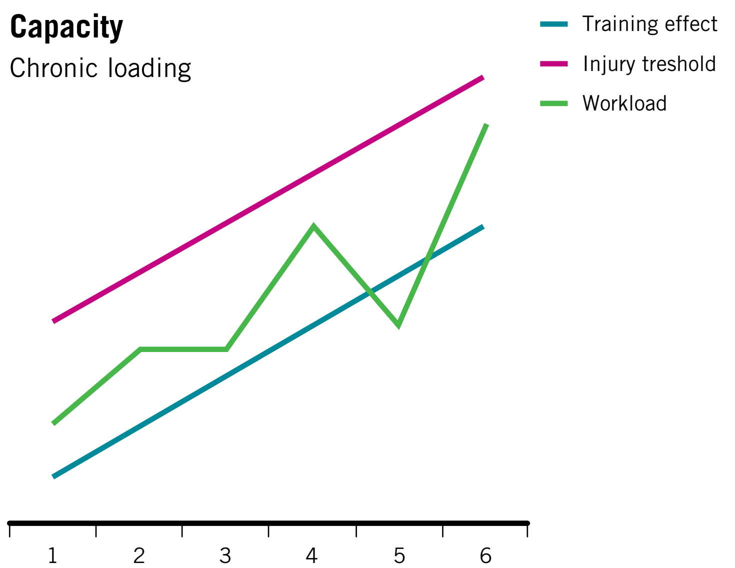

Figure 1: Capacity is represented well by the training workload (green), which sits above the training effect line (blue), representing positive adaptation and an increase in CAPACITY or injury threshold (red). A workload above the red line or below the blue line increases injury risk by overloading current injury threshold or by a negative change to the injury threshold (underloading), causing a reduced capacity.

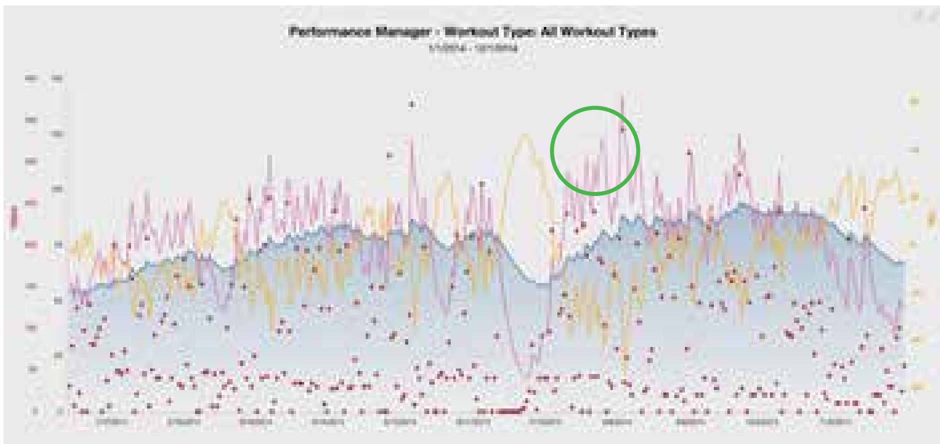

Figure 2: Training load modelling for a cyclist for 1 year. Each red dot represents a workout and its corresponding training stress. The blue line represents fitness (chronic load), the purple line represents fatigue (acute load), and the yellow represents freshness (acute vs chronic). The green circle denotes a potential area of increased injury risk due to high acute loads after a low load period leading to a diminished chronic load.

Recreational cyclists have also been shown to have high prevalence of knee and lumbar overuse injury, but also high levels of neck and shoulder pain[6], potentially a result of being less adapted and having poorer bike positions.

A SYSTEMATIC REVIEW OF FACTORS ASSOCIATED WITH CYCLING OVERUSE INJURY

Cycling overuse injury theory has been largely based around performance data, anecdotal evidence and clinical expertise. The relationship between many bike-fit and biomechanical factors and cycling overuse injury, has never been empirically proven. In a recent systematic review on the topic, 24 papers were identified, with most being of poor quality[8]. Data synthesis showed that no strong evidence exists in the literature relating cycling overuse pain or injury to a bike-fit, body- or load-related parameter. Moderate evidence was shown for an increase in lumbar flexion having a relationship with lumbar pain, as well as moderate evidence showing that load (training volume or event) was related to an increase in symptoms varying from lumbar and perineal pain to pins and needles, numbness and erectile dysfunction. Importantly there was moderate evidence of no relationship between many bike- and body-related parameters and injury. There is a need to evaluate these risk and injury management theories considering the limited evidence for risk factors identified.

CAPACITY IN CYCLING OVERUSE INJURY

As with any overuse, overload or 'training load error'[9] injury or pain, one must consider the capacity of the athlete generally, as well as the capacity of the tissue involved. Tissue and bone is constantly evolving through a process of mechanotransduction, with good loading having an anabolic effect and over-loading or under-loading a potentially catabolic effect[10,11]. Hence, cumulative stress or load above the level of capacity of the tissue or bone can cause overuse pain or injury. Importantly, tissue and bone can adapt to have a greater capacity to withstand load and similarly an entire kinetic chain or athlete can improve their capacity with the appropriate training. The cyclist's body needs enough load to adapt and improve, but not so much load that it is loaded beyond capacity, which becomes an issue of 'training load management'.

TRAINING LOAD MANAGEMENT

Overuse injury in many sports has been linked to an imbalance in the relationship between acute loading (short-term load over 1 to 7 days) and chronic loading (long-term cumulative loading over 4 to 8 weeks). Chronic load builds capacity to withstand acute load[12]. While this model has not been analysed for its relationship to pain and injury in cycling, clinical experience dictates that this concept has resonance in cycling overuse injury presentation. Cyclists are most likely to develop injury following a rapid increase in load, such as when preseason training is resumed after a winter break, after an interruption due to a fall, as well as during intense periods of the season. When injuries are apparently 'caused' by a change in equipment, it is normally because the change was made at an inappropriate time of the season when the cyclist was already close to their limit of load tolerance.

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Figure 3: Maximum knee extension is a key bike-fitting parameter, which typically ranges from 35° to 40° among professional riders. Patellofemoral joint contact pressures may be minimised by selecting a higher saddle position, with maximum knee extension between 30° and 35°. Reproduced with permission from Brukner & Khan's Clinical Sports Medicine, 5th edition, Volume 2, Injuries, McGraw-Hill, Sydney, 2017. Artist: Vicky Earle.

Figure 4: Frontal-plane knee motion in cycling (a) excessive valgus motion of the knee is thought to contribute to a range of knee injuries. (b) Improving the alignment of the hip, knee and ankle may lead to improvement of symptoms. Reproduced with permission from Brukner & Khan's Clinical Sports Medicine, 5th edition, Volume 2, Injuries, McGraw-Hill, Sydney, 2017. Artist: Vicky Earle.

Figure 5: Patellofemoral compression force is increased through (i) greater knee flexion increasing the patella tendon moment arm and hence the knee extensor moment (ii) increased quadriceps tendon force. Hence excessive quadriceps use potentially increases risk of anterior knee pain[28].

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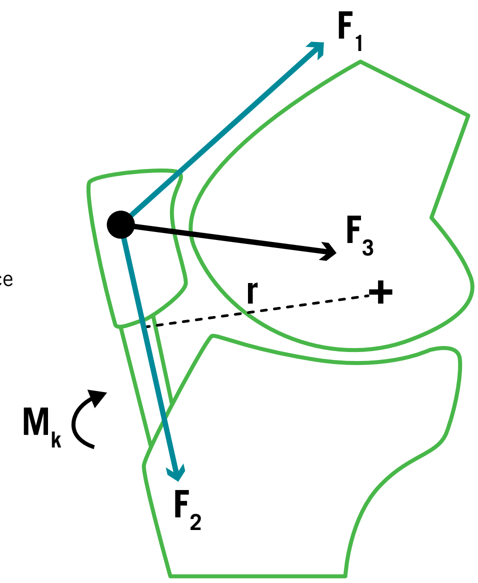
F_1 = Quadriceps tendon force
F_2 = Patellar tendon force
F_3 = Patellofemoral compression force
+ = Rotation axis
r = Patella tendon moment arm
M_k = Knee extensor moment
$M_k = r \times F_2$



A key component to successful management of cycling injuries, therefore, is load management. The clinician, cyclist and their coach should establish the volume, intensity and frequency of cycling that the rider can tolerate and create a systematic plan to increase these parameters over time. Wherever possible, loading should be quantified using a power meter and training software should be used to monitor the acute and chronic training load. An example of this type of monitoring is shown below.

THE CYCLING KINETIC CHAIN

Contemporary management of sporting overuse injury has embraced the concept of the kinetic chain as a collection of interacting segments, with a problem in one segment biomechanically affecting another[13]; given the closed-chain nature of cycling biomechanics, one must consider a similar proposition. In the ideal world of no training load errors or extrinsic factors (bike-fit); intrinsic factors (the kinetic chain) such as anatomical anomalies, poor cycling technique or reduced neuromuscular control would be the main component of cycling overuse injury and pain.

Clinically, one pattern of dysfunction of the lower limb kinetic chain that may present is an inability of the athlete to appropriately utilise the gluteal bulk under kinetic chain loading, while maintaining adequate lumbar-pelvic position and controlling dynamic knee valgus. At the same time the perfect 'chain' needs to adequately dissipate force through the ankle-calf complex. There is a moderate level of evidence that a loss of

Figure 6: Spinal position in cycling (a) Ideally, forward bend should be achieved evenly throughout the spine (b) Cyclists with low back pain often adopt a more flexed lumbar spine, with less anterior pelvic tilt and a more extended thoracic spine. Artist: Vicky Earle.

lumbar extension control is associated with lumbar pain[14] and lower levels of evidence that an increase in medial knee alignment and increased dorsiflexion are associated with knee injury[15] and aberrant pedaling[16,17]. These kinematic factors relate to cycling kinetic chain dysfunction and there is merit in analysing cycling overuse injury from a kinetic chain loading perspective.

Hence, once an appropriate training plan is established, intrinsic and extrinsic risk factors should be assessed.

The following section covers biomechanical factors thought to be associated with the most common cycling injuries – knee pain and lumbar pain.

Knee pain

The knee is the most common site of overuse injury among cyclists of all levels[4-8]. A majority of knee complaints are related to the patellofemoral joint[18]. However, there are a range of differential diagnoses including iliotibial band syndrome (ITBS) , infrapatellar fat pad impingement, medial plica irritations, pre-patellar bursitis and medial patellofemoral ligament strains[18,19]. Although tendinopathy is generally rare in cyclists, pain can also arise from the quadriceps tendon enthesis on the superolateral or superomedial patella.

Various biomechanical factors may play a role in the development of anterior knee pain in cyclists, including patellofemoral joint compression forces, knee kinematics in the frontal plane and rotational torques in the lower limb[15,20-22]. Biomechanical models have shown that patellofemoral joint contact pressure is inversely related to saddle height[20], leading to the common belief that cycling with lower bicycle saddle heights increases the risk of patellofemoral pain development[16,19,21]. However, this remains to be confirmed in high-quality risk factor studies of competitive cyclists, particularly since one study found that altering the saddle height led to negligible changes in patellofemoral joint contact pressure[23]. Nevertheless, it is commonly advised that cyclists with patellofemoral pain ride in a relatively high saddle position, with maximal knee extension of approximately 30° (Figure 3).

Excessive medial motion of the knee in the frontal plane (Figure 4) may also be a risk factor for patellofemoral pain. This theory is supported by one study showing that

> **The knee is the most common site of overuse injury among cyclists of all levels**

cyclists with a history of knee pain adopt a more medial knee position compared to uninjured cyclists[15], although retrospective analyses cannot determine cause and effect. Knee motion may be altered by motor control training of the gluteals and/or quadriceps[13] or through manipulation of the cyclist's shoes and pedals. For example, foot position can be adjusted using small angled wedges between the shoe and the pedal-cleat or underneath the forefoot or by using custom-made insoles. However, studies have shown that manipulation of cycling shoes and pedals have an extremely unpredictable effect on knee motion[24,25]. It is therefore important to test each individual's response, making sure that adjustments lead to symptomatic improvement.

Rotational torque at the knee caused by the fixation of shoes to the pedals may also be a factor in patellofemoral pain in cycling. After the introduction of modern cleated pedals in the 1980s there were anecdotal reports of an increase in the prevalence of knee injuries among cyclists[18,22]. It was thought that the natural rotation of the lower limb during the pedalling cycle was constrained by fixing the shoe, leading to increased stress at the knee joint. Therefore, 'floating' pedals were designed that allowed a small degree of axial rotation, which attenuated the rotational torque at the knee[22]. Although there is no direct evidence that floating pedals reduce injury, their design has been widely accepted and they remain the most popular type used by cyclists today.

Diminished ability to recruit the gluteal muscles may cause a relative overuse of the quadriceps muscle-tendon unit and an overall increase in compressive forces at the anterior knee. The gluteals and quadriceps are the 'power' muscles of the pedal stroke, the hamstrings and calves play a more co-ordinative role[26]. During laboratory based 'cycle to fatigue' protocols, the power muscles begin to dominate and activate to a greater degree under higher levels of exertion[26,27]. Under high-load conditions if the gluteal muscles are deficient then the activity required of the quadriceps is further increased, with the resulting pattern producing a greater quadriceps force and higher patella-femoral compression forces[28].

Strength training in cycling

- *The notion of strength training off the bike is highly contentious. Road cycling culture has encouraged on-bike strength training, with gym-based training seen to cause leg soreness, to potentially lead to weight gain, and to be difficult to periodise within the busy racing season.*
- *There is strong evidence that road cycling has a detrimental effect on bone density, with one study comparing competitive road cyclists and a matched control group showing that 9% of cyclists and 3% of controls were classified as osteoporotic, whereas 25% and 10% of cyclists and controls, respectively, were osteopenic[31].*
- *Rønnestad[32] showed that with 12 weeks of strength training twice per week in a group of high-level road cyclists, many performance parameters are improved, without significant weight gain. Strength training can also be beneficial for bone health[33] and kinetic chain optimisation.*
- *There is compelling evidence that strength training in cyclists is essential as a long-term health benefit as well as for improving performance. Cycling coaches, managers and practitioners have a responsibility to inform and educate the world's road cycling population.*

Bike fitting

There are many approaches to bike fitting, ranging from simple anthropometry-based formulae to dynamic approaches utilising high-tech equipment.

As bike fitting involves the optimisation of a wide range of competing variables, such as aerodynamics, comfort and control, it always involves compromise. Despite the recent rapid pace of technological development in the cycling industry, there remains little research into bicycle equipment and injury, and bike fitting remains just as much an art as it is a science. We encourage sports medicine clinicians to work closely with bike fitters in considering the cyclist's previous and current injuries, cycling goals and physical limitations.

Low back pain

Although transient back discomfort can be considered normal in cycling, studies have shown that performance-limiting low back pain is common among amateur[6] and elite cyclists[7,29].

Cyclists with low back pain typically present with non-specific symptoms provoked by the maintenance of sustained flexion positions and they can often be classified as having a flexion-pattern motor control dysfunction[30]. Using a remote posture monitoring system, Van Hoof et al showed that cyclists with low back pain adopt a more flexed position in their lumbar spine than pain-free cyclists (Figure 6)[14]. This may be related to a number of pathomechanical mechanisms of low back pain[30], such as flexion/relaxation inhibition or fatigue of the erector spinae muscles and mechanical creep of the spine's viscoelastic tissues. However, these theories remain largely untested in cyclists.

Encouraging a relaxed, anteriorly-tilted pelvic position, with an even distribution of flexion throughout the spine is often important in the overall clinical management of cyclists with low back pain. A number of equipment modifications may help facilitate this, including lowering the saddle, raising the handlebars and shortening or lengthening the overall reach.

Excessive lateral flexion and/or rotation of the spine while cycling may also

Table 1

	Formula-based approach
Description	*There are a number of formula-based approaches that convert anthropometric measurements (e.g. inseam height) to bicycle setup parameters. Some well-known approaches include the 'Trochanteric Method' and one is named after two-time Tour de France winner Greg LeMond.*
Advantages	*Quick and easy. Cyclists can perform measurements themselves.*
Limitations	*One-size-fits-all approach that does not consider the cyclist's physical limitations. Highly unreliable and variable results.*
	Static angle-based approach
Description	*The cyclist's major joint angles are measured with a goniometer while they sit on the bike without cycling. The bike is adjusted to position each joint within a predetermined 'optimal' range of motion. Sometimes referred to as the Holmes method.*
Advantages	*Good reliability[33].*
Limitations	*Does not consider dynamic cycling technique. "Optimal" angles generally not evidence-based.*
	Dynamic angle-based approach
Description	*Dynamic measure of joint angles collected with 2-D or 3-D motion analysis over a period of time and averaged as rider is actually riding.*
Advantages	*Good reliability[33]. Accounts for the rider's technique and physical limitations.*
Limitations	*Does not consider kinetic variables such as power distribution between legs.* *'Optimal' angles generally not evidence-based.*
	Combined-input approach
Description	*Combination of data streams such as power, pedal forces, saddle pressure with motion analysis.*
Advantages	*Multiple sources of data can lead to more informed clinically reasoned decisions.*
Limitations	*More data does not always lead to better clinical decisions. Little research to assist data interpretation.* *Validity and reliability unknown.*

Table 1: Advantages and limitations of modern bike fitting methods.

Table 2

Key issues in cycling overuse injury management
Training load management
Bike-fit
Kinetic chain analysis

Table 2: Key issues in cycling overuse injury management and treatment as part of a detailed clinically-reasoned process including – but not exclusively using – technology.

contribute to back pain, particularly if it is asymmetrical. This can be caused by a range of factors, such as large leg-length differences, hip range of motion limitations and asymmetrical muscle activation patterns, as well as issues with seat position. These should be considered as a part of the comprehensive management of the cyclist with low back pain.

MANAGEMENT OF OVERUSE CYCLING INJURIES

There is little clinical evidence regarding the management of cycling overuse injuries. We have previously identified the importance of 'training load management" in injury prevention and management, as well as a bike-fit provided by an experienced practitioner, which is an essential starting point, as a grossly inappropriate position on the bike will limit the body's ability to optimise performance, comfort and aerodynamics. Taking a trial and error approach to changes, with constant assessment and re-assessment of reference data points (i.e. pain, stability, co-ordination, kinematics, power, saddle pressure), utilises good clinical reasoning in the bike-fit process.

It is important to acknowledge that bike-fit is a fluid process, with a change in the body perhaps requiring a change in bike-fit.

Accurate diagnosis is always a pre-requisite to dealing with overuse injury, as well as using diagnostic and medical interventions as indicated. Optimal management of overuse injury requires a knowledge of aetiology and an understanding of the cycling kinetic chain. Local biomechanical anomalies such as excess lumbar flexion, excess knee valgus and excess knee bend or straightening can be related to local pain, but one must analyse the entire chain for potential deficit and prioritise intervention accordingly.

TURNING THE WHEEL TOWARDS EVIDENCE-BASED PRACTICE

Overuse injuries in cycling have been largely ignored in the cycling science literature, likely due to the emphasis on performance rather than comfort, fewer resources compared to other high-profile sports, the relatively low rates of time-loss injuries at the elite level and injury management lacking good clinical and empirical reasoning.

Figure 7: Modern bike fitting is an interactive process incorporating data from a variety of sources such as three-dimensional motion analysis, shoe and saddle pressure distribution and pedal force application.

While there are differing methods for assessing biomechanical aspects of pedalling, characteristics of the cyclists' body or bike-specific measures, there seems to be strong agreement that training load management, bike-fit and kinetic chain analysis, are essential components in the assessment and treatment of cycling overuse pain and injury.

Contemporary management of cycling overuse injury in high-performance athletes is shifting towards an approach based on a theoretical framework, as well as the use of clinical and reasoning skills, with technology serving as a useful tool in this process. The challenge for those involved in cycling injury management is to take the knowledge and experience of the past, question its validity and add to the currently limited evidence base.

An opportunity exists for cycling to follow the lead of other sports in developing a framework within the teams, national squads and governing bodies, encouraging injury surveillance, risk factor analysis and controlled trials, to aid the development of best practice cycling injury management protocols.

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References
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Paul Visentini B.App.Sci. (PHTY), Grad.Dip. Man.Ther.

Specialist Sports Physiotherapist, Clinical Director

Physiosports Brighton

Melbourne, Australia

Ben Clarsen Ph.D., M.Sc., P.T.

Physiotherapist

Norwegian Olympic Training Ventre (Olympiatoppen)

Oslo, Norway

Contact: paul@physiosports.com.au