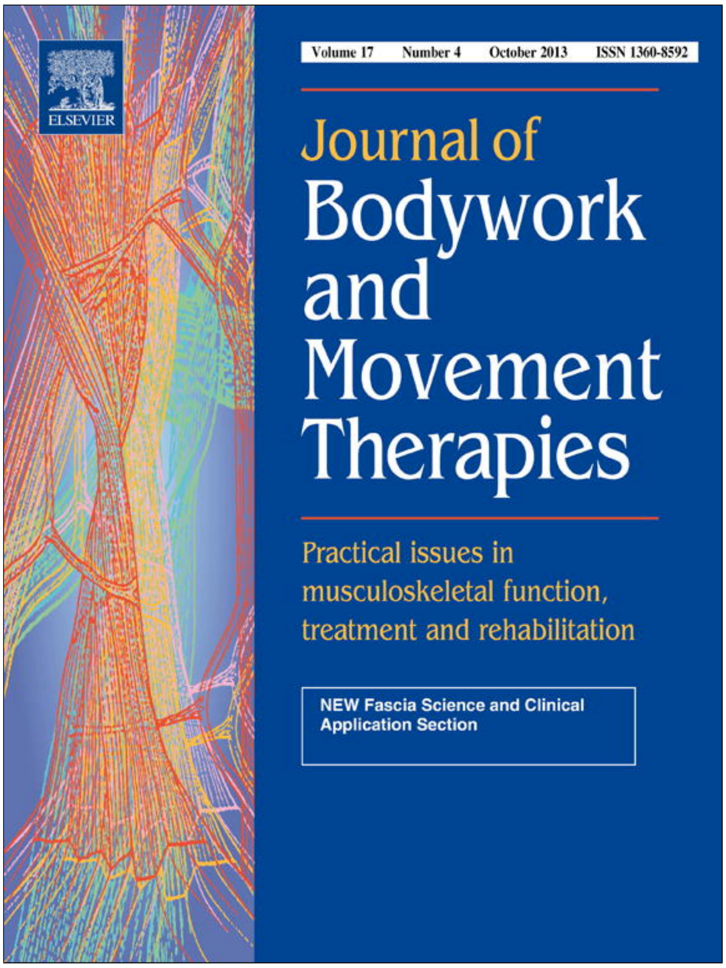
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FASCIA SCIENCE AND CLINICAL APPLICATIONS: FASCIAL IMAGING

Ultrasound characteristics of the lateral retinaculum in 10 patients with patellofemoral pain syndrome compared to healthy controls

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Patellofemoral pain syndrome;
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Summary *Background:* Histopathologic changes of the lateral retinaculum are described in patients with patellofemoral pain syndrome (PFPS). No information is available on the presence of structural changes of the lateral retinaculum on ultrasound examination in patients with PFPS.
Purpose: To describe ultrasound characteristics and colour Doppler findings in patients with unilateral PFPS and in healthy controls.
Methods: 10 patients with unilateral PFPS and 10 healthy control subjects underwent ultrasound and colour Doppler examination of the lateral retinaculum of both knees. Thickness of the lateral retinaculum was measured at three predefined locations. In addition presence of neovascularisation was assessed.
Results: Thickness of the lateral retinaculum of both affected (mean [SD] of three locations 4.0 [1.4] mm, 95%CI: 1.2–6.8) and asymptomatic (3.7 [0.8] mm, 95%CI: 2.1–5.3) knees was increased in the patient group compared to the control subjects (3.0 [0.1] mm, 95%CI: 2.8–3.2), although not reaching statistical significance. Positive colour Doppler signals of the lateral retinaculum were found in 4 patients and in none of the control subjects (4/10 versus 0/10; 2×2 Fisher's exact test 1-tailed $p = 0.0433$; 2-tailed $p = 0.0866$; mid p value $= 0.0217$).

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Conclusions: The results of these measurements indicate a trend towards a larger thickness of the lateral retinaculum and showed neovascularisation measured by ultrasound and colour Doppler examination in patients with PFPS. The larger thickness of the lateral retinaculum on ultrasound examination was found in both affected and in asymptomatic knees of the patients, supporting the concept that PFPS is a bilateral rather than a unilateral disorder. Further research is needed to unravel the role of the lateral retinaculum in pathogenesis of PFPS and to clarify the role of the lateral retinaculum as a target for therapy in patients with PFPS.

Introduction

Patellofemoral pain syndrome (PFPS) is a common disorder and accounts for a quarter of knee injuries seen in sports medical practice (Baquie and Brukner, 1997; Devereaux and Lachmann, 1984). PFPS is characterized by peripatellar pain in absence of other pathologies. Patellofemoral pain is provoked by weight bearing activities like running, jumping, stair climbing, squatting and by prolonged sitting with flexed knees. Through the years, several theories on the pathogenesis of PFPS have been postulated. Chondromalacia was held responsible for PFPS until the seventies of the last century, but different studies revealed no clear relationship between anterior knee pain and chondromalacia (Aleman, 1928; Royle et al., 1991; Sanchis-Alfonso, 2011). From that time until the end of the twentieth century, PFPS was mainly explained as the result of patellofemoral malalignment (Ficat et al., 1975; Holmes and Clancy, 1998; Hughston, 1968; Insall, 1979). Currently the concept of patellofemoral malalignment is questioned because not all patients with patellofemoral malalignment are symptomatic. On the other hand, many patients with anterior knee pain lack signs of patellofemoral malalignment of the patellofemoral joint on computed tomography (Sanchis-Alfonso, 2008). In 1996 Dye shed new light on the pathogenesis of knee complaints by postulating the model of tissue homeostasis and in 1999 this model was adapted to PFPS (Dye, 1996; Dye et al., 1999). Dye stated that in the pathogenesis of patellofemoral pain, loss of homeostasis of innervated patellofemoral tissues plays a more important than the presence of structural abnormalities. In the model of tissue homeostasis, patients with a normal anatomy of the patellofemoral joint can become symptomatic when they are exposed to a supraphysiologic load, whereas patellofemoral malalignment might act as a predisposing factor in the development of PFPS (Post, 2005; Sanchis-Alfonso et al., 1998). Patellofemoral malalignment impairs tissue homeostasis and leads to provocation of peripatellar pain after minimal or moderate changes in loading of the knee. According to Dye the most likely sources of nociceptive output in patients with patellofemoral pain are the innervated peripatellar soft tissues and the intraosseous environment of the patella. In this context authors have emphasized the role of the lateral retinaculum in the provocation of pain in PFPS (Fulkerson, 1983; Fulkerson et al., 1985; Mori et al., 1991; Sanchis-Alfonso et al., 1998, Sanchis-Alfonso and Roselló-Sastre, 2000, Sanchis-Alfonso et al., 2001, 2005). Fulkerson described demyelinisation and fibrosis in the lateral retinaculum of patients with patellofemoral pain, which resembles the histopathologic picture of Morton's neuroma (Fulkerson et al., 1985). Mori et al. showed degenerative changes of the nerves in the lateral retinaculum of patients with patellofemoral pain (Mori et al., 1991). Sanchis-Alfonso et al. found hyperinnervation and hypervascularisation of the lateral retinaculum in patients with PFPS (Sanchis-Alfonso et al., 1998, 2005; Sanchis-Alfonso and Roselló-Sastre, 2000). According to the histopathology of tendinosis, Sanchis-Alfonso et al. did not find signs of inflammation in the lateral retinaculum in these patients (Sanchis-Alfonso et al., 1998, 2005; Alfredson et al., 1999, 2001, Alfredson and Lorentzon, 2003).

In longstanding tendinopathy histopathologic changes in collagen lead to abnormal signals on sonographic evaluation of the tendon (Peers and Lysens, 2005; Mitchell et al., 2009). Ultrasound examination of tendinosis shows swelling of the tendon often combined with disturbances in the organisation of collagen with hypoechogenic zones. On power Doppler ultrasonography neovascularisation can be demonstrated in tendinosis. In the literature there is scarce information about the ultrasound aspect and anatomy of the lateral retinaculum, mainly obtained from cadaveric knee specimens (Starok et al., 1997). As far as we know there are no studies that describe the ultrasound characteristics of the lateral retinaculum in patients with PFPS or in healthy subjects. The aim of the current study was to gather information on the ultrasound characteristics of the lateral retinaculum in 10 patients with unilateral PFPS and to compare those characteristics with 10 healthy volunteers. We hypothesized that thickness of the lateral retinaculum in the affected knee of patients with PFPS would be larger compared to the unaffected knee and compared to the control subjects.

Methods and subjects

Subjects

For this observational study 10 patients with unilateral PFPS who satisfied the inclusion criteria (Table 1) were recruited from our sports medical practice and outpatient physiotherapy department. Prior to the study all patients underwent a physical examination of both knees to rule out passive instability and joint line tenderness. In the patients X-ray examination of the affected knee was performed to rule out patella alta and signs of patella dysplasia. Ten control subjects without any history or presence of knee complaints were recruited from hospital staff. Before admittance all participants were given both oral and written information regarding the nature and purpose of the study. All participants gave their informed consent for participation in the study.

Table 1 Inclusion criteria for the patients and exclusion criteria for patients and control subjects.

Inclusion criteria	Exclusion criteria
Age 18–50 year	Current back, hip or ankle pain
Unilateral knee pain around the patella with an insidious onset existing for longer than 6 months	Any pain in back, hip or ankle in the last year requiring attention from a health care professional
Full range of motion in hips, knees and ankles at physical examination	Previous surgery or traumatic injury to back, hip, knee or ankle
Normal passive stability of the knee	Joint effusion in the knee; tenderness of the apex patellae at physical examination
	Signs of patellar tendinopathy on ultrasound examination

Procedure

Ultrasound images were obtained by an experienced radiologist in musculoskeletal ultrasound examination, who was blinded for the affected knee of the patients. Each subject underwent an ultrasound examination of the lateral retinaculum of both knees. To rule out patellar tendinopathy the patellar ligament of both knees were examined as well. Ultrasound examination was conducted with a Siemens Sonoline Antares scanner (Mountain View, CA, US) with a 5 cm 13 MHz linear array transducer. The lateral retinaculum was scanned in a transverse plane with 10° flexion of the knee. The tip of the probe was placed against the lateral side of the middle of the patella perpendicular to the skin surface (Fig. 1). Compression of the skin and underlying tissues was avoided. Thickness of the lateral retinaculum was measured respectively at 0.5, 1.0 and 1.5 cm lateral from the edge of the underlying femur (Fig. 2). This three-point measurement was conducted because it was unclear from literature whether the retinaculum has an equal thickness over its entire length. Thickness of the lateral retinaculum was measured as the distance between the superficial and deep boundary of the retinaculum (Fig. 3). Presence or absence of neovascularisation was assessed by colour Doppler examination at the lateral retinaculum with the knee in two positions (10° resp. 90° flexion).

Figure 1 Ultrasound examination of the lateral retinaculum in a transverse plane with 10° flexion of the knee; tip of the probe is placed against the lateral side of the middle of the patella.

Data analysis

A univariate two-factor ANOVA was applied, where thickness of the lateral retinaculum was the dependent variable and affected/unaffected (or left/right for controls) knees were the independent variables. A Shapiro–Wilk test was performed on the residuals to test for data normality.

A Kruskal–Wallis test for independent samples was performed to investigate differences between the affected/not affected knees of the patients compared to the mean of left and right leg of the control subjects. Differences between patients and control subjects regarding the colour Doppler signals were investigated using a Fisher's Exact test.

The level of significance was set at 0.05 for all statistical tests. Statistical analyses were all conducted using Statistical Package for Social Scientists (SPSS 18.0, Chicago, IL).

Results

In Table 2 characteristics of patients and control subjects are shown. None of the patients or control subjects showed signs of patellar tendinopathy on ultrasound examination. On radiologic examination of the knee (AP, lateral and tangential patella) signs of patella alta or patella dysplasia were absent in all patients.

In Table 3a and Table 3b and in Fig. 4 the results of the ultrasound measurements of thickness of the lateral retinaculum in millimetres are depicted for patients and control subjects respectively. The mean thickness of the

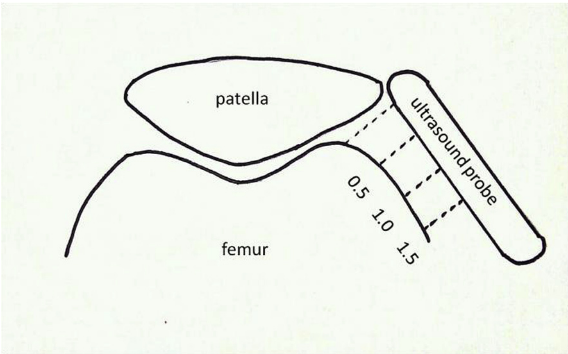

Figure 2 Measurement of lateral retinaculum thickness at 0.5, 1.0 and 1.5 cm lateral from the edge of the femur.

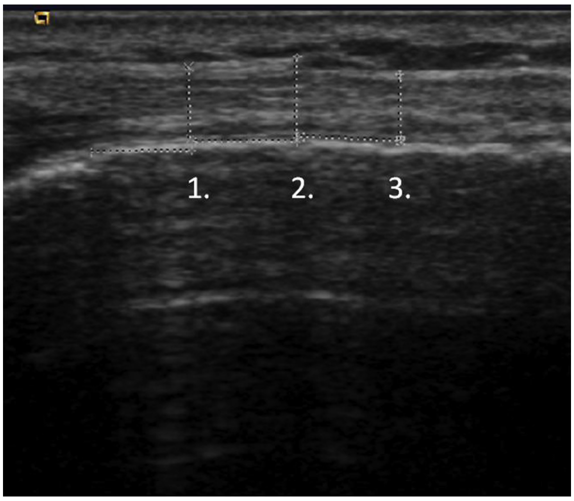

Figure 3 Thickness of the lateral retinaculum was measured as the distance between the superficial and deep boundary of the retinaculum; 1 = 0.5 cm, 2 = 1.0 cm and 3 = 1.5 cm lateral from the edge of the femur.

lateral retinaculum in the affected leg of patients was larger on all measurement points in comparison to the non-painful knee, but differences were not statistically significant. A two-factor ANOVA revealed no significant main effect of measuring points ($F(1,54) = 0.002$) and no main effect of affected/not affected knee ($F(1,54) = 1.037$) in patients. For control subjects, no main effects were found for measuring points ($F(1,54) = 0.256$) or for left/right knee ($F(1,54) = 0.883$). Mean thickness of the lateral retinaculum at the three measurement points in the affected knees of patients is 4.0 (1.4) mm, in the control subjects mean thickness on the three measurement points is 3.0 (0.1) mm. Because of the heterogeneity of the variances, the differences between patients and control subjects were tested with a non-parametric test. A Kruskal–Wallis test revealed no significant difference between the affected knee of the patients and the mean value of the left and right knee of the control subjects ($H(1) = 2.286$, $p = 0.131$). Also, no differences were detected between the unaffected knee and the mean value of the left and right knee of the control subjects ($H(1) = 2.287$, $p = 0.130$). Fig. 5 shows a graphical representation of the results of differences in thickness of the lateral retinaculum between affected and asymptomatic knee for patients and between left and right knee of the control subjects at the three measurement points.

Table 2 Characteristics of patients and control subjects, presented as mean (standard deviation). PFPS: Patella femoral pain syndrome.

	Number	Gender	Age (years)
PFPS group	10	4 men 6 women	26.5 (8.3)
Control group	10	4 men 6 women	32.0 (8.3)

Positive colour Doppler signals of the lateral retinaculum were seen in 4 patients and in none of the control subjects. A one-tailed Fisher's exact test demonstrates a significant difference between patients and control subjects ($p = 0.0433$; two-tailed: $p = 0.0866$; mid p value $= 0.0217$). In two patients positive colour Doppler signals were found in the affected knee, one with the knee in 10° flexion and one with the knee in 90° flexion. In two patients positive colour Doppler signals were found in the unaffected knee, one in 10° flexion and in the other patient both at 10° and 90° knee flexion. Fig. 6a shows positive colour Doppler signals of the lateral retinaculum of the affected knee in one of the patients with the knee in 10° flexion. In Fig. 6b there is absence of colour Doppler signals in the unaffected knee of the same patient with the knee in 10° flexion.

Discussion

The results of this study suggest differences in ultrasound characteristics of the lateral retinaculum in patients with PFPS compared to normal subjects. In the control subjects the variation in thickness of the lateral retinaculum was very small, with a standard deviation of 0.1 and a mean thickness of 3 mm. As shown in Fig. 5 there is a remarkable pattern in the difference between the affected and asymptomatic knee in the patient group, compared to the difference between left and right knee in the control subjects. We have no clear explanation for the wide variation in the measurements of the patients. Statistical evaluations of thickness of the lateral retinaculum have to be interpreted with caution because of the width of the confidence intervals in the patient group, which was larger than in the control subjects. This might have been the result of insufficient power of our study. Statistical power and sample size calculations are based on the baseline incidence of population variance. Before the start of this study population variance of ultrasound measurements of the lateral retinaculum were not known to the authors. This observational study is a first attempt to get insight into the ultrasound characteristics of the lateral retinaculum in patients with PFPS and in normal subjects. Further research is necessary to confirm normal values of lateral retinaculum thickness in healthy subjects. Minimum clinically important difference has to be defined between patients with PFPS and healthy subjects and between symptomatic and asymptomatic knees in patients. In this study thickness of the lateral retinaculum of the affected knee in patients was just slightly increased compared to the asymptomatic knee. A reason for this could be the fact that PFPS often occurs in both knees. Bilateral complaints have been reported in about two-thirds of PFPS patients (Goldberg, 1991; Vähäsarja, 1995). More recent studies of Jensen et al. show that initial unilateral knee pain in PFPS can lead to the development of bilateral complaints via central modulation of the nervous system (Jensen et al., 2007).

The finding of increased thickness of the lateral retinaculum of the asymptomatic knee in the patients in comparison to the mean of left and right knee of the control subjects corresponds with results of Hudson and Darthuy, who investigated iliotibial band tightness in PFPS

Table 3a Thickness of the lateral retinaculum in millimetres at 0.5, 1.0 and 1.5 cm lateral from the edge of the patella in patients with the patella femoral pain syndrome. Aff. knee: affected knee; Asympt. knee: asymptomatic knee; SD: standard deviation; 95%CI: 95% confidence interval.

Patients	Aff. knee 0.5 cm	Asympt. knee 0.5 cm	Aff. knee 1.0 cm	Asympt. knee 1.0 cm	Aff. knee 1.5 cm	Asympt. knee 1.5 cm
1	5.9	4.9	6.0	4.3	6.7	3.9
2	2.7	3.5	2.5	3.6	2.7	3.7
3	3.6	2.8	3.7	2.3	3.3	2.9
4	2.3	4.5	2.3	4.6	2.5	4.4
5	6.3	4.8	5.6	5.2	6.1	4.4
6	3.5	2.5	3.3	3.0	2.9	2.8
7	2.8	2.6	3.3	2.7	2.9	2.8
8	3.1	4.2	3.0	3.6	3.3	4.0
9	4.6	3.6	4.9	4.1	5.4	3.3
10	5.2	3.0	4.4	3.6	4.1	4.2
Mean	4.0	3.6	3.9	3.7	4.0	3.6
SD	1.3	0.9	1.2	0.8	1.5	0.6
95%CI	1.4–6.6	1.8–5.4	1.5–6.3	2.1–5.3	1.0–7.0	2.4–4.8

(Hudson and Darthuy, 2009). They found tighter iliotibial bands in the non-painful knee of the patients in comparison to control subjects measured by decreased hip adduction during the Ober's test. This finding fits with the idea of PFPS as a bilateral disorder. Questions remain about the relationship between tight iliotibial band and thickening of the lateral retinaculum in PFPS. The anatomical relationship between iliotibial band and lateral retinaculum is close, with superficial oblique and deep transverse layers of the lateral retinaculum originating from the iliotibial band (Standring, 2005). Given this anatomical relationship it is conceivable that thickening of the lateral retinaculum can have an effect on iliotibial band tightness in PFPS or vice versa. The question whether thickening of the lateral retinaculum and tight iliotibial band are cause or effect in PFPS asks for further prospective studies.

In the present study we found positive colour Doppler signals of the lateral retinaculum in 4 patients and in none of the control subjects. Two patients had positive colour Doppler signals in the unaffected knee, which again supports the assumption that PFPS is a bilateral disorder. Positive colour Doppler signals may be the result of neovascularisation in the lateral retinaculum, comparable to those seen in tendinosis (Peers and Lysens, 2005; Mitchell et al., 2009). Hypervascularisation is explained by an increased production of Vascular Endothelial Growth Factor (VEGF) (Sanchis-Alfonso et al., 2005). Hypoxia is supposed to be responsible for a release of Nerve Growth Factor (NGF) and VEGF in PFPS (Sanchis-Alfonso et al., 2005). Sanchis-Alfonso hypothesized that periodic short episodes of ischemia in the lateral retinaculum, due to a mechanism of vascular torsion or vascular bending, could play a role in the pathogenesis of PFPS by triggering neural proliferation of perivascular localized nociceptive axons (Sanchis-Alfonso, 2008). Pain during prolonged sitting with bent

Table 3b Thickness of the lateral retinaculum in millimetres at 0.5, 1.0 and 1.5 cm lateral from the edge of the patella in control subjects in left and right knee. SD: standard deviation; 95%CI: 95% confidence interval.

Control subjects	Left 0.5 cm	Right 0.5 cm	Left 1.0 cm	Right 1.0 cm	Left 1.5 cm	Right 1.5 cm
1	3.4	2.9	3.0	3.1	3.0	3.3
2	3.0	3.1	3.0	2.9	3.2	2.9
3	3.2	3.2	3.2	3.1	3.2	3.2
4	2.8	2.9	2.9	3.1	2.9	3.1
5	3.3	3.1	3.2	3.1	3.2	3.0
6	2.6	2.4	2.7	2.7	2.3	2.2
7	2.9	2.8	2.9	2.9	3.1	2.9
8	2.8	3.0	2.9	2.9	2.9	2.9
9	3.4	3.3	3.2	3.1	3.2	3.1
10	2.8	2.9	2.8	2.8	2.9	2.8
Mean	3.0	3.0	3.0	3.0	3.0	2.9
SD	0.3	0.2	0.2	0.1	0.3	0.3
95%CI	2.4–3.6	2.6–3.4	2.6–3.4	2.8–3.2	2.4–3.6	2.3–3.5

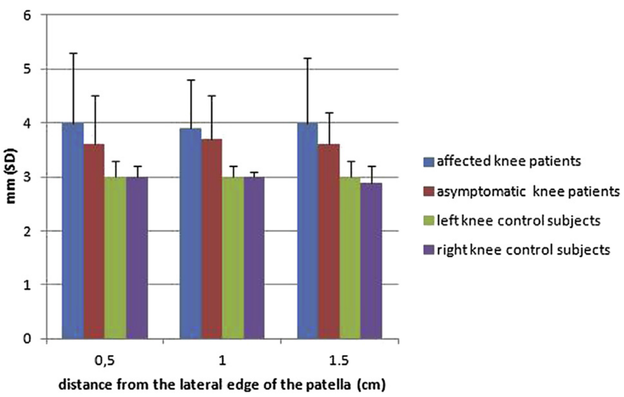

Figure 4 Thickness of the lateral retinaculum in patients and control subjects. SD: standard deviation.

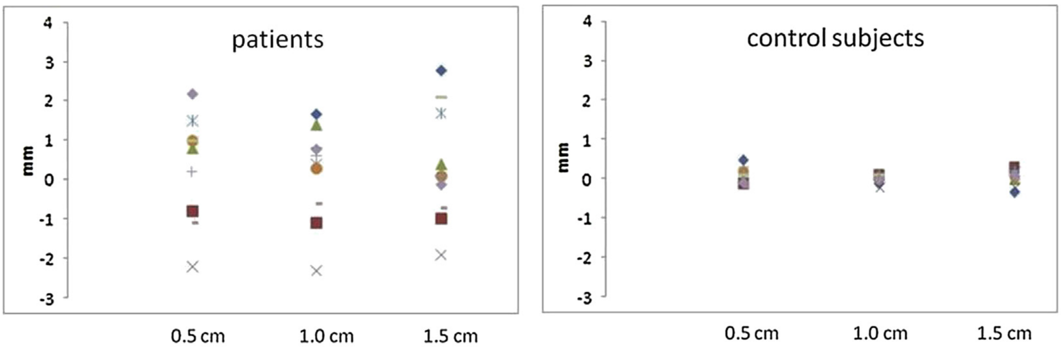

Figure 5 Differences in thickness of the lateral retinaculum between affected and asymptomatic knee for patients and between left and right knee in control subjects at 0.5, 1.0 and 1.5 cm lateral from the edge of the femur.

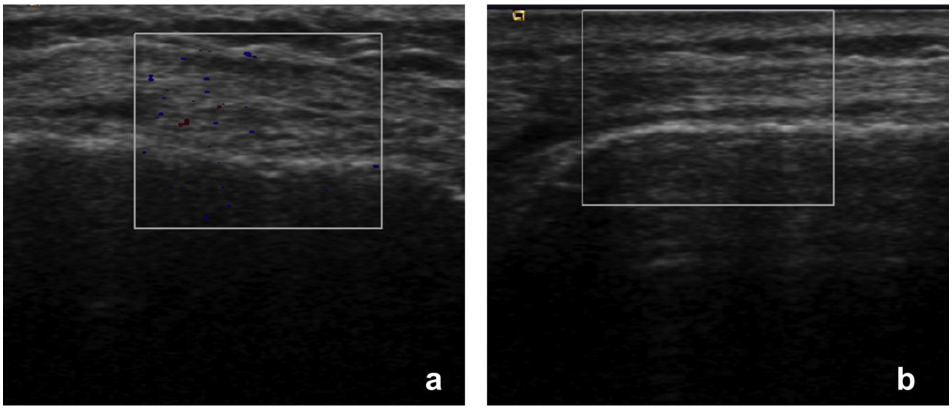

Figure 6 a. Colour Doppler signals of the lateral retinaculum of the affected knee of one of the patients with the knee in 10° flexion; note the inhomogenous aspect of the lateral retinaculum. b. Absence of colour Doppler signals of the lateral retinaculum of the unaffected knee of the same patient with the knee in 10° flexion.

knees in patients with PFPS can be explained by this model. In our study we found one patient who had positive colour Doppler signals with the knee in 10° flexion and absence of colour Doppler signals with 90° degrees flexion of the knee. This observation possibly fits with the theory that sitting with bent knees can cause a decrease in blood supply of the lateral retinaculum by vascular bending or torsion. Further research is necessary to unravel the meaning of positive colour Doppler signals of the lateral retinaculum in PFPS.

Figure 7 Stretching manoeuvre of the lateral retinaculum.

Knowledge of possible structural changes of the lateral retinaculum can be used in the therapy of PFPS. There is some literature on the topic of stretching of the iliotibial tract in PFPS, but studies on the effect of stretching of the lateral retinaculum in PFPS is lacking (Wang et al., 2006). It is our experience that a stretching manoeuvre of the lateral retinaculum often provokes recognizable pain in patients with PFPS. Repeated stretching of the lateral retinaculum can lead to reduction of symptoms during the therapy traject (Fig. 7). Further studies are necessary to elucidate the role of stretching of the lateral retinaculum in the therapy of PFPS. Given the remarkable similarity between histopathologic changes of the lateral retinaculum in PFPS and changes seen in tendinosis, future research may also shine new lights on the efficacy of therapeutic modalities used in tendinosis for patients with PFPS.

Conclusion

Based on the results of this observational study a slightly larger thickness of the lateral retinaculum appears to occur in patients with PFPS measured by ultrasound examination. Positive colour Doppler signals were seen in almost half of the patients but not in the control group. These abnormalities on ultrasound examination were not only seen in the symptomatic knees, but also in the unaffected knees of the patients. This finding fits with earlier studies suggesting that PFPS is a bilateral rather than a unilateral disorder. Structural changes of the lateral retinaculum in PFPS on ultrasound examination are in line with histopathologic changes of the lateral retinaculum as described earlier and resemble those found in tendinopathy. Further research is necessary to unravel the role of the lateral retinaculum in the pathogenesis of PFPS and to clarify the role of the lateral retinaculum as a possible target for therapy in patients with PFPS.

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