

Prevention and management of knee osteoarthritis and knee cartilage injury in sports

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ABSTRACT

Articular cartilage defects in the knee of young or active individuals remain a problem in orthopaedic practice. These defects have limited ability to heal and may progress to osteoarthritis. The prevalence of knee osteoarthritis among athletes is higher than in the non-athletic population. The clinical symptoms of osteoarthritis are joint pain, limitation of range of motion and joint stiffness. The diagnosis of osteoarthritis is confirmed by the symptoms and the radiological findings (narrowing joint space, osteophyte formation and subchondral sclerosis). There is no strong correlation between symptoms and radiographic findings. The aetiology of knee osteoarthritis is multifactorial. Excessive musculoskeletal loading (at work or in sports), high body mass index, previous knee injury, female gender and muscle weakness are well-known risk factors. The high-level athlete with a major knee injury has a high incidence of knee osteoarthritis. Cartilage injuries are frequently observed in young and middle-aged active athletes. Often this injury precedes osteoarthritis. Reducing risk factors can decrease the prevalence of knee osteoarthritis. The prevention of knee injury, especially anterior cruciate ligament and meniscus injury in sports, is important to avoid progression of knee osteoarthritis.

Osteoarthritis is the most common musculoskeletal disease and is responsible for decreasing the quality of life among young, active athletes as well as older people.¹ The number of people who are affected by osteoarthritis is increasing due to the increasing age of the population. Obesity, excessive stress to the knee (at work or in sports), previous knee injury and muscle weakness around the knee are known risk factors.^{2–5} In analysing preventive possibilities, these risk factors are very important.

The aim of this review is to evaluate the prevalence of knee osteoarthritis and the relationship between sports activity and osteoarthritis, and furthermore to summarise the prevention and treatment of knee osteoarthritis and cartilage injury in sports, in order to reduce the increasing impact of knee osteoarthritis.

PREVALENCE OF KNEE OSTEOARTHRITIS IN SPORTS

The prevalence of knee osteoarthritis increases with age.¹ Symptomatic knee osteoarthritis occurs in 10–38% people aged 60 years or older.^{6–8} This number is increasing due to the ageing of the population. In professional and recreational athletes, the prevalence of knee osteoarthritis depends on the intensity, frequency and level of sports event (table 1).

The prevalence of knee osteoarthritis among former soccer players is 19–29%, long distance runners 14–20% and weight lifters 31%.^{9–13} There are some limitations in these studies. Previous studies that showed the relationship between the sports event and the prevalence of knee osteoarthritis have various definitions and criteria for osteoarthritis, the selection of athletes and the method of analysis.

DEFINITION OF KNEE OSTEOARTHRITIS

Osteoarthritis is a group of diseases in which the homeostasis of articular cartilage chondrocytes, extracellular matrix and subchondral bone is damaged mechanically and biologically.¹⁴ Although osteoarthritis may be initiated by multiple factors, including genetic, metabolic and traumatic, they involve all of the tissues of the joint.¹⁴ Osteoarthritis includes morphological, biochemical, molecular and biomechanical changes of both cells and matrix, which leads to softening, fibrillation and ulceration, loss of articular cartilage, sclerosis and eburnation of subchondral bone, osteophytes and subchondral cysts.¹⁴ Clinical osteoarthritis is characterised by joint pain, tenderness, limitation of movement, crepitus, occasional effusion and variable degrees of inflammation. Most physicians diagnose knee osteoarthritis not only by the symptoms, but by the radiological findings. The usual radiographs are read according to the Kellgren and Lawrence (K&L) classification: grade 0, no changes; grade 1, doubtful narrowing of the joint space and possible osteophytic lipping; grade 2, definite osteophytes and possible narrowing of the joint space; grade 3, moderate multiple osteophytes, definite narrowing of the joint space and some sclerosis and possible deformity of the bone ends; grade 4, large osteophytes, marked narrowing of the joint space, severe sclerosis and definite deformity of the bone ends. Conventionally, osteoarthritis has been defined as starting at K&L grade 2 or more.¹⁵

It is important to be aware of the considerable discrepancy between symptoms and radiological findings in osteoarthritis. Fifteen to 81% of patients with radiographic findings have knee pain in a recent systematic review.¹⁶ On the other hand, patients who have early painful osteoarthritis might not necessarily have radiographic changes.

POST-TRAUMA KNEE OSTEOARTHRITIS IN SPORTS

Injuries such as knee ligament tears, meniscal injuries and fractures involving articular

surfaces have been shown as strong risk factors for knee osteoarthritis.^{3 10 17–19} According to Kujala *et al*,¹⁰ the risk of knee osteoarthritis is increased almost five times in male former top-level athletes with previous knee injuries (OR 4.73). Some studies reported that articular surface incongruities greater than 3 mm increased local contact stress.²⁰ Consequently, precise reduction and fracture fixation is needed to avoid knee osteoarthritis after articular surface fracture. Meniscus injury is a risk factor for knee osteoarthritis.^{3 18 22} Table 2 shows the prevalence of radiological knee osteoarthritis after meniscectomy with long-term follow-up. The mechanical load-sharing function is damaged by injured or resected meniscus.³³ The relationship between tear characteristics and the degree of progression of knee osteoarthritis is controversial.^{29 31 34 35} Some papers reported that preoperative participation in high-level sport is a risk factor for developing radiological knee osteoarthritis.^{27 29 36} The anterior cruciate ligament (ACL) injury is well known as a risk factor for knee osteoarthritis with or without reconstruction (table 3).^{37–41} Gillquist and Messner⁴² reported that isolated meniscus tear and subsequent repair, or ruptures of the ACL seemed to increase the osteoarthritis risk 10-fold

compared with an age-matched, uninjured population. In addition, Øiestad *et al*⁴³ showed that the most frequent risk factor for the development of knee osteoarthritis in an ACL-injured athlete was meniscal injury. The prevalence of knee osteoarthritis with combination ACL and meniscus injury was much higher than that with isolated ACL injury. Early diagnosis and effective treatment and ensuring complete rehabilitation after ACL and meniscus injury should decrease the risk of osteoarthritis among sports participants.

ARE THE SPORTS THEMSELVES CAUSING OSTEOARTHRITIS?

Epidemiological studies have showed that participation in some competitive sports increases the risk of osteoarthritis.^{4 44 45} Moderate exercise has a low risk of leading to osteoarthritis. Furthermore, there is evidence that appropriate exercise reduces disability in the knee.⁴⁶ Sports activities including high-intensity and direct joint impact as a result of contact with other participants appeared to increase the risk of osteoarthritis.⁴⁷ Repetitive impact and twisting loads to the knee were also associated with joint degeneration.^{5 10 48 49} To avoid knee osteoarthritis, participants should pay attention

Table 1 The prevalence of knee osteoarthritis in sports

Author	Year	Subject	Number	Mean age (years)	Prevalence of knee osteoarthritis
Roos <i>et al</i> ⁹	1994	Former soccer players	286	55	15.5% (elite level) 4.2% (non-elite)
Kujala <i>et al</i> ¹⁰	1995	Former top-level athlete	117	45–68	1.6% (control) 3% (shooter) 29% (soccer) 31% (weight lifter) 14% (runner)
Turner <i>et al</i> ¹¹	2000	Former professional football players	284	56.1	29% (right knee) 22% (left knee)
Drawer and Fuller ¹²	2001	Retired professional soccer players	185	47.6	19% (right knee) 21% (left knee)
Chakravarty <i>et al</i> ¹³	2008	Long distance runner	45	76	20%

Table 2 Meniscus injury as a risk factor for knee osteoarthritis

Author	Year	Number	Follow-up period	Prevalence radiological knee osteoarthritis
Jørgensen <i>et al</i> ²³	1987	147	4.5 and 14.5 years	12% Osteoarthritis change (4.5 years follow up) 42% Osteoarthritis change (14.5 years follow up)
Maletius and Messner ²⁴	1996	40	12–15 years	55% Osteoarthritis change
Burks <i>et al</i> ²⁵	1997	181	10–15 years	62% Osteoarthritis change (more than K&L grade 2) with isolated ACL injury 80% Osteoarthritis change (more than K&L grade 2) with combined ACL injury
McNicholas <i>et al</i> ²⁶	2000	53	30 years	36% Osteoarthritis change
Chatain <i>et al</i> ²⁷	2000	317	10–15 years	31.2% Osteoarthritis change (medial meniscectomy)
Bonneux and Vandekerckhove ²⁸	2002	29	8±1.5 years	43% Osteoarthritis change
Chatain <i>et al</i> ²⁹	2003	471	11 years	21.5% Osteoarthritis change (medial meniscectomy) 37.5% Osteoarthritis change (lateral meniscectomy)
Englund <i>et al</i> ³⁰	2003	155	16±1 years	43% Osteoarthritis change
Englund and Lohmander ³¹	2004	317	18±2 years	27% Osteoarthritis change
Englund <i>et al</i> ³²	2004	170	20±2 years	62% Osteoarthritis change

ACL, anterior cruciate ligament; K&L, Kellgren and Lawrence grade.

Table 3 ACL injury as a risk factor for knee osteoarthritis

Author	Year	Background	Number	Study method	Prevalence of knee osteoarthritis
Neyret <i>et al</i> ³⁹	1993	Non-specific sports	93	Cohort 20–35 years follow-up	86% Osteoarthritis with untreated ACL injury
von Porat <i>et al</i> ³⁸	2004	Male soccer player	205	Cohort 14 years follow-up	78% Radiological osteoarthritis change (41% more than K&L grade 2)
Nebelung and Wuschech ³⁹	2005	High-level athlete	19	Cohort 35 year follow-up	42% TKA with untreated ACL injury
Ait Si Selmi <i>et al</i> ⁴⁰	2006	Non-specific sports	103	Cohort 17 years follow-up	14–26% Osteoarthritis with reconstructed ACL (37% with reconstructed ACL and meniscectomy)
Øiestad <i>et al</i> ⁴¹	2010	Non-specific sports	181	Cohort 10–15 years follow-up	62% Radiological osteoarthritis (more than K&L grade 2) with isolated ACL injury 80% radiological osteoarthritis (more than K&L grade 2) with combined ACL injury

ACL, anterior cruciate ligament; K&L, Kellgren and Lawrence grade; TKA, total knee arthroplasty.

to individual risk factors, frequency and intensity of sports activity.

THE CARTILAGE INJURY IN ATHLETES

In a study of 993 consecutive arthroscopies in patients with knee pain from Norway, articular cartilage changes were noted in 66% of the knees and isolated, localised cartilage lesions in approximately 20% of the cases.⁵⁰ Full-thickness cartilage lesions were found in 11% of the knees. Sports participation was the most commonly reported activity (49%). Most of the patients with localised cartilage lesions were in the younger age groups (median age 30 years). The most serious cartilage injuries, ICRS grades III and IV were commonly located at the medial femoral condyle followed by the patella. A single full-thickness area of more than 2 cm² was observed in 6% of all knees, and half of these patients had a cartilage lesion as their only pathology. Fifty per cent of these larger lesions (grades III–IV and >2 cm²) were localised in the medial femoral condyle and 13% in the femoral trochlea.

Cartilage treatment should be aimed at restoring normal knee function by the regeneration of hyaline cartilage in the defect, and to achieve a complete integration of the new cartilage to the surrounding cartilage and underlying bone. Recent years have seen several new surgical procedures emerge with the aim to improve function and to create normal cartilage. Unfortunately, clinical studies have been limited by methodological weaknesses. Over the past 10 years, marrow-stimulating procedures such as the microfracture method have been widely used and so far no other procedure has surpassed the microfracture results. The main developmental research has occurred in autologous chondrocyte implantation (ACI), which was first described in 1994.⁵¹ Newer techniques combining scaffolds, cells and growth factors have since been developed.^{52–57}

Ninety per cent of rotational injuries to the knee include the so-called bone bruise lesion.⁵⁸ Follow-up MRI studies of patients with bone bruises suggest that this may lead to degeneration of the cartilage and early arthritis.⁵⁸ In addition, it has been shown that isolated cartilage injuries may lead to degeneration of the adjacent cartilage.⁵⁴ These changes may be caused by the abnormally high stresses acting on the rim of the defect. The cartilage surface opposing an isolated cartilage injury often show fibrillation caused by mechanical irritation.⁶⁰ It is thus suggested that rotational injury to the knee with a bone bruise and subsequent cartilage changes may progress into degenerative arthritis. Moreover, the presence of concomitant injuries (eg, ACL injury or meniscus injury) and malalignment of the lower extremity influences the management of these lesions.^{48 61–63} Below is a brief description of the most used techniques for cartilage treatment.

Microfracture

Microfracture as a minimally invasive and simple procedure and is considered the first choice of treatment for patients with previously untreated cartilage defects. This technique has the goal of recruiting pluripotential stem cells from the marrow by penetrating the subchondral bone. The preferable cartilage lesion for this method is relatively small in size (1–2 cm²). Only two controlled, randomised clinical studies exist.^{64 65} Knutsen *et al*⁶⁴ have found good pain relief after 2 years of follow-up in 70–80% of patients, whereas Gudas *et al*⁶⁵ found superiority of the osteochondral autologous transplantation over microfracture at 1, 2 and 3-year time points. Furthermore, the Norwegian study comparing ACI with microfracture did not see a deterioration in the clinical results even 5 years after surgery.⁶⁶ There are few studies investigating the rate of return to sports after microfracture.^{65 67–70} Steadman *et al*⁶⁷ reported that 76% of National Football League players returned to play 4.6 more seasons after microfracture. In contrast, Namdari *et al*⁶⁸ showed that only 58% of National Basketball Association players were able to return to play at least 1 more season after microfracture. There is an obvious need for studies with more participants.

Autologous chondrocyte implantation

Autologous chondrocytes for cell transplantation to regenerate cartilage has been widely used.^{51 71–73} The procedure involves harvesting of 2–300 mg of cartilage through an arthroscopic procedure, followed 2–4 weeks later by an arthrotomy, in which the cells are injected under a cover of periosteum or a synthetic membrane. So far the results of four controlled studies have been published. Bentley *et al*⁷⁴ showed that after 19 months, 88% of the patients in the cell group versus 69% in the mosaic group had good to excellent results based on two non-validated scoring systems. Horas *et al*⁷⁵ found no differences between cells and mosaicplasty after 2 years. Dozin *et al*⁷⁶ also concluded that ACI and mosaicplasty were clinically equivalent and similar in performance. The Norwegian study⁶⁴ found no difference between cell transplantation and microfractures—both leading to improvement in more than 75% of patients after 2 years.⁶⁴ There was no significant difference in macroscopic or histological results between the two treatment groups and no association between the histological findings and the clinical outcome at the 2-year time point. Furthermore, the Norwegian study comparing ACI with microfracture did not see a deterioration in the clinical results even 5 years after surgery.⁶⁶ Hypertrophy of tissue seemed to be the major cause for re-operations after ACI.⁷⁰ Recently, Saris *et al*⁹⁸ published a 3-year follow-up of optimised chondrocyte implantation resulting in improved clinical outcomes compared with

microfracture. Kreuz *et al*⁷⁹ showed that the rate of return to preinjury levels of sports after ACI among regular or competitive sports athletes was 94% at the 18-month follow-up. The improvement will peak at approximately 2 years, and it does not seem to deteriorate up to 8 years. At the moment the procedure is reserved for patients with large defects on the weightbearing surface of the knee joint. The defects should not be deeper than approximately 5 mm without being bone grafted. ACI may be preferred as a second-line treatment for large defects. Microfracture was recently found to have less favourable results in treating patellofemoral lesions, and ACI may be a better option for trochlear defects.⁸⁰

Matrix-guided ACI

Matrix-guided ACI was invented to improve upon the disadvantages of ACI (hypertrophy of the graft, the uneven distribution of chondrocytes within the defect and the potential for cell leakage). In matrix-guided ACI, chondrocytes are cultured and implanted in scaffold. However, so far the clinical and histological results have not been reported to be better than conventional ACI.⁸¹

Mosaicplasty and osteochondral autologous grafts

An alternative to biological regeneration of a defect is to replace it with a substitute. Several orthopaedic companies have produced coring drills, which will harvest plugs from areas with relatively less weightbearing such as the intercondylar notch or the most lateral part of the femoral condyle. The plugs are then placed in the defect in predrilled cylinders. The clinical data were first published by Bobic⁸² and Hangody *et al*,⁸³ and the results matched those after chondrocyte transplantation by Brittberg *et al*.⁵¹ The recent study by Bentley *et al*⁷⁴ showed less encouraging results for this technique, whereas the studies by Horas *et al*⁷⁵ and Dozin *et al*⁷⁶ reported more optimistic results. Furthermore, the study by Gudas *et al*⁶⁵ has shown significant superiority of this technique over microfracture procedures, and showed that the rate of return to sports after mosaicplasty was 93% at an average of 6.5 months. There is an obvious need for longer follow-up studies. The use of this technique is limited only by the size of the defect due to the necessity of harvesting from relatively less weightbearing areas. Synthetic plugs have recently been developed for clinical use as a substitute for autologous graft (True-Fit; Smith and Nephew, Andover, MA, USA).^{84–86} However, no long-term results have been published.

MSC transplantation

Mesenchymal stem cell (MSC) transplantation has been introduced to repair cartilage lesions avoiding the disadvantages of other methods. MSC retain both high proliferative potential and multipotentiality, including chondrogenic differentiation potential. A number of animal studies with this method have been reported.⁸⁷ The use of MSC for cartilage repair is still at the early stage. More clinical studies are needed.

TREATMENT OF KNEE OSTEOARTHRITIS IN ATHLETES

Surgical treatment

Patients with knee osteoarthritis who are not obtaining adequate pain relief and functional improvement from a combination of rehabilitation and pharmacological treatment are considered for surgical treatments. There is agreement that arthroscopic debridement is not an efficient procedure in osteoarthritis patients.⁸⁸ For the young and active

athletes with symptomatic medial unicompartmental knee osteoarthritis, high tibial osteotomy (HTO) may avoid the progression of disease. The HTO can be done with an open-wedge osteotomy or lateral closing-wedge osteotomy. The medial tibial osteotomy is a popular technique and avoids detachment of the tibialis anterior muscle, the risk of peroneal nerve palsy and loss of correction to the lateral tibial osteotomy.⁸⁹ For older athletes with knee osteoarthritis, unicompartmental or total knee arthroplasty (TKA) may be considered to improve quality of life as well as some sports activity. Even though HTO and knee arthroplasty are common, there is limited literature reporting on the relationship between sports activity and knee surgery. Only two studies that reported clinical results involving return to sports and heavy works after HTO were found. They showed that 75–91% of patients after HTO were engaged in sports and recreational activities and regained the frequency and duration of sports activities.^{90–91} In the older patient group, several studies reported that more than 90% of patients after unicompartmental knee arthroplasty and more than 60% of patients after TKA returned to the same level of sports activity as before surgery.^{92–96} Further studies focusing on the appropriate level of sports activity after knee intervention and the prevention of implant problems (prosthetic wear out, loosening) among athletes are clearly needed.

PREVENTION OF KNEE OSTEOARTHRITIS IN SPORTS

As the number of people who have osteoarthritic disease is increasing, the prevention of osteoarthritis is important and necessary. Osteoarthritis has three strong risk factors (excessive musculoskeletal loading, high body mass index and previous knee injury) in which prevention may work. According to Hochberg,⁹⁷ avoiding squatting and kneeling and carrying heavy loads during work have been associated with a reduction of 15–30% in the prevalence of osteoarthritis in men. Another study showed a significant exposure–response relationship between symptomatic knee osteoarthritis and squatting and kneeling.^{98–99} Overweight is a risk factor for knee osteoarthritis. Weight reduction reduces not only the symptoms and progression of osteoarthritis, but also the risk of acquiring osteoarthritis.^{100–101} The Osteoarthritis Research Society International Group strongly recommends that patients with osteoarthritis lose weight and maintain weight at a lower level in overweight patients.¹⁰² Maintaining the body mass index at 25 kg/m² or below would reduce osteoarthritis in the population by 27–53%.^{97–98} As mentioned, knee injuries such as knee ligament tears, meniscal injuries and fractures involving the articular surfaces is a strong risk factor for knee osteoarthritis. Prevention programmes for sports injury, especially ACL injury, have recently shown encouraging results. Norwegian studies showed that the prevention of ACL injuries was possible with the use of neuromuscular training programmes.^{103–105} According to Felson⁹⁸ prevention of joint injuries would give an additional 14–25% reduction in the prevalence of osteoarthritis.

CONCLUSION

Ligament, meniscal and cartilage injuries are common in sports. Unfortunately, at present the treatment being surgical or rehabilitation does not seem to avoid the development of osteoarthritis in the knee. Much is happening in research on surgical as well as rehabilitation procedures in this field. Clearly, a greater emphasis on prevention is necessary.

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