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ORIGINAL STUDY

Etiology of knee pain in elite cyclists: A 14-month consecutive case series

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Overuse injuries of the knee are a common cause of missed training and competition days in elite cyclists, however the underlying conditions causing this knee pain are not well defined. We conducted a diagnostic study, investigating a consecutive series of 53 high level cyclists with non-traumatic knee pain over a 14 month period. Demographic data on the participants' cycling specialty and training level was noted. Clinical information concerning knee pain intensity, location and occurrence were collected using a questionnaire. Our results show 7 different overuse injuries were identified. The prepatellar friction syndrome accounted for the majority of these overuse injuries (46%), while medial plica syndrome (15%), biceps femoris tendinopathy (7.5%), patellar tendinopathy (9.4%), infrapatellar plica friction syndrome (7.5%), infrapatellar fat pad impingement (5.7%) and iliotibial band syndrome (3.7%) were other causes of knee pain in these athletes. In contrast to current belief, our results show that instead of patellofemoral cartilage overload, friction related overuse injuries are the most frequent and underestimated cause of knee pain in high level cyclists.

Keywords : cycling ; friction related overuse injuries ; prepatellar friction syndrome ; differential.

INTRODUCTION

Competitive cycling is a very demanding sport with cyclists training and racing for multiple hours at high velocity and intensity *(12)*. Due to the repetitive nature of the pedalling activity with up to 80 - 100 revolutions per minute, overuse injuries are quite common *(2)*. Many epidemiological studies concerning the high incidence of overuse injuries in elite and recreational cyclists have found that knee overuse injuries are the most prevalent *(3,4,39,40)*. One study which focused on 65 professional road cyclists, found that overuse accounted for 62% of the injuries *(4)*. A recent survey of 109 professional cyclists found that the most common injury in professional cyclists was lower back pain (46%), followed by knee pain (23%) *(11)*. Although knee pain was less frequent than low back pain, it accounted for 57% of injury related time loss *(11)*. De Bernardo et al. found that 32% of overuse injuries were located around the

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knee in a cohort of 51 active professional cyclists *(6)*. This result corresponds with a study of the National Team athletes of the British cycling squad where knee injuries were the second most common injury (18%) and the main cause of total days lost for training/competition *(32)*. Recent review articles mainly focus on factors associated with knee pain in cyclists without using a differential diagnosis *(7,25)*. Despite the epidemiological evidence, little is known about the underlying clinical entities leading to knee pain in high level cyclists. Since the introduction of the term "cyclists' knee" *(31,34)*, knee pain in cyclists has been assimilated to "anterior knee pain", "chondromalacia" or "patellofemoral pain syndrome". Many studies focused on knee pain in cyclists often state that patellofemoral pain syndrome is the underlying cause, without any proof of evidence *(1,16)*.

In our experience treating high-level cyclists, the above-mentioned knee conditions are only rarely seen in these athletes. In this study we report the results of 53 cyclists' knees, outlining a comprehensive differential diagnosis of typical overuse injuries. This study describes the clinical features, physical examination and diagnostic imaging modalities of the most frequent clinical entities in our practice.

MATERIALS AND METHODS

We conducted a single centre prospective diagnostic study. Between October 2015 and December 2016 all cyclists visiting our outpatient sports clinic with knee pain exclusively related to cycling activities, were included. All patients were evaluated by the two senior authors (TC and SC). Knee pain during cycling was the primary inclusion criterium. Chronic overuse injuries originating from minor trauma were included while all acute traumatic knee injuries, such as fractures or ligamentous injury, were excluded. All patients gave their informed consent before participating in the study.

Demographic data, the average number of hours of training per week, the average number of miles per year, their cycling discipline (road cycling, cyclo-cross, mountain bike racing or a combination) and their training/competition level (recreational, amateur competition, UCI U23, UCI Continental, UCI Pro-continental and UCI World Tour) were noted. Data about duration of the injury, prior trauma, medical history of the complaint and a specific cycling related knee pain questions were collected. A thorough work-up was conducted in each case, consisting of medical imaging (ultrasound, MRI and radiography) as necessary according to the suspected underlying pathology and a medical examination. Treatments were noted and return to competition (if applicable) at the last follow up was recorded.

RESULTS

Over the course of 14 months, 48 cyclists with 53 painful knees were included. Our population consisted of 45 male and 3 female cyclists. Three patients were included more than once, as they presented with either a new injury in the previously treated knee (n = 3) and/or a new injury to the contralateral knee (n=2). The age of the participants ranged between 13-61 years, with an average of 29 years. Our series consisted of 15 high mileage recreational and 33 competitive cyclists (Table I).

Table I. — Training level and distribution of patients

Training level	Number of patients
Recreational	15
Amateur competition	7
UCI U23	12
UCI Continental	6
UCI Pro-continental	6
UCI Worldtour	2

Different cycling disciplines were included; 35 road cyclists, 2 cyclo-cross cyclists, 2 mountain bikers and 7 cyclists who combined different disciplines.

The average annual training distance of the cohort was 17149 ± 9729 km. Professional cyclists (UCI U23, Continental, Pro-Continental and World Tour) in our series rode 22536 ± 8284 km on average and non-professional cyclists rode on average 9111 ± 5226 km. The average weekly training time of

amateur cyclists was 8.2 ± 3.9 hours and 16.2 ± 5.1 hours for professional cyclists.

Median duration of knee pain was 6 months. A wide range in the duration of the injury was observed, ranging from 1 week to almost 10 years. The injury duration mostly depended on the level of the rider, the severity and onset of the complaints and the success of previous treatments. Professional cyclists tend to consult faster than non-professional cyclists (median duration of 2.8 months versus 21 months respectively).

Eleven clinical entities were found to be the cause of cycling induced pain around the knee in our patient cohort.

Four cases (8%) were classified as "miscellaneous" as they consisted of an osteochondritis dissecans lesion of the medial femur condyle, a symptomatic mucoid degeneration of the anterior cruciate ligament, a medial meniscus tear and a vastus medialis muscle impingement.

Seven specific clinical entities were identified encompassing the remaining 44 patients and will be outlined by their location (anterior, medial or lateral side).

Figure 1. — Intraoperative image of the superomedial patella ridge showing a fascial defect, thickening of the prepatellar fascia with neovascularisation of the deep layer.

Anterior knee pain

Prepatellar friction syndrome

The prepatellar friction syndrome (PPFS) is an extra-articular cause of anterior knee pain *(10)*. In this syndrome, repetitive microtrauma due to overuse or a direct (minor) traumatic impact can damage the normal triple-layer organization of the fascia overlying the patella *(17)*. The impairment of normal gliding of the fascial layers leads to abnormal friction with repeated flexion of the knee during cycling. Focal defects in the intermediate layer or thickening and neovascularity of the prepatellar fascia can be found intraoperatively (Fig.1). The prominent superomedial or superolateral ridges of the patella are particularly at risk. PPFS was found to be the most prevalent cause (46%) of knee pain diagnosed in this patient cohort.

A typical case usually presents with anterior knee pain during cycling. The pain starts during or after a long training, training camp or multiday competition. A crash or minor trauma to the patella, like hitting the stem or handlebar, can initiate PPFS. Fifty-two percent of the patients diagnosed with prepatellar friction syndrome recalled a preceding trauma to the knee.

Cycling at a high cadence or wearing tight leg warmers may aggravate the pain. Lowering the cadence or cycling 'en danseuse' may alleviate the pain. This can be explained either by reducing the friction of the soft tissues over the patella or by a decrease of the maximal knee flexion angle which also reduces the pressure. Of note, these characteristics are the opposite of what is typically reported in a suspected patellofemoral pain syndrome.

Clinical examination can reveal a defect or irregularities in the prepatellar fascial layers by superficial palpation. Pain can be elicited by local pressure over the pathological spot; this may be the superolateral, superomedial or inferomedial ridge of the patella.

Ultrasound (Fig.2) and MRI (Fig.3) are able to demonstrate the presence of PPFS. These imaging techniques typically show a disturbance in the triple layer structure of the prepatellar fascia, more specifically a defect, thickening of the fascia or fluid between the layers.

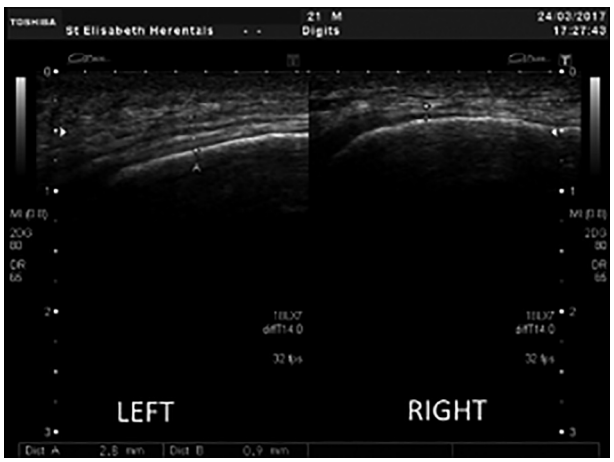

Figure 2. — Ultrasound image showing the presence of prepatellar friction syndrome. An irregular and thickened prepatellar fascial layer is visible for the left knee.

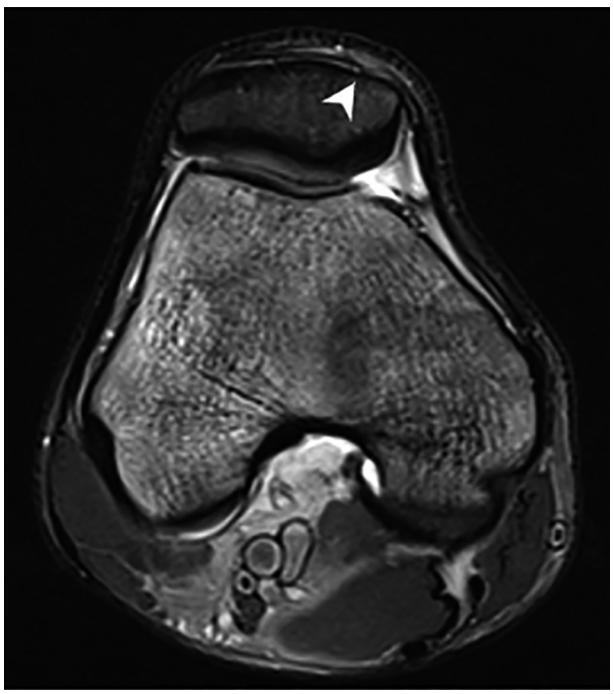

Figure 3. — MRI image showing the presence of PPFS. An irregular and hyperintense prepatellar fascial layer is visible at the medial ridge (white arrow).

In this cohort 15 patients underwent an MRI and in 11 cases the diagnosis was confirmed (73%). 22 of 23 PPFS patients were investigated with ultrasound. Ultrasound demonstrated prepatellar fascial thickening, fascial defect and thickening in 64% of cases. In 4 patients medical imaging could not confirm the clinical diagnosis.

Acute presentations of PPFS can be managed conservatively with a period of rest or low-dose steroid. Chronic symptoms and posttraumatic PPFS are often treated with surgery. Of the patients with PPFS in our study cohort, 91% underwent surgery. All competitive cyclists were able to return to racing at the last follow up.

Infrapatellar plica friction syndrome

The 'infrapatellar plica friction syndrome' or IPPFS is a relatively rare cause of chronic refractory anterior knee pain in the high mileage cyclist in our series. The pain is caused by the accumulated friction of the infrapatellar plica or 'ligamentum mucosum' over the intercondylar cartilage during flexion-extension of the knee.

Patients typically present with anterior knee pain that emerges after some hours of cycling. The pain increases with higher cadence, but quickly subsides when cycling activity is ceased, and is localized slightly inferior or deep to the patella.

Infrapatellar plica friction syndrome was the cause of anterior knee pain in 4 patients of our study cohort (7.5%). Of these, 3 patients underwent anarthroscopic resection of the ligamentum mucosum, leading to complete symptom relief for all 3 patients. A 4th patient healed after local steroid injection in combination with six weeks of rest.

Clinical examination is atypical, with a tender anteromedial and -lateral Hoffa as the most frequent finding.

MRI imaging of the knee is able to visualize the existence of an infrapatellar plica, but does not allow distinction between symptomatic or non-symptomatic infrapatellar plicae. The infrapatellar plica can best be visualized in T2-weighted sagittal images without fat suppression where the structure will appear isointense in respect to the neighbouring ligamentous structures of the knee *(14,28,30,35)*. Cothran et al. found that a high T2 signal along

the course of the IPP that extended into Hoffa's fat pad was suggestive of a plica injury *(13)*. All four patients underwent an MRI of the knee and showed a thickened infrapatellar plica. The combination of the history, examination and MRI findings in this population will direct diagnosis. Intra-articular findings during knee arthroscopy consist of linear scratching of the intercondylar notch at the site where the IPP slides back and forth over the cartilage (Fig.4).

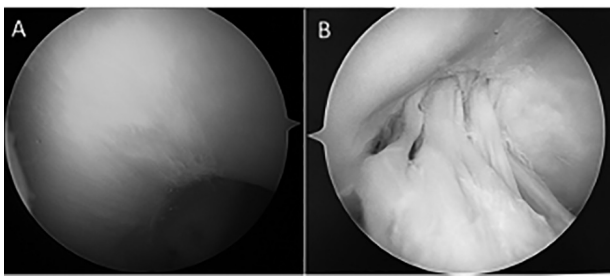

Figure 3. — MRI image showing the presence of PPFS. An irregular and hyperintense prepatellar fascial layer is visible at the medial ridge (white arrow).

Infrapatellar fat pad syndrome

The infrapatellar fat pad, or Hoffa's fat pad, is a richly vascularized and innervated, extra-synovial structure in the anterior compartment of the knee. Though its' function is still not completely understood, it can be a cause of knee pain in athletes *(30)*. The pathophysiological mechanism has been defined as "impingement of the hypertrophic fat pad between articular surfaces of the knee" typically originating from forceful hyperextension of the knee. A potential cause is the forceful repetitive flexion and extension movement occurring during cycling which leads to irritation, inflammation and oedema in the fat pad. This oedema could lead to an increase in volume and further impingement *(5)*. In our cohort, 3 cyclists were diagnosed with Hoffa impingement or inflammation.

Knee pain was typically located infrapatellar, mostly more lateral or medial to the patella tendon. Pain could typically be elicited by forced hyperextension of by direct pressure over the affected fat pad. MRI imaging can reveal oedema in the posterosuperior fat pad on T2 FS images and an inflamed infrapatellar bursa *(18)*.

In our study MRI imaging showed abnormal findings (a cyst and fat pad oedema) in two of 3 patients. One patient underwent an ultrasound imaging showing inflammation.

The combination of clinical findings and imaging has proven to be conclusive in the differential diagnosis for infrapatellar fat pad syndrome, patellofemoral pain, infrapatellar plica syndrome or patellar tendinopathy.

Treatment consisted of a therapeutic cortico-steroid injection into Hoffa's fat pad. If conservative treatment failed, an arthroscopic evaluation is warranted where the hypertrophic fat pad can be resected. This procedure was performed for one patient in our series. In longstanding cases adhesions and fibrosis may occur *(27)*.

Patellar tendinopathy

Five participants suffered patellar tendinopathy. Patellar tendinopathy or jumper's knee is not a typical bike related condition, as it occurs more often in jumping sports. In cyclists, poor bike fit (extrinsic) or tight quadriceps muscles (intrinsic) are possible causes.

Diagnosis is mainly clinical but can be aided by ultrasound or MRI. In our series 1 of 3 MRI investigations showed clear tendinosis and 1 out of 5 ultrasounds demonstrated pathologic changes in the patellar tendon.

All 5 patients were treated conservatively with a combination of physiotherapy for stretching and excentric excercises, extracorporal shockwave treatment (2/5) or platelet-rich plasma injections (4/5).

Two professional cyclists returned to their preinjury competition level at their last follow up.

Patello-femoral pain syndrome

None of our patients showed clinical evidence of patello-femoral pain syndrome, i.e. no pain during squatting, stair climbing or prolonged sitting ("movie sign"). Imaging studies showed no significant patellofemoral chondral damage or patellofemoral malalignment in any of the patients.

Medial sided knee pain

Medial Plica

The most frequent cause of medial sided knee pain in our patient cohort was the medial plica syndrome (15%) *(35)*. Plicae are inward folds of synovial lining and are remnants of embryologic synovial septae. Although the presence of an infrapatellar plica is more common than the medial parapatellar plica, the latter is more frequently symptomatic. The medial plica stretches over the medial condyle as a thin elastic band. An inflammatory response after blunt trauma or repetitive friction can turn the plica into an inelastic fibrotic band causing impingement and friction over the medial condyle *(35)*.

The patients in our series reported a medial sided knee pain most exclusively during cycling. They could also sometimes feel rubbing of the plica itself.

Clinical examination reveals a tender and swollen cord at the medial parapatellar border. Valgus alignment, tibia internal rotation and foot hyperpronation can increase the stretch on the medial structures *(38)*. Although the diagnosis is mainly clinical, MRI imaging can reveal the presence and extent of inflammation of the plica. All three patients underwent MRI which confirmed presence of an inflamed or torn medial plica.

Pain free cycling after a local anaesthetic injection may confirm the diagnosis. Treatment depends on the chronicity of the symptoms. In acute onset medial plica syndrome a short period of rest and non-steroidal anti-inflammatory medication is mandatory *(33,35)*. The authors have good results with intra-plical injection of corticosteroids, which was performed successfully in 6 out of 8 patients. Two patients underwent arthroscopic resection of the medial plica, one patient after failure of the conservative treatment and one patient who suffered from longstanding symptoms.

Lateral sided knee pain

Biceps femoris friction syndrome and tendinopathy

Lateral sided knee pain is often caused by biceps femoris pathology. An abnormal anterior insertion of the biceps femoris tendon on the fibular head or a bony prominence on the fibular head can predispose to snapping *(26,29)*. One study found that 5.8% of knee overuse injuries in professional cyclists consisted of biceps femoris pathology *(6)*. Biceps femoris tendon snapping is mainly known as a runners' pathology *(37)*.

In our patient cohort 4 patients were diagnosed with biceps femoris friction over a prominent fibular head.

The clinical presentation of biceps femoris friction syndrome is characteristic. The cyclist has posterior to lateral knee pain during cycling. Pain typically persists some hours after training. Snapping of the biceps femoris tendon can be felt . We believe that "biceps femoris friction syndrome" is part of the spectrum of snapping biceps syndrome sharing the same pathomechanics but without frank subluxation of the tendon. Friction of the tendon leads to inflammation of the underlying bursa and tendinopathy. MRI shows tendinopathy of the biceps femoris tendon or fluid in the subtendinous bursa. X-ray of the knee may demonstrate fibular head abnormalities like a prominent bony protuberance.

In all four patients MRI showed tendinopathy of the biceps femoris tendon (one longitudinal tear of the tendon). Ultrasound was positive in 2 of 4 cases. Radiographs confirmed a prominent fibular head in 3 of 4 participants.

Primary treatment is mainly conservative consisting of rest and stretching. Lowering the saddle and putting the foot in some external rotation may also alleviate the strain and friction on the biceps femoris tendon. If conservative measures fail, a surgical release of the tendon with trimming of the prominence of the fibular head can be performed. Three patients of our cohort underwent this surgical procedure which led to complete pain relief.

Iliotibial band syndrome

The iliotibial band syndrome (ITBS) is a frequent overuse injury in both runners and cyclists *(20,23,36)*.

During flexion and extension of the knee the position of the iliotibial band changes relative to the lateral femur condyle. At the bottom of the pedal stroke, around 30° of knee flexion, the posterior fibres of the ITB are located over the lateral condyle near the edge of the impingement zone. Farrell et al. concluded that, although cyclists spent less time in the impingement zone at a lower force, the number

of repetitions is the primary contributor to the development of ITBS in cyclists *(21)*.

Athletes usually complain of a stabbing lateral-sided knee pain, arising during the course of a ride. Two patients suffered from iliotibial band syndrome in our cohort.

Clinical examination reveals a local tenderness over the posterior fibres of the ITB with a positive Noble's test. The Ober test is used to evaluate ITB tightness. Although ITBS is a mainly clinical diagnosis, medical imaging such as ultrasound and MRI can aid in the diagnosis by showing the presence of fluid in the underlying bursa (Fig.5).

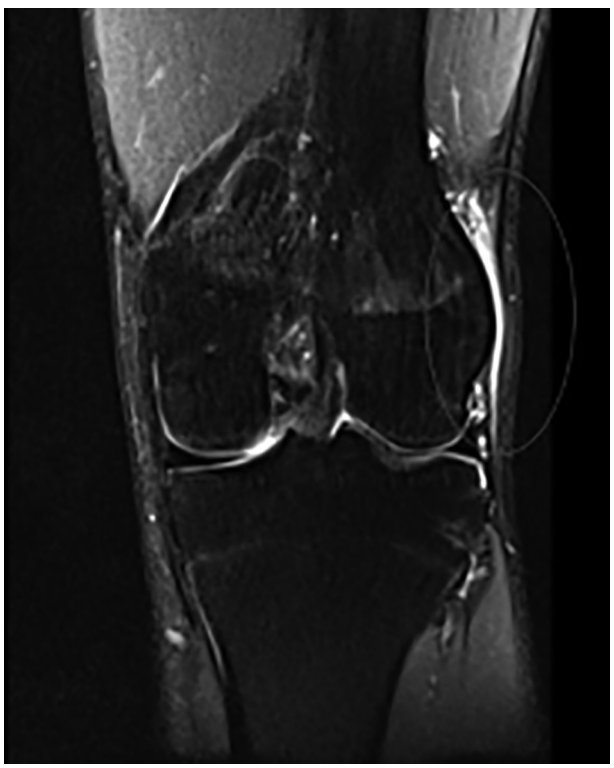

Figure 5. — Coronal T2-weighted MRI image of a right knee showing the presence of hyperintense fluid in an inflamed bursa underlying the iliotibial band (circle) in a patient suffering ITB friction syndrome.

Two UCI U23 in our cohort suffered from ITB syndrome, both diagnoses were confirmed on MRI.

Treatment for ITBS mainly consists of conservative measures. Both intrinsic and extrinsic factors can predispose an athlete to developing ITBS. Contributing intrinsic factors are leg length discrepancy, primary ITB tightness, external tibial rotation of more than 20°, varus knee alignment and foot overpronation *(24)*. Extrinsic factors should be addressed first, such as adjusting the bike fit and/or cleat positioning. A saddle position too high or too far back may increase the stretch on the ITB. A cleat which is too externally rotated (cycling toed-in) or lateral placed (adducted leg) may also cause ITBS. A short period of rest is often advised together with stretching of the ITB. Local infiltration with corticoid can give temporary relief but should be used with caution. If extensive conservative treatment fails, iliotibial band bursectomy *(22)* is an option. Both patients in our series underwent this surgery and returned to their previous level of racing.

DISCUSSION

This study gives a comprehensive diagnostic overview of cycling overuse injuries of the knee. In contrast to many other studies the patellofemoral pain syndrome, although often cited as the prime cause of anterior knee pain in cyclists, did not occur in our patient cohort.

Many studies have reported the occurrence of knee overuse injuries in cycling. However, only few outlined the possible underlying causes of knee overuse injuries *(6,8,15,23,38,39)*. Table II gives an overview of the proposed differential diagnoses in literature.

Our results showed that for a total of 53 elite cyclists' knees 7 different types of overuse injuries could be found besides the patellofemoral pain syndrome. In our experience over years dealing with high level cyclists, patellofemoral joint pathology is a rather uncommon cause of knee pain in high level cyclists and should only be determined when confirmed by medical imaging. In the absence of patellofemoral abnormalities on medical imaging, other possible causes have to be considered. Table 3 gives an overview of the typical features for each syndrome with clinical examination, diagnostic imaging and preferred treatment.

Although a possible explanation for the absence of patellofemoral pain syndrome in this study cohort could be the sample size or selection bias, we feel that there are significant contradictions in the

Table II. — Overview of studies reporting overuse injuries of the knee in cyclists.

Study	Study Population	Study Setup	Types of Injury
Weiss (1985)[4]	132 amateur cyclists	Retrospective questionnaires	3,5% Patellofemoral stress syndrome 5,4% Medial knee pain 4 % Ilitiobial band syndrome
Holmes et al.(1991)[33]	354 amateur to professional cyclists	Clinical case-series	37% Chondromalacia patellae 14% Iliotibial band problems 13% patellar tendinopathy 13% medial plica irritations
Bakkes et al. (1993)[40]	902 cyclists	Retrospective questionnaires	29% Knee pain
Wilber et al. (1995)	518 recreational cyclists	Retrospective questionnaires	41,7% Overuse injuries
Dannenberg et al. (1996)[41]	1638 recreational cyclists	Prospective study with questionnaire and clinical examination	43% Overuse injuries
Callaghan and Jarvis (1996)[42]	500 elite cylcists	Prospective study with questionnaire and clinical examination	33% Knee problems
Barrios et al. (1997)[6]	65 professional cyclists	Prospective study with clinical examination	8% Anterior knee pain 15% Chondromalacia patella
Dettori et al. (2006)[39]	Literature review of 10 articles	Literature review of 10 articles	Patellofemoral pain syndrome Patellar tendonitis Ilitiobial band friction syndrome
Wanich et al. (2007)[26]	Literature review	Literature review	Patellar tendinitis Quadriceps tendinitis Pes anserine bursitis Medial plica syndrome
Clarsen et al. (2010)[7]	109 elite and recreational cyclists	Retrospective interviews	57% Anterior knee pain causing time loss
De Bernardo et al. (2012)[8]	51 road top level cyclists	Retrospective interviews	5,8% Patellofemoral pathology 5,8% Patellar tendinopathy 5,8% Biceps femoris tendinopathy 14,4% Ilitiobial band friction syndrome
Althunyan et al. (2017)[14]	283 professional and amateur cyclists	Cross-sectional study using online questionnaires	25,8% Anterior knee pain

clinical presentation and history that plead against patellofemoral pain syndrome as a common cause of knee complaints in high-level cyclists. Firstly, most cyclists consulting with a knee overuse injury complain of pain almost exclusively during cycling. There is no typical movie sign, or pain when walking stairs or during squatting as typically seen in patellofemoral pain syndrome. Secondly, the main treatment for patellofemoral pain syndrome consists of quadriceps strengthening exercises and cycling *(9,19)*. However, the quadriceps is definitely one of the most developed muscles in high level cyclists. Attributing anterior knee pain solely to a "cyclists' knee" or chondromalacia patellae in a high mileage or professional cyclist often leads to a delayed diagnosis. These athletes are often treated with hyaluronic acid infiltrations and physiotherapy, with poor results.

On the other hand, our results suggest that the majority of overuse injuries around the knee in cycling are friction related. Prepatellar friction syndrome was the most common anterior located knee injury, and the medial plica was the most common medial located knee injury. These syndromes are rare clinical entities in the general population, but are more prevalent in high mileage cyclists, which is intuitively explained by the extreme amount of pedalling revolutions performed by these athletes.

Limitations of this study are the relatively limited number of participants and a single-centre case series. A referral and selection bias might skew the results to more surgically treated pathology. It is possible that some clinical entities are therefore underreported in our series if they are successfully treated by team doctors, general practitioners, physiotherapists etc. We acknowledge that certain syndromes are controversial or scarcely described in literature (infrapatellar plica friction syndrome, fat pad impingement, prepatellar friction syndrome),

however we tried to isolate a specific subpopulation of high mileage and professional cyclists and outlined our diagnostic results.

CONCLUSION

This is the first study which gives a prospective diagnostic overview of overuse injuries in high-level cyclists. Our results show that friction related overuse injuries are a frequent and probably under-rated cause of knee pain in high level cyclists. Patellofemoral pain syndrome, though often suggested as a primary diagnosis in the literature, seems to be unusual in high level cycling. Thorough history, clinical examination and additional imaging techniques provide the ultimate key to a prompt and correct diagnosis. Successful treatment of the specific type of overuse injury will increase the recovery rate and ensure rapid return to pain-free cycling activities.

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