J SPORTS MED PHYS FITNESS 2015;55:953-61

One injection of platelet-rich plasma associated to a submaximal eccentric protocol to treat chronic jumper's knee

J. F. KAUX [1], J. L CROISIER [2], O. BRUYERE [3], C. RODRIGUEZ DE LA CRUZ [2], B. FORTHOMME [1], G. BRABANT [2], S. LAPRAILLE [2], V. LONNEUX [2], D. NOEL [2], C. LE GOFF [4], A. GOTHOT [4], J. COLLETTE [4], J. M. CRIELAARD [1]

[1]*Physical Medicine and Sports Traumatology Department University and University Hospital of Liège Liège, Belgium*
[2]*Physiotherapy Service Department of Motility Sciences University of Liège, Liège, Belgium*
[3]*Department of Public Health Epidemiology and Health Economics University of Liège, Liège, Belgium*
[4]*Department of Clinical Biology University Hospital of Liège University of Liège, Liège, Belgium*

***Aim*. Jumper's knee is a frequent chronic overuse syndrome of the proximal part of the patellar tendon. Platelets contain lots of growth factors which could enhance the healing process of tendons. The aim of this study was to clarify the possible efficacy of one injection of Platelet-rich plasma (PRP) in cases of rebel jumper's knees.**

***Methods*. Twenty patients with chronic proximal patellar tendinopathy were enrolled. Assessments were made before infiltration of PRP, and 6 weeks and 3 months after the infiltration, using a 10-point visual analogic scale of pain, clinical examinations with a pressure algometer, algofunctional scores (IKDC and VISA-P), functional assessments (isokinetic and optojump evaluations) and imagery (ultrasounds and MRI). The PRP was obtained with an apheresis system (COMTEC®, Fresenius-Kabi, Bad Homburg, Germany). Six millilitres of PRP were injected without local anesthetic. One week after infiltration, patients started a standardized sub-maximal eccentric reeducation.**

***Results*. During daily activities pain significantly decreased with time. At functional evaluation, it decreased as well, but without significant functional improvement. No improvements in the imagery measurements were observed. Younger patients seemed to be more susceptible to have an improvement of pain by the PRP infiltration.**

***Conclusion*. This study demonstrates that a local infiltration of PRP associated with a submaximal eccentric protocol can improve symptoms of chronic jumper's knee in patients non-responsive to classical conservative treatments.**

KEY WORDS: Platelet-rich plasma - Knee - Tendinopathy - Blood component removal.

Jumper's knee is a frequent overuse syndrome of the proximal part of the patellar tendon, frequently observed in sportsmen with repetitive eccentric stresses on the knee extensor apparatus.[1] This condition is very common in jumping sports; in volleyball and basketball the prevalence reaches around 30 to 45%.[2] In soccer, shoots and plyometric trainings can also be traumatic for the patellar tendon, and this tendinopathy has a prevalence of 2 to 3%.[3] Finally, it remains often chronic even if a thorough conservative treatment is well done. Moreover, the option of a surgical treatment can be disappointing.[4]

New treatments are being developed for tendinopathies.[1] Injection of platelet-rich plasma (PRP) is one of these. Platelets contain many growth factors that could have the potentiality to enhance the healing process of tendons.[5] Even if *in vitro* and animal experiments have demonstrated this stimulation of tendon healing process,[6-8] clinical series are subject to controversy. Indeed, various papers seem to show a benefit to use PRP in case of tendinopathy, but one randomized controlled trial on Achilles tendinopathies did not show any improvement linked to PRP infiltrations.[9]

Corresponding author: J. F. Kaux, Physical Medicine and Sport Traumatology, University Hospital of Liège, Avenue de l'Hôpital, B35, 4000 Liège, Belgium. E-mail: jfkaux@chu.ulg.ac.be

The aim of our study was to clarify the possible efficacy of one injection of PRP in cases of rebel jumper's knee. Contrary to the other studies that used only algofunctional scores and imaging findings, we added as well different dynamic methods and techniques to evaluate the efficacy of the infiltration of PRP. These ones correspond more to the complaints and disabilities of the sportsmen with jumper's knee.

Material and methods

Thirty-nine potential subjects were identified among patients who were consulting our Sports Traumatology Department, and met the following inclusion criteria: proximal patellar tendinopathy for longer than 3 months, and no satisfactory improvement after 3 months of conservative management (including eccentric intervention and shock wave therapy). The patients could not have benefited from any treatment during the last month before infiltration of PRP. For these patients, the impending therapeutic option was only surgical. However, 4 subjects chose not to participate and 13 were excluded from the survey due to exclusion criteria: platelet concentration in blood below $1.5x10^5/\mu L$ (N.=1), anterior traumatic knee injuries (N.=2), anterior lower limb muscle injuries (N.=3) and symptomatic patellar syndrome (N.=7). The criteria of other previous injuries were established to avoid measurement bias during functional evaluation. Therefore, 22 patients (19 men and 3 women, mean age 28.8 years) with jumper's knee for more than 3 months (mean 17.6 months; from 4 to 62 months) were enrolled after having signed an informed consent form. The sports they practised were: soccer (N.=8), jogging (N.=4), basketball (N.=3), karate (N.=3), volleyball (N.=2), tennis (N.=2), judo (N.=2), mountain biking (N.=2) and boxing (N.=1). Due to pain, their sports capacities were decreased.

The assessments were made using different scores:

— 10-point visual analogic scale of pain (VAS): 0 is interpreted as the absence of pain, 10 corresponds to the worst imaginable pain.[10] This subjective pain score was used during daily activities, while pain during physical activities was evaluated by algofunctional scores;

— clinical examination using a pressure algometer commander (JTech Medical Industries, Salt Lake City, UT, USA): this tool is a force gauge that permits to quantify the minimum amount of pressure (in kPa) required to produce pain in the proximal part of the patellar tendon.[11] Subjects were instructed to say «stop» when the sensation changed from pressure to pain and the force in kPa would then be recorded by a console. The mean of 3 successive measurements was used. All the measurements were made by the same examiner;

— International Knee Documentation Committee form (IKDC): this scoring system measures symptoms, functions and sports activity in patients who have a knee condition. On this scale, from 0 to 100, 0 correspond to the minimal activity linked to maximal symptoms. and 100 means no limitation and absence of symptoms during daily and sports activities;[12]

— Victorian Institute of Sport Assessment - Patellar questionnaire (VISA-P): this scale is an index of severity of symptoms in patients with jumper's knee. The maximal value for an asymptomatic and fully performing subject is 100 points and the theoretical minimum is 0;[13]

— isokinetic assessment was performed by the same investigator using a Cybex Norm (Cybex International, Medway, MA, USA) after a 10-minutes warm-up on a cycle ergometer.[14] The patient was in a sitting position. The studied modalities were concentric 60°/s (C60) and 240°/s (C240), and eccentric 30°/s (E30) on both quadriceps. A VAS score was used to quantify pain resulting from each test;

— two days after the isokinetic evaluation, one leg counter movement jump (CMJ) and drop jump (DJ) evaluations were performed using an optojump device (Microgate, Bolzano-Bozen, Italy), after a 10-minutes warm-up on a cycle ergometer.[15] Three one-leg jumps for each modality and for each side were recorded, and the best one was retained. A VAS score was also used to quantify pain during each test;

— ultrasounds (US) examinations with an 18MHz probe were performed by the same investigator (X2000, Siemens, Munich, Germany). The following pieces of information were recorded: echotexture, tendon maximal thickness, ratio between the thickness of the pathological and the healthy parts of the tendon, sagittal hypo-echoic length, and amount of neovascularization using colour Doppler;

— magnetic resonance imaging (MRI) examinations were performed by the same investigator (Symphony 1.5T, Siemens, Munich, Germany). The fol-

lowing pieces of information were recorded: tendon maximal thickness, ratio between the thickness of the pathological and the healthy parts of the tendon, and sagittal hyper-intensity length.

The whole evaluation was made before the infiltration of PRP, and 6 weeks and 3 months after the injection. After a period of 6 months, they were contacted by phone, and asked to fill out a standardized questionnaire on the evolution of pain and the return to sports activities (same sport and level than before).

Before platelets were collected, a count of hematological cells of the patient was done in laboratory. After a local disinfection, a catheter was introduced in one vein of the forearm of each upper limb and connected to the apheresis machine (COM.TEC and kit CS5L, Fresenius-Kabi).[16] This machine offered a reproducible PRP from the autologous blood of each patient, with only very limited concentration of erythrocytes and leucocytes. Indeed, it calculated the time needed for the blood taking, in function of the patient's platelets concentration and anthropometric parameters. We decided to collect platelets with a concentration of around 8.5-9.10^5 platelets/µL.[17] The samples of the patients' PRP were sent to a laboratory for an analysis for quality control purpose.

Just before infiltration, 300µL of $CaCl_2$ were added to the PRP to activate the platelets.[17]. Six mL of PRP were injected in the patellar tendon after disinfection with dermal Isobetadine; 2mL in the lesion itself (observed by US and MRI), and 2mL on both sides of the lesion. No local anesthetic was used to avoid a decrease of the platelet activity linked to a pH modification.[18] Just after the infiltration, patients were given local cryotherapy. In case of pain, they could not take any anti-inflammatory drugs, but only type I or II classical painkillers. After 5 to 7 days of relative rest, while they could have a little local inflammatory reaction with increase of pain, they started a standardized progressive sub-maximal eccentric program supervised by a physical therapist, three times a week, for 5 weeks (Figure 1). The patient benefited also from electro-stimulation, stretching of the quadriceps, and cryotherapy. Ten minutes of cycloergometer with low resistance were also added to the program after 2 postinfiltrative weeks. This re-educative program was chosen because isokinetic devices were not available at each physiotherapist's practice.

Figure 1.—Standardized progressive sub-maximal eccentric exercise supervised by a physical therapist. The eccentric exercise was done using the weight of the patient's body. The patient started with the back against the wall. On the pathological leg (the left side in this case), he would then slide slowly his back down the wall until his leg would be bent at a certain angle. Then, he had to push on both legs to return to the starting position. The angulation and the number of sessions were progressively increased during the re-education, respectively from 60° to 90° and from 5 to 7 sessions of 15 repetitions, following the Stanish criteria. Thirty seconds of rest were allowed between the sessions.

Results were expressed as the mean±standard deviation of the mean (SD). Changes over time were assessed using generalized linear mixed models (GLMM). Differences in the baseline characteristics of patients presenting or not a clinically relevant improvement in VAS were assessed using an analysis of variance (ANOVA). Pearson correlation coefficients were used to assess the relationship between changes in various outcomes. Statistical analyses were done with the software Statistical Analysis System, ver-

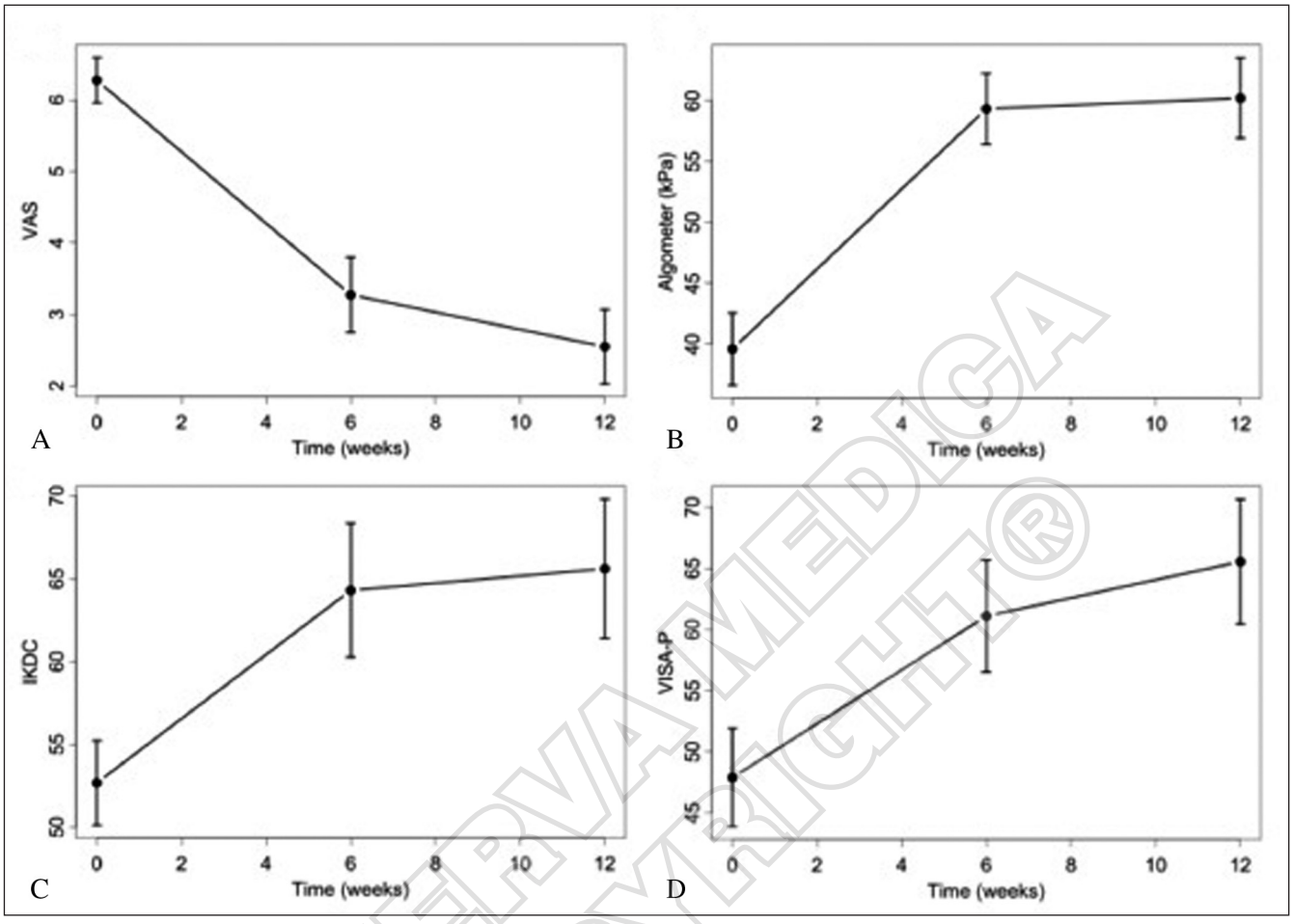

Figure 2.—Results of the algo-functional evaluations. A) VAS score evolution; B) algometer evolution; C) IKDC score evolution; D) VISA-P evolution.

sion 9.1 (SAS Institute, Caro, NC, USA) and a level of significance was set at 5%.

This protocol was accepted by the Ethic Committee of the University Hospital of Liège (number 2010/105; Belgian number B7072018785).

Results

Among the 22 patients included in the study, one decided to stop the study before the 6th weeks evaluation for personal reasons, and a second one was excluded from the rest of the study because of an exuberant inflammatory reaction for which he had to take NSAIDs and antibiotics.[19]

The concentration of the PRP used for the infiltration was 884.88±70.82 x 10^3/µL, with nearly neither erythrocytes (<0.001 x 10^6/µL) nor leucocytes (<0.001 x 10^3/µL). No significant difference was observed between platelet concentrations of the PRP injected in the whole group of patients.

The VAS decreased with time, from 6.3±1.4 before infiltration to 3.3±2.4 (P<0.0001) and 2.6±2.3 (P=0.0001) respectively at 6 weeks and 3 months (Figure 2A).

Values obtained with the pressure algometer increased with time, from 396.2±133.1 kPa before infiltration to 593.5±130.5 kPa (P<0.001) and 602.3±147.4 kPa (P<0.001) respectively at 6 weeks and 3 months (Figure 2B).

TABLE I.—*Inclusion and exclusion criteria. The criteria of other previous injuries were established to avoid measurement bias during functional evaluation.*

Inclusion criteria	— Proximal patellar tendinopathy diagnosed clinically, by US and MRI — Symptoms for longer than 3 months — No satisfactory improvement after minimum 3 months of conservative management (including a compliant good-quality eccentric exercise program eccentric intervention and shock wave therapy prior to the study) — No treatment during the last month before infiltration of PRP — The impending therapeutic option was only surgical
Exclusion criteria	— Platelet concentration in blood below $1.5x10^5/\mu L$; — Anterior traumatic knee injuries — Anterior lower limb muscle injuries — Symptomatic patellar syndrome — No motivation for this therapy (PRP infiltration).

The IKDC score increased with time, from 52.7±11.4 before infiltration to 64.3±18.0 (P=0.03) and 65.6±18.8 (P=0.024) respectively at 6 weeks and 3 months (Figure 2C).

The VISA-P score increased with time, from 47.9±17.9 before infiltration to 61.1±20.4 (P=0.05) and 65.6±22.8 (P=0.03) respectively at 6 weeks and 3 months (Figure 2D).

A strong correlation between the evolution of IKDC and VISA-P was observed (r=0.78, P<0.0001).

Significant correlations between the evolution of algometer values and the evolutions of IKDC (r=0.53, P=0.016) and VISA-P (r=0.45, P=0.045) were observed.

Results obtained for the isokinetic evaluation are presented in Table I. The analysis of the body-weight normalized peak torque for the quadriceps in C60 showed significant differences, before infiltration, between subjects who reported a decrease of pain (VAS below or equal to 1) and the others, we observed a significant difference between the 2 groups (2.87N.m/Kg vs 2.23N.m/Kg; P=0.01). A significant correlation was observed between eccentric performance of the quadriceps at 30°/s and the VAS results corresponding to the exercise (r=0.68, P=0.001).

Values obtained for the optojump evaluation are listed in Table II. Only the correlation between DJ results and VAS reported for this test (r=0.68, P=0.001) was significant.

The maximal thickness of the tendon calculated by US was: 8.0±2.4 mm, 8.0±1.8 mm and 8.3±1.9

TABLE II.—*Results of the isokinetic and optojump evaluation.*

	Before infiltration (T1)	6 weeks after infiltration (T2)	3 months after infiltration (T3)
Isokinetic evaluation			
Quad C60 patho	197.7±43.8 N.m	190.4±43.0 N.m	181.6±44.4 N.m (P=0.04 T1/T3)
Quad C60 healthy	203.8±42.8 N.m	197.0±40.2 N.m (P=0.05 T1/T2)	190.7±38.9 N.m (P=0.05 T1/T3)
VAS C60	2.6±2.9 N.m	2.0±2.2 N.m	2.3±2.1
Quad C240 patho	114.0±30.5 N.m	113.9±34.1 N.m	114.9±32.5 N.m
Quad C240 healthy	127.5±28.6 N.m	131.0±24.9 N.m	131.0±26.3 N.m
VAS C120	1.93±2.67 N.m	1.55±2.1 N.m	1.25±1.34 N.m
Quad E30 patho	171.7±84.4 N.m	192.4±72.3 N.m	188.6±75.0 N.m
Quad E30 healthy	222.6±63.9 N.m	235.2±74.2 N.m	227.4±58.3 N.m
VAS E30	4.7±3.3	3.3±2.6	3.6±2.6
Optojump evaluation			
CMJ patho	12.5±3.2 cm	13.1±4.3 cm	12.5±4.2 cm
CMJ healthy	13.6±3.2 cm	14.0±3.35 cm	14.1±3.6 cm
VAS CMJ	3.1±2.7	1.8±2.1	2.3±2.7
DJ patho	13.2±3.9 cm	14.4±3.7 cm	13.9±4.1 cm
DJ healthy	14.9±3.7 cm	15.3±3.4 cm	15,5±3.6 cm
VAS DJ	3.1±2.7	2.0±2.2	2.6±2.8

Quad: quadriceps; patho: pathological; VAS: visual analogic scale; C60: concentric 60°/s; C240: concentric 240°/s; E30: eccentric 30°/S; CMJ: counter movement jump; DJ: drop jump. Level of significance: P<0.05.

mm respectively before infiltration, at 6 weeks and 3 months. No significant difference was observed with time (P=0.26). The same observation was made for the ratio between the pathological and the normal thickness of the tendon (P=0.17). The values were as follows: 1.6±0.2, 1.5±0.3 and 1.5±0.3 respectively. The sagittal hypoechoic areas increased with time but without significance (P=0.05) and were respectively 15.3±7.14mm, 19.5±10.9 mm and 21.9±12.2 mm. Concerning color Doppler signal, 14 tendons out of 20 had one before infiltrations, 15 after 6 weeks and 16 after 3 months.

The maximal thickness of the tendon calculated by MRI was: 8.7±2.1 mm, 9.2±2.7 mm and 9.8±2.4 mm respectively before infiltration, at 6 weeks and 3 months. The thickness of the tendons increased significantly with time (P=0.02). On the other hand, the ratio between the pathological and the normal thickness of the tendon significantly decreased with time (P=0.003), principally between 0 and 6 weeks, and remained stable between 6 weeks and 3 months (P=0.1) and were respectively 1.5±0.3, 1.4±0.3 and 1.4±0.2. The sagittal hypersignal areas increased significantly with time (P=0.01) and were respectively 16.9±4.5 mm, 22.6±8.6 mm and 21.1±8.4 mm.

Interestingly, patients who had a VAS equal or below 1 after 3 months post-infiltration were younger, but without significance (P=0.08), than those who had more pain: respectively 24.7 and 32.2 years old. Moreover, these younger patients had a significant increase of the IKDC score (P=0.003), and a significant decrease of pain during isokinetic evaluation in C60 (P=0.02) and E30 (P=0.008), and during DJ evaluation on optojump (P=0.01).

From the 20 patients who benefited of the infiltration of PRP and who finished the study, 15 were able to return to sport (75%): 10 to the same sport than before infiltration (50%) and 7 to the same level of practice (35%). Only 3 underwent surgery (15%) and 2 stopped practicing sports (10%).

Discussion

Tendinopathy is highly prevalent and is one of the most frequently self-reported musculoskeletal conditions in sportsmen and physical workers.[1] Conservative treatments are not completely satisfactory and the recurrence of symptoms is common. This is why different experimental treatments are now being developed including PRP infiltration.[1]

By releasing different platelet growth factors, PRP may be a new therapeutic option for chronic tendinopathies.[9] Its ease of preparation, relatively low cost, and minimal invasiveness could be arguments in its favor.

Up to now, there is no general agreement on the method to prepare the PRP and each technique provides a very different PRP,[20] with variations in the platelet concentrations and of the amount (if any) of erythrocytes and leucocytes. White blood cells could adversely affect wound healing through the release of proinflammatory factors responsible for extracellular matrix degradation.[21] Moreover, it has been demonstrated that leukocyte-rich PRP leads to a bigger early local inflammation.[22] In addition, erythrocyte lysis releases free radicals that harm tissue structures.[23] We thus think that ideal PRP should not contain any erythrocytes or leucocytes, and that the quality of the PRP could perhaps partially explain the variable results observed in the literature. For our study, we used an apheresis machine that provided a reproducible PRP from one patient to another. The platelet concentration was always around 8.5-9 x 10^5/µL, and it contained nearly no erythrocytes or leucocytes, corresponding to P3-x-Aα of the PRP «PAW» classification system.[24] This concentration corresponds to the one generally used in studies.[17] Apparently, a concentration below 3.8 x 10^5 platelets/µl would be inefficient and above 1.8 x 10^6 platelets/µl would induce a paradoxically inhibitory effect.[17]

All the patients in this study suffered from a chronic jumper's knee for more than 3 months and failed conservative management, including treatments like long term eccentric reeducation (>20 sessions) or shock wave therapy. To be included in this study, the patients had to have stopped these treatments for more than 1 month before inclusion of the study to avoid bias due to these managements. These patients were thus possible candidates for a surgical treatment. This is why they were considered as their own control to verify the efficacy of PRP treatment, considering the failure of other conservative managements.

We observed a very significant improvement of the algofunctional status (VAS, algometer, IKDC and VISA-P) as soon as 6 weeks after the infiltra-

tion of PRP. This improvement continued to a lesser extent up to 3 months (Figure 2). These results confirm the good improvement of the algofunctional status after infiltrations of PRP in case of patellar tendinopathy observed by Volpi *et al.*[25], Kon *et al.*,[26] Filardo *et al.*[27] and Brown *et al.*[28] Interestingly, we noticed that patients, who presented, after 3 months, a satisfactory recovery, defined as a decrease of VAS equal or below 1 and a significant improvement of IKDC and VISA scores, presented a tendency to be younger. Even if the duration of symptoms was similar in patients presenting or not a satisfactory recovery, this could partly be explained by the greater healing potential of subjects younger than 30 years.[1] Moreover, we observed that these subjects had also a significant improvement of VAS during functional test (below or equal to 1 during DJ and below or equal to 2.5 during maximal E30). This pain could be considered by the patients as reasonable. These criteria could be considered as factors of good evolution after an infiltration of PRP in a jumper's knee and would be integrated in the return to play criteria. In this particular recurrent tendinopathy, 75% of the patients returned to sport with a significant decrease of pain 3 months after the infiltration of PRP, 50% in the same discipline, and 35% recovered the same level than before the infiltration. These results are less good than those of other studies on the infiltration of PRP in case of patellar tendinopathy.[25-28] Probably due to the fact that in our study only recurrent proximal patellar tendinopathies at the apex of the patella were included, and not corporeal patellar tendinopathies, which are often less rebel to conservative management. On the other hand, contrary to Kon *et al.*[26] and Filardo *et al.*[27] who proceeded to 3 infiltrations of PRP in their series, we did only one infiltration as Volpi *et al.*[25] and Brown *et al.*[28] The infiltration was done in *loco dolenti* after a US location of the lesion and on the two sides of the tendon. The location of the pathological area is easy in this case and it has been demonstrated that PRP tended to distribute beyond the local area of injection.[29]

After the infiltration of PRP and after the possible temporary local inflammatory syndrome (2-3 days), it is necessary to apply a submaximal eccentric load, without pain, to guide the tendon healing process.[30, 31] Otherwise, the cicatrization of the tendon will lose mechanical properties like in chronic tendinopathies,[30] perhaps due to an anarchic synthesis and organization of collagen, not parallel to strength lines.

Contrary to other series studying, the effect of PRP to treat tendinopathies in which only the algofunctional and imagery evaluations were made, we evaluated the performances in dynamic conditions, using isokinetic dynamometer and optojump devices. We thought that the more the knee is painful, the less it is able to develop strength or to jump high. This was confirmed by a significant correlation between results of the E30 and VAS during the evaluation. Physical performances, measured with the isokinetic dynamometer and the optojump devices, increased between 0 and 6 weeks and remained relatively stable until 3 months. Astonishingly, these values were, on average, not significantly modified, probably due to the great standard deviations between patients. However, pain during these activities seemed to decrease (Tables I, II), essentially between 0 and 6 weeks. When we analyzed the isokinetic results of patients who initially reported more pain, we observed that pain during isokinetic C60 and E30, and DJ on optojump was also significantly lessened by the end of the follow up. These observations demonstrated that a PRP infiltration could decrease individual pain of jumper's knee during maximal functional analytical activities. A significant correlation between these tests and the evolution of the VAS during the evaluation was demonstrated and has corroborated our hypothesis. These original findings could not be compared to others in the literature, as they were never analyzed in other series studying infiltration of PRP in patellar tendinopathy.

No improvement of bilateral difference of strength in E30 was observed even if pain decreased during this test. By inference, the aim of re-education is to decrease pain but also to improve strength performances. Thus in practice, once pain has sufficiently decreased, it would perhaps be relevant to perform an isokinetic test to evaluate the deficit of strength in the pathological quadriceps, with the aim to normalize the performance if necessary. Indeed, the lack of strength of the quadriceps could perhaps induce an inability to lock the knee and could be one of the risk factors of patellar tendinopathies;[31] thus it must be compensated once the pain as decreased enough in case of patellar tendinopathy. It should be encouraged to follow eccentric exercises in the long term. Furthermore, subjects who had a greater reduction of pain after the infiltration of PRP had a better strength

of the quadriceps in C60 before infiltration. We could forecast that subjects who would have a better prognostic after an infiltration of PRP in case of patellar tendinopathy would have the better initial strength performances in C60.

Contrary to the articles by Volpi *et al*.[25] and Filardo *et al*.,[27] imaging findings in our study did not show any decrease of the pathological lesion, but an increase of the hypoechoic lesion in US and in the hyper signal in MRI. Moreover, Doppler color signal appeared with time in patients who did not have any before the infiltration and the thickness of tendons increased in the MRI findings. As demonstrated, a trend for increased vascularity up to 6 months following PRP infiltration could be observed.[32, 33] Besides, it is well known that there is clearly a delay between clinical observation and imagery findings.[34] The explanation of this increase of «inflammation» in the tendon could be that the healing process initiated by platelets is not finished at 3 months even if the patient observed a significant decrease of pain. As the healing process of tendon is not finished at 3 months, we have encouraged patient to carry on the reeducation program at home for weeks.

Only one diabetic patient had an increase of pain associated with an exuberant local inflammation of the knee for weeks.[19] A possible diagnosis of complex regional pain syndrome was brought-up due to the absence of decrease of pain under anti-inflammatory drugs and colchicine or under a 3-month bi-antibiotherapy. Some other patients (N.=7) presented a normal little transient increase of pain associated with a little local inflammatory syndrome which decreased within 5 days.

Finally, for us, factors of good prognosis after an infiltration of PRP in case of chronic jumper's knee would be:

— platelet concentration around 8.5-9 x 10^5/µL, without erythrocytes or leucocytes;

— submaximal eccentric reeducation starting the week after the infiltration;

— young people (<30 years old);

— better strength of the quadriceps in E30 and C60 before infiltration;

— no diabetic patient.

Our study presents some limitations. First, due to the absence of a favorable evolution with a non-invasive therapeutic they already had followed, it was not ethical to propose this type of treatment again as placebo. We did not have the permission to have an invasive control group (infiltration of saline or plasma), and it was dangerous to do a corticosteroid infiltration in or around this tendon due to the risk of rupture.[1] This study was thus prospective with a follow-up of 3 months. Second, the patients benefited of a progressive sub-maximal eccentric program using the weight of the body for a greater compliance of the patients to postinfiltration re-education. Moreover isokinetic devices were not available at each physiotherapist's practice. However, this protocol would be more standardized and controlled if the exercises were performed on an isokinetic dynamometer.[14] Third, as the 2 functional tests were relatively aggressive for the patellar tendons, the evaluation at the 6th week after the infiltration could partly abort in some patients, the healing process initiated by the infiltration of PRP; this may explain the increase of pain experienced by some patients after these tests were done at 6 and 12 weeks after infiltration.

Conclusions

Our series has demonstrated that a local infiltration of PRP associated to a submaximal eccentric protocol can improve symptoms of chronic jumper's knee unresponsive to other conservative treatments. Our PRP, obtained with an apheresis system, allowed us to obtain a reproducible PRP without either erythrocytes or leucocytes. The originality of our study was that we added dynamic evaluations (isokinetic and optojump assessments) to static evaluation (algometer, alto-functional scores and imagery). Even if we did not observe any significant difference of performances, pain during functional testing tended to be reduced after 3 months of follow-up. Naturally, a randomized controlled study with the same functional evaluations would be the best way to confirm our findings.[35]

References

1. Kaux JF, Forthomme B, Le Goff C, Crielaard JM, Croisier JL. Current opinion on tendinopathy. J Sports Sci Med 2011;10:238-53.
2. van der Worp H, van Ark M, Zwerver J, van den Akker-Scheek I. Risk factors for patellar tendinopathy in basketball and volleyball players: a cross-sectional study. Scand J Med Sci Sports 2012;22:83-90.
3. Hagglund M, Zwerver J, Ekstrand J. Epidemiology of patel-

lar tendinopathy in elite male soccer players. Am J Sports Med 2011;39:1906-11.
4. Larsson ME, Kall I, Nilsson-Helander K. Treatment of patellar tendinopathy-a systematic review of randomized controlled trials. Knee Surg Sports Traumatol Arthrosc 2012;20:1632-46.
5. Nurden AT, Nurden P, Sanchez M, Andia I, Anitua E. Platelets and wound healing. Front Biosci 2008;**13**:3532-48.
6. Anitua E, Andia I, Sanchez M, Azofra J, del Mar Zalduendo M, de la Fuente M *et al*. Autologous preparations rich in growth factors promote proliferation and induce VEGF and HGF production by human tendon cells in culture. J Orthop Res 2005;23:281-6.
7. Lyras DN, Kazakos K, Verettas D, Polychronidis A, Tryfonidis M, Botaitis S *et al*. The influence of platelet-rich plasma on angiogenesis during the early phase of tendon healing. Foot Ankle Int 2009; 30:1101-6.
8. Kaux JF, Drion PV, Colige, A, Pascon F, Libertiaux V, Hoffmann A *et al*. Effects of platelet-rich plasma (PRP) on the healing of Achilles tendons of rats. Wound Repair Regen 2012;20:748-56.
9. Kaux JF, Crielaard JM. Platelet-rich plasma application to treat chronic tendinopathies: a review. Acta Orthop Belg 2013;79:10-5.
10. Joyce CR, Zutshi DW, Hrubes V, Mason RM. Comparison of fixed interval and visual analogue scales for rating chronic pain. Eur J Clin Pharmacol 1975;8:415-20.
11. Keele KD. Pain-sensitivity tests; the pressure algometer. Lancet 1954;266:636-9.
12. Irrgang JJ, Anderson AF, Boland AL, Harner CD, Kurosaka M, Neyret P *et al*. Development and validation of the international knee documentation committee subjective knee form. Am J Sports Med 2001;29:600-13.
13. Visentini PJ, Khan KM, Cook JL, Kiss ZS, Harcourt PR, Wark JD. The VISA score: an index of severity of symptoms in patients with jumper's knee (patellar tendinosis). Victorian Institute of Sport Tendon Study Group. J Sci Med Sport 1998;1:22-8.
14. Croisier JL, Forthomme B, Namurois MH, Vanderthommen M, Crielaard JM. Hamstring muscle strain recurrence and strength performance disorders. Am J Sports Med 2002;30:199-203.
15. Glatthorn JF, Gouge S, Nussbaumer S, Stauffacher S, Impellizzeri FM, Maffiuletti NA. Validity and reliability of Optojump photoelectric cells for estimating vertical jump height. J Strength Cond Res 2011; **25**:556-60.
16. Moog R, Zeiler T, Heuft HG, Stephan B., Fisher EG, Kretschmer V *et al*. Collection of WBC-reduced single-donor PLT concentrates with a new blood cell separator: results of a multicenter study. Transfusion 2003;43:1107-14.
17. Lopez-Vidriero E, Goulding KA, Simon DA, Sanchez M, Johnson DH. The use of platelet-rich plasma in arthroscopy and sports medicine: optimizing the healing environment. Arthroscopy 2010;26:269-78.
18. Foster TE, Puskas BL, Mandelbaum BR, Gerhardt MB, Rodeo SA. Platelet-rich plasma: from basic science to clinical applications. Am J Sports Med 2009;37:2259-72.
19. Kaux JF, Croisier JL, Léonard P, Le Goff C., Crielaard JM. Exuberant inflammatory reaction as a side effect of platelet-rich plasma infiltration for treating one case of tendinopathy. Clin J Sport Med 2014;24:150-2.
20. Kaux JF, Le Goff C, Seidel L, Péters P, Gothot A, Albert A *et al*. [Comparative study of five techniques of preparation of platelet-rich plasma]. Pathol Biol (Paris) 2011;59:157-60 [Article in French].
21. Pizza FX, McLoughlin TJ, McGregor SJ, Calomeni EP, Gunning WT. Neutrophils injure cultured skeletal myotubes. Am J Physiol Cell Physiol 2001;281:C335-41.
22. Dragoo JL, Braun HJ, Durham JL, Ridley BA, Odegaard JI, Luong R *et al.* Comparison of the acute inflammatory response of two commercial platelet-rich plasma systems in healthy rabbit tendons. Am J Sports Med 2012;40:1274-81.
23. Jiang N, Tan NS, Ho B, Ding JL. Respiratory protein-generated reactive oxygen species as an antimicrobial strategy. Nat Immunol 2007;8:1114-22.
24. DeLong JM, Russell RP, Mazzocca AD. Platelet-rich plasma: the PAW classification system. Arthroscopy 2012; 28:998-1009.
25. Volpi P, Marinoni L, Bait C, De Girolamo L, Schoenhuber H. Treatment of chronic patellar tendinosis with buffered platelet riche plasma : a preliminary study. Medicina Dello Sport 2007;60:595-603.
26. Kon E, Filardo G, Delcogliano M, Presti ML, Russo A, Bondi A *et al.* Platelet-rich plasma: new clinical application: a pilot study for treatment of jumper's knee. Injury 2009;40:598-603.
27. Filardo G, Kon E, Della Villa S, Vincentelli F, Fornasari PM, Marcacci M. Use of platelet-rich plasma for the treatment of refractory jumper's knee. Int Orthop 2010;34:909-15.
28. Brown J, Sivan M. Ultrasound-guided platelet-rich plasma injection for chronic patellar tendinopathy: a case report. PM R 2010;2:969-72.
29. Loftus ML, Endo Y, Adler RS. Retrospective analysis of postinjection ultrasound imaging after platelet-rich plasma or autologous blood: observational review of anatomic distribution of injected material. AJR Am J Roentgenol 2012;199:W501-5.
30. Virchenko O, Aspenberg P. How can one platelet injection after tendon injury lead to a stronger tendon after 4 weeks? Interplay between early regeneration and mechanical stimulation. Acta Orthop 2006;77:806-12.
31. Kaux JF, Drion P, Libertiaux V, Colige A, Hoffmann A, Nusgens B *et al.* Eccentric training improves tendon biomechanical properties: A rat model. J Orthop Res 2013;31:119-24.
32. van der Worp H, van Ark M, Roenink S, Pepping GJ, van den Akker-Scheek I, Zwerver J. Risk factors for patellar tendinopathy: a systematic review of the literature. Br J Sports Med 2011;45:446-52.
33. Chaudhury S, de La Lama M, Adler RS, Gulotta LV, Skonieczki B, Chang A *et al.* Platelet-rich plasma for the treatment of lateral epicondylitis: sonographic assessment of tendon morphology and vascularity (pilot study). Skeletal Radiol 2012;42:91-7.
34. Khan KM, Foster BB, Robinson J, Cheong Y, Louis L, Maclean L *et al.* Are ultrasound and magnetic resonance imaging of value in assessment of Achilles tendon disorders? A two year prospective study. Br J Sports Med 2003;37:149-53.
35. Smets F, Croisier JL, Forthomme B, Crielaard JM, Kaux JF. Applications cliniques du Plasma riche en plaquettes (PRP) dans les lésions tendineuses : revue de la littérature. Science & Sport 2012;27:141-53.

Acknowledgements.—We would like to thank the doctors P. Simoni and V. Alvarez who performed the imaging examinations and the nurses of the Blood Transfusion Centre of the University Hospital of Liège for their efficacy. We would particularly like to thank the patients who participated in the study, and the doctors (especially Dr B. Godon and Dr J. Vervier) and surgeons (especially Dr C. Daniel and Dr J. P. Delcour) who referred them to us.

Fundings.—This study was supported by the Foundation Lejeune-Lechien and the ADEPS grants of the Léon Frédéricq Funds.

Conflicts of interest.—The authors certify that there is no conflict of interest with any financial organization regarding the material discussed in the manuscript.

Received on December 6, 2013.
Accepted for publication on February 18, 2014.
Epub ahead of print on June 19, 2014.