The Knee 21 (2014) 21–27

Contents lists available at ScienceDirect

The Knee

Does knee joint proprioception alter following medial patellofemoral ligament reconstruction?☆

T.O. Smith [a,*], C.J.V. Mann [b], S.T. Donell [b]

[a] Faculty of Medicine and Health Sciences, University of East Anglia, Norwich, UK
[b] Institute of Orthopaedics, Norfolk and Norwich University Hospital & Faculty of Medicine and Health Sciences, University of East Anglia, UK

ARTICLE INFO

Article history:
Received 23 May 2012
Received in revised form 19 September 2012
Accepted 22 September 2012

Keywords:
Patellar dislocation
Operation
Joint position sense
Observational
Rehabilitation

ABSTRACT

Background: This study firstly aimed to determine whether proprioception deficits, as measured by joint position sense (JPS), occur in people following recurrent patellar dislocations. Secondly, to determine whether JPS changes following medial patellofemoral ligament reconstruction (MPFL) reconstruction for patellar instability.

Methods: Thirty people following recurrent patellar dislocation were recruited. Pre-operative JPS was assessed using the passive angle reproduction test. Through this, an assessor moved a participant's limb to a target position. This was returned to neutral, before finally moving the limb again, whilst requiring the participant to indicate when they thought the target angle was reached. The actual angular error (AAE) was calculated as the difference between the perceived angle and target angle. Clinical outcomes included the Kujala Patellofemoral Disorder Score, the International Knee Documentation Committee (IKDC) form, pain, knee motion, extensor muscle strength and frequency of patellar dislocation. Outcomes were assessed pre-operative, 6 weeks, 3 and 12 months.

Results: Mean AAE was 2.2° (inner range) to 3.9° (mid-range); this was not clinically significant. There was no statistically significant difference between the baseline-and-6 week, 6 week-and-3 month or baseline-and-12 month AAE measures ($p = 0.38$ to 1.00). There was a statistically significant improvement in functional outcomes as measured by the Kujala score, IKDC form, reduced pain and increased extension strength from baseline to 12 months ($p < 0.01$).

Conclusions: Following recurrent patellar dislocation, patients exhibit minimal deficits in JPS. Whilst MPFL reconstruction significantly improved clinical and functional outcomes for this population, this operation did not significantly alter JPS during the first post-operative year.

1. Introduction

Patellar instability and dislocation are painful debilitating conditions which have a major impact on the ability of people to participate in occupational and recreational pursuits [1]. Patellar instability may occur from a weak or poorly recruited VMO, tight lateral soft tissues (such as the lateral retinaculum, vastus lateralis or the iliotibial band), patella alta, trochlear dysplasia, or torn medial soft tissues such as the medial patellofemoral ligament (MPFL) [2].

The MPFL is the major static soft-tissue stabiliser to lateral patellar dislocation [3]. This ligament is damaged or ruptured during the majority of lateral patellar dislocations [4,5]. Over recent years, advances have been made in the reconstruction and repair of the MPFL for people with recurrent patellar dislocation [6,7]. Various methods of performing this operation have been described, including allografts and autographs to reconstruct the ligament. These have included the adductor magnus tendon [7], quadriceps tendon [6,8], and gracilis and hamstring tendon [9], using different fixation methods such as suture anchors, buttons or inferential screw fixation [6–10]. The results of these operations are favourable with regard to reducing recurrent patellar dislocation and functional outcomes [9,11].

Proprioception encompasses several different components including joint position sense (JPS), velocity, movement detection and force [12]. It is derived from mechanoreceptors in the muscle, joint capsule, tendon, ligaments and skin [13]. Trauma to these receptors can damage this feedback system. This may make the limb more susceptible to injury with reduced motor control [14–16]. This principle has been previously reported in cohorts with anterior cruciate ligament injury [17] and meniscal injury [18]. Furthermore, Baker et al's [14] work indicated that pain originating from the patellofemoral joint may also be related to reduce proprioceptive capability. It is therefore

☆ Study conducted at the Norfolk and Norwich University Hospital and the University of East Anglia.

* Corresponding author at: Queen's Building, Faculty of Medicine and Health Science, University of East Anglia, Norwich Research Park, Norwich, NR4 7TJ, UK. Tel.: +44 1603 593087; fax: +44 1603 593166.
E-mail address: toby.smith@uea.ac.uk (T.O. Smith).

0968-0160/$ – see front matter © 2012 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.knee.2012.09.013

hypothesised that reconstruction of such injured structures to improve symptoms and clinical outcomes may restore proprioceptive feedback mechanisms to the entire knee [17].

Others have suggested that there may be a significant deterioration in proprioceptive capability following patellar dislocation [15,16]. However, only one study has previously assessed proprioceptive capability in a patellar instability cohort. Jerosch and Prykma [15] assessed JPS in 30 healthy controls and nine individuals following recurrent patellar dislocation. They reported a statistically significantly greater angle reproduction error (i.e. poorer proprioception) in those who had experienced recurrent patellar dislocations compared to healthy controls ($p<0.05$) [15]. However, these findings are based on the results of a small, underpowered sample of people following lateral patellar dislocation. Furthermore whilst no studies have assessed the effect of proprioception following patellar surgery, with other knee procedures such as ACL reconstruction, partial medial meniscectomy and medial meniscal repair, post-operative knee proprioception significantly improved compared to the pre-operative status [17–19].

The purposes of this study were therefore firstly to determine whether proprioceptive deficits, as measured by JPS, are evident in a sufficiently powerful cohort of people who have experienced recurrent patellar dislocations. Secondly, to determine whether JPS changed over time following a MPFL reconstruction for patellar instability. Finally, the clinical outcomes of this cohort were also examined to determine whether function, muscle strength or pain altered following MPFL reconstruction during the first post-operative year.

2. Materials and methods

An observational, non-experimental repeated measures study design was used.

2.1. IRB/ethical approval

Ethics approval was obtained from the local ethics committee before people were identified and approached.

2.2. Inclusion/exclusion criteria

Participants were eligible for inclusion if they were:

- Listed for an elective MPFL reconstruction due to recurrent patellar dislocation and current instability symptoms.
- Aged 16 years upwards, presented with clinically normal tibiofemoral joints (i.e. negative ligamentous, chondral or degenerative tibiofemoral injury).
- Provided informed written consent.

Participants were not eligible if:

- Presented with trochlear dysplasia characterised by a boss height of greater than 4 mm on lateral X-ray [20].
- It was predicted that they were unable to undertake the assessment.
- Allergic to the adhesive tape used in the assessment procedure.
- Evidence of symptomatic patellofemoral osteoarthritis.
- Any medical conditions known to affect proprioception e.g. diabetes mellitus, arteriosclerosis, cerebral vascular accident, Parkinson's, Alzheimer's, polyneuropathy, or alcohol or drug abuse.
- An unwillingness to participate.

2.3. Sample size

A power calculation was performed [21] based on a previously reported standard deviation of the knee angle deviation in actual-to-perceived measurements of individuals following recurrent patellar dislocation of 3.9, plus a minimally important clinical difference (MICD) between patellar instability and healthy controls of 4.6° [15]. With a power of 90% and at the 5% level of significance, this indicated that a sample of 18 people would be required, based on performing a parametric data analysis. However in the event that the data were not normally distributed and that participants were lost during the follow-up period, the sample size was increased by 40% to 30 participants.

2.4. Surgical/post-operative procedures

The surgical and post-operative rehabilitation procedures were standardised. All participants underwent a MPFL reconstruction using the same technique [22]. In this, a portion of the semitendinosus or gracilis tendon was harvested as a free graft. A single anteromedial bony tunnel was made using a 4.5 mm drill in the extreme medial border of the patella. The graft was passed through this, and then through the second layer of the medial retinaculum. The double-bundle was then whip-stitched together and passed into a femoral pit (7 mm wide and 30 mm deep) made just distal to the adductor tubercle. The graft was tensioned at 70 degrees flexion and secured with a bioabsorbable screw (Milagro, DePuy: 7 mm by 23 mm).

Post-operatively there were no restrictions on weight-bearing or knee range of motion. Participants were instructed, as soon as they could, to commence knee range of motion and strengthening exercises dependent on pain. Each was initially provided with crutches to permit mobility but encouraged to progress off these once pain had reduced. An out-patient physiotherapy appointment was arranged on discharge to physiotherapy within a week after the operation. During these sessions participants progressed their knee range of motion and strength using a graded exercise programme.

2.5. Measurements

The primary outcome measure was proprioception assessed using a passive angle reproduction test described by Jerosch and Prymka [15] and Barrett et al. [23]. Whilst the validity and reliability of this method have yet to be assessed in this population, this method was chosen as it has been successfully undertaken in previous studies assessing proprioception following anterior cruciate ligament, medial meniscal surgery and patellar dislocations, thereby allowing comparison of study findings [15,24].

All data collection measurements were performed by a single researcher using the operated knee to prevent inter-rater variability. An electronic goniometer (Biometrics, Model SG150, Biometrics, Gwent, UK) was used to determine knee joint angle. Tests were performed with the participant positioned supine. Four pre-determined 'target' angles were chosen for each knee at random. For the left knee these were 10°, 30°, 60° and 80°, and 15°, 30°, 50° and 75° for the right knee. The order of the pre-defined angles assessed was randomised using a concealed allocation method of sealed envelopes to prevent an order effect from occurring [21]. For interpretation, angles 10° and 15° were categorised inner range, 50° and 60° mid-range and angles 75° and 80° were termed outer range [25].

All tests were commenced from 0° knee flexion. A passive angle reproduction test method was used to assess joint position sense. Thus, the participant's knee was passively positioned in one of the pre-determined target angles as measured using the electronic goniometer. This was held for 5 s. The knee was returned to 0° flexion and then participants were asked to close their eyes to prevent them from being able to see the position of their knees. After a one second delay, the researcher passively flexed the knee slowly, and the participant was asked to indicate when they thought that the target angle had been reached. Fig. 1 demonstrates the hand-placement and assessors position for this test. The angle of knee flexion when the participants

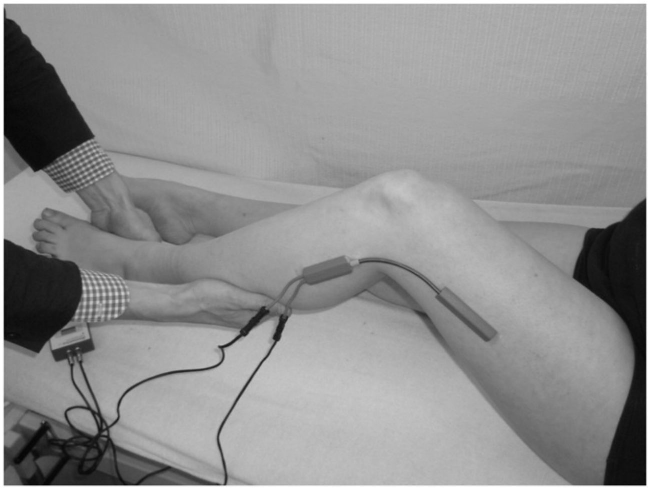

Fig. 1. Assessor's position and handling for the passive angle reproduction test.

reported that the target angle had been reached was recorded. The inaccuracy of JPS was recorded as the difference between the perceived angle and target angle of flexion to determine the Actual Angular Error (AAE). After each measurement the knee is returned to 0° flexion for a 10 second period. This was repeated for each of the pre-determined target angles for the operated knee. None of the participants reported patellar instability symptoms during pre-operative JPS testing.

Secondary outcomes included the Kujala Patellofemoral Disorder Score [26] and the International Knee Documentation Committee subjective knee evaluation form (IKDC) [27] to assess participant's perceptions of their patellar function. Both have been shown to be reliable and valid in this population [28]. Other secondary measures included: pain as measured by a 10 cm visual analogue scale (VAS); knee joint range of movement measured using a standard goniometer; sporting participation reported by the participant; frequency of recurrent patellar dislocation; and knee extensor muscle strength of the operated knee at 0°, 40°, and 80° knee flexion assessed using a hand-held dynamometer (Basic Force Gauge, Mecmesin, Slinfold, West Sussex, UK). All muscle strength assessments were made with the participant's arms positioned across their body, seated on the edge of an elevated plinth, and feet raised above the ground. Each was given verbal encouragement to push as hard as possible through the dynamometer during a five second test. The dynamometer was held by the assessor who applied counter resistance during the testing procedure. One test was taken for each knee flexion position. The maximum force generated was recorded for each knee angle.

2.6. Follow-up period

On the participant's in-patient admission prior to surgery, baseline pre-operative characteristics were collected. These data included: gender, age, Beighton hypermobility score [29], duration of knee instability, other joint disability of the operated leg, contralateral knee instability, disability of the contralateral leg; multi-joint dysfunction, knee extensor muscle strength at 0°, 40°, and 80° knee flexion as assessed using a hand-held dynamometer, VAS pain, and knee range of movement were collected. In addition, the angle joint reproduction test, the Kujala and IKDC scores were also assessed.

Participants were then reviewed at 6 weeks, 3 months and 12 month follow-up appointments where they completed a Kujala, IKDC score forms, and a pain VAS, and the angle reproduction test was performed. The participant's operated knee range of movement was assessed manually using a goniometer, and knee extensor muscle strength at 0°, 40°, and 80° flexion was assessed using the hand-held dynamometer. Each participant was also asked whether they had experienced a recurrent patellar dislocation at each follow-up appointment. The follow-up time periods were selected to allow for changes during participant's rehabilitation to be detected, whilst not assessing them too frequently to avoid the development of a learnt effect for the JPS measurement technique [15].

2.7. Data analysis

The normality of each outcome from the dataset was determined using the Shapiro–Wilks statistic. This was reported as $p<0.05$, supporting the use of parametric analyses.

The objective of this study was to determine whether knee JPS altered following MPFL reconstruction. Accordingly, the AAE for each angle measured from baseline, to 6 weeks, 3 months and 12 month intervals was determined through the mean difference and standard deviation (SD) values for each time-point. The within-group statistical difference for these time-periods was determined using a paired student *T*-test with 95% confidence intervals (CI).

An assessment of the clinical outcomes following MPFL reconstruction was also determined descriptively by assessing the mean and standard deviation values for the Kujala, IKDC score forms, pain VAS, operated knee range of movement and isometric knee extensor muscle strength at 0°, 40°, and 80° knee flexion. The within-group differences in these outcomes over the follow-up period were assessed using a paired student *T*-test with 95% CIs.

Throughout the analyses, $p<0.05$ was considered a statistically significant difference. All analyses were undertaken using STATA version 11.0 (STATA, StataCorp LP, Texas, USA).

3. Results

A total of 30 people were recruited and entered into the study from May 2008 to January 2011. All underwent an uneventful MPFL reconstruction and commenced post-operative rehabilitation. During the follow-up period, three participants were lost to follow-up at the 6 week assessment, 9 at 3 months, and 9 at 12 months. The study flow is presented as Fig. 2.

3.1. Demographics

A summary of the baseline characteristics for the 30 participants is presented in Table 1. This indicates that the mean age of the 16 males and 14 females was 23 years (SD = 6.4). Mean duration from first-time patellar dislocation to surgery was 95 months (SD = 82). The mean Beighton score was 3, indicating a low incidence of joint hypermobility within the cohort. Nine participants (30%) demonstrated a Beighton score ≥ 6 indicating clinically meaningful signs of joint hypermobility [36]. Eleven participants (37%) reported current contralateral patellofemoral instability symptoms at the time of surgery. The pre-operative IKDC and Kujala scores indicated that the cohort were functionally limited at the time of their operation, whilst reporting mild pain symptoms with a mean VAS score of 32 out of 100. Pre-operatively 14 participants (47%) reported being non-sporting, seven (23%) sometimes participated in recreational sports, seven (23%) considered that they were well-trained and frequently participated in sports, whilst two participants (7%) considered themselves as highly competitive sports-people.

3.2. Joint position sense measurements

Baseline JPS measurements indicated that the cohort presented with some angle reproduction error compared to the target angle with a mean AAE value of 2.2° (inner range) to 3.9° (mid-range; Table 2), which was not a clinically significant difference.

There was no statistically significant difference between the baseline-and-6 week, 6 week-and-3 month or baseline-and-12 month AAE values ($p = 0.38$ to 1.00; Table 3). The only statistically significant change in JPS occurred from 3 months-to-12 months for the mid-range assessment ($p = 0.02$; 95% CI: −4.20 to −0.47). However as Table 3 demonstrates, this difference was only by 1.9° thereby not clinically significant. As Table 3 demonstrates, there was no clinically important change in JPS between the follow-up appointments with the exception of outer-range JPS from 3-to-12 months and the 30° and outer-range measurements between the baseline-to-12 month measurement where the mean difference ranged from 5.0 (SD = 5.3) to 7.4 (SD = 15.4; Table 3).

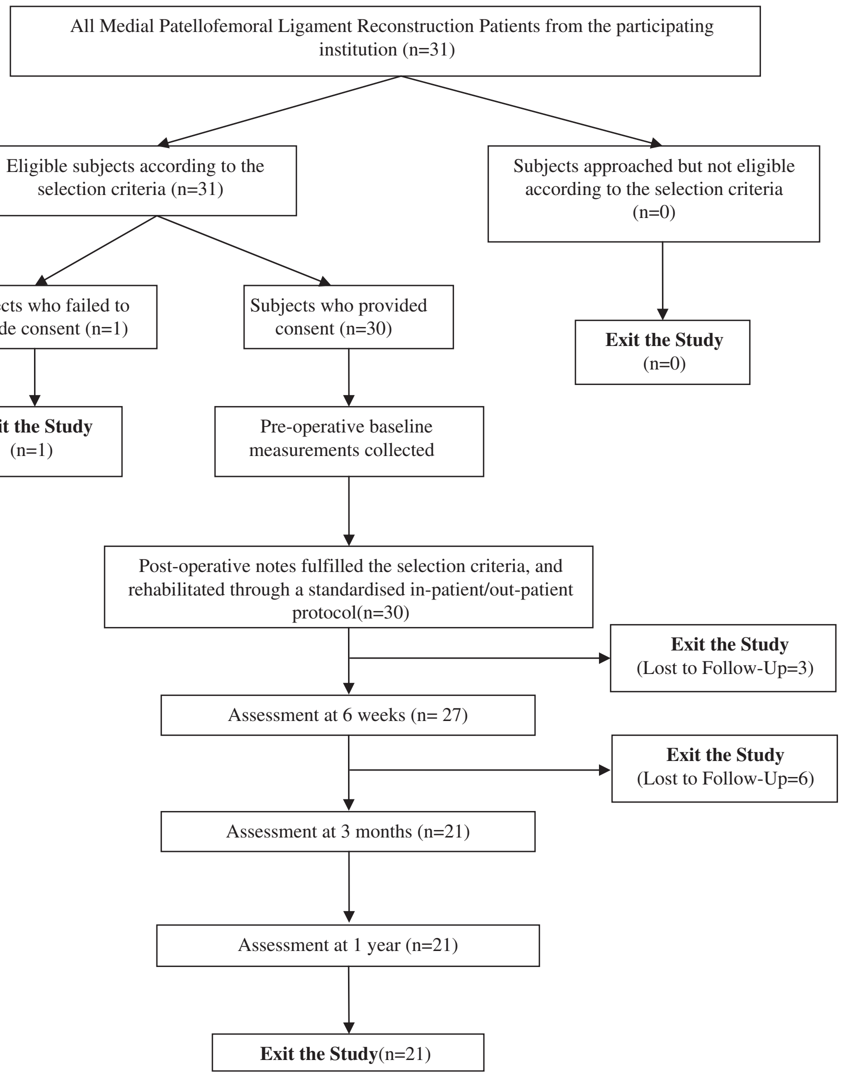

Fig. 2. Study flow-chart.

3.3. Clinical outcomes

Tables 4 and 5 show that there was a significant improvement in clinical and functional outcomes 3 months after surgery compared to earlier. Whilst there was a statistically significantly greater extension lag at 6 weeks compared to baseline ($p = 0.02$; 95% CI: 0.33, 3.84) this was clinically not significant, with a difference of 1.7°. There was however a statistically significant difference in isometric knee extension strength at 80° knee flexion with a difference of 20 N ($p = 0.01$; 95% CI: −38.73, −10.97). For all other outcomes, there was no statistically significant difference during the initial 6 weeks. There was however a statistically significant improvement in functional outcomes between 6 weeks and 3 months as assessed by Kujala score ($p = 0.01$; 95% CI: −15.17, −2.83). Whilst there was also a statistically significant increase in isometric knee extension strength at 0° ($p = 0.01$; 95% CI: −23.20, −9.71).

The most significant changes occurred from 3-to-12 months with a statistically significant improvement in functional outcomes in Kujala score, IKDC score and reduced pain measurements ($p < 0.01$; Table 5), and a statistically significant increase in isometric muscle strength for all measurements. Similarly, when compared to pre-operative levels, the cohort reported a statistically significant difference with greater functional and clinical outcomes at 12 months ($p < 0.01$; Table 5). Only knee range of motion remains a non-statistically significant change between 3-to-12 months and baseline-to-12 months. However, as Table 4 indicated, the mean values for this were originally −0.3° to 141°.

In relation to sporting participation, participants either remained at a similar perceived level of sporting engagement, or had an increased perception at 1 year post-operation. Of those who classified themselves as 'non-sporting', 10 (71%) remained the same when asked at 1 year post-operation. One person reported at 12 months that they sometimes participated in sport, whilst two post-operatively considered that they were well-trained and frequently participated in sports compared to

Table 1
Baseline cohort demographics.

Characteristic	
N	30
Mean age in years (SD)	23.1 (6.4)
Gender (male/female)	16/14
Operated limb (left/right)	16/14
Mean Beighton score (SD)	2.9 (3.5)
Duration since first-time patellar dislocation in months (SD)	94.7 (81.9)
Contralateral PFI (%)	11.0 (36.7)
Ipsilateral limb MSK pathology (%)	1.0 (3.3)

MSK — musculoskeletal; PFI — patellofemoral instability; SD — standard deviation.

Table 2
Mean angle reproduction error (°) at inner, mid, outer-range and 30° knee flexion following MPFL reconstruction.

	Actual angular error (°)			
	Inner-range	30°	Mid-range	Outer-range
Baseline	2.2 (2.1)	3.4 (3.0)	3.9 (3.6)	3.6 (3.5)
6 weeks	2.2 (1.9)	2.7 (2.8)	3.0 (2.8)	3.4 (3.1)
3 months	2.0 (1.8)	2.8 (2.8)	2.7 (3.3)	3.4 (3.4)
12 months	2.0 (2.5)	4.1 (6.2)	3.1 (3.2)	6.7 (6.7)

Table 3
Mean and statistical difference in angle reproduction error (°) at inner, mid, outer-range and 30° knee flexion following MPFL reconstruction during initial first post-operative year.

Follow-up period	Actual angular error							
	Inner-range		30°		Mid-range		Outer-range	
	Mean	p-Value (95% CI)	Mean	p-Value (95% CI)	Mean	p-Value (95% CI)	Mean	p-Value (95% CI)
Baseline to 6 weeks	2.0	0.57 (−1.54,0.87)	3.3	0.48 (−1.11,2.27)	2.5	0.74 (−1.47,2.05)	2.5	0.50 (−0.92,1.83)
6 weeks to 3 months	1.5	1.00 (−0.96,0.96)	2.2	0.74 (−1.61,1.17)	2.9	0.41 (−1.15,2.70)	3.3	0.64 (−1.13,1.80)
3 months to 12 months	1.6	0.84 (−1.25,1.52)	2.6	0.29 (−4.88,1.55)	1.9	0.02 (−4.20,−0.47)	6.6	0.14 (−16.64,2.64)
Baseline to 12 months	2.6	0.80 (−1.49,1.92)	5.0	0.60 (−4.42,2.62)	4.0	0.78 (−2.67,3.52)	7.4	0.38 (−11.57,4.62)

CI — confidence intervals.

Table 4
Table presenting clinical outcomes (mean/standard deviation).

Outcomes	Baseline	6 weeks	3 months	12 months
IKDC	52.7 (19.5)	50.1 (19.7)	56.6 (21.2)	77.7 (24.1)
VAS pain	32.2 (25.8)	27.2 (25.0)	25.3 (22.7)	16.3 (23.6)
Kujala score	65.3 (17.6)	65.4 (16.9)	71.0 (18.7)	84.1 (20.6)
Knee extension ROM	−0.3 (1.8)	−2.5 (5.3)	0.0 (0.0)	0 (0.0)
Knee flexion ROM	140.7 (13.3)	139.8 (15.6)	141.0 (11.9)	140.4 (14.8)
Isometric 0° knee extension strength (N)	32.1 (14.6)	30.1 (14.4)	44.2 (20.6)	57.9 (24.6)
Isometric 40° knee extension strength (N)	44.5 (28.6)	50.3 (28.7)	63.2 (41.4)	85.2 (38.8)
Isometric 80° knee extension strength (N)	60.1 (47.0)	69.1 (33.3)	88.3 (48.7)	101.0 (49.4)
Recurrent dislocation (%)	–	1 (3.3)	0 (0.0)	0 (0.0)

IKDC — International Knee Documentation Committee form; N — Newtons; ROM — range of motion; VAS — visual analogue scale.

being non-sporting pre-operatively. Of those who pre-operatively considered that they 'sometimes participated in sports', this remained the same for six participants (86%) but perceived sporting engagement decreased for one participant (14%) who, at 1 year post-operatively, perceived herself as 'non-sporting'. Similarly, one participant who considered that she was 'well-trained and frequently participated in sports' reduced her perception of her sporting engagement to only 'sometimes sporting'. However, both these participants were still attending physiotherapy at the 1 year follow-up assessment. In the 'well trained frequently sporting' group, three participants (43%) remained at the same sporting engagement, and two participants reported that they had greater sporting engagement, considering themselves as highly competitive sports people (29%). In those who pre-operatively considered themselves as highly competitive sports people, both these participants reported the same perceived level of participation at 1 year post-operatively. Sports which participants specifically reported returning to at 1 year post-MPFL reconstruction included soccer (n = 5), rugby (n = 2), cricket (n = 2), netball (n = 1) and cycling (n = 1).

One participant experienced a recurrent patellar dislocation post-operatively. This 18 year-old participant's Beighton score was 9. She experienced this recurrent dislocation 4 weeks post-operatively.

4. Discussion

The findings of this study indicate that following recurrent patellar dislocation there is minimal deficit in JPS, and that this is maintained during the first year following MPFL reconstruction. There is also a significant improvement in functional outcomes, pain and isometric knee extension strength at 12 months following MPFL reconstruction. These findings are contrary to the Jerosch and Prymka's [16] study which is the only previous trial which has assessed JPS in this population. They assessed 30 healthy participants compared to nine people with recurrent patellar dislocation, finding an angle deviation of 12.4° as opposed to the highest value of 6.7° in our cohort pre-operatively (Table 2). Whilst both cohorts recruited people who had experienced recurrent patellar dislocation, Jerosch and Prymka's [16] cohort were described as being "post-traumatic". However the duration between last dislocation and assessment was not clearly described, along with whether participants presented with joint swelling or damage to other structures. None of the participants in the current study presented with an 'acute' dislocation event and associated soft-tissue swelling or acute inflammatory response. Proprioception may have been reduced due to surrounding soft tissue injury to the infra-patellar synovial bursa, medial retinaculum, vastus medialis and joint capsule [30]. Furthermore, our cohort reported only mild pain at baseline (Table 1). However, if Jerosch and Prymka's [16] cohort had recently experienced a patellar dislocation, then they may have presented with higher pain scores. Pain can cause the abnormal discharge of small-diameter groups III and IV (pain) and large-diameter group II (proprioceptive) afferent nerve signals which can attribute abnormal JPS and abnormal muscle spindle activity [31]. This may have accounted for the difference between the studies.

A potential weakness in this study may be measurement error. The passive joint reproduction method adopted has not been assessed for its reliability or validity with this population. This method of assessing JPS possesses good intra-rater reliability (Spearman's Correlation Coefficient $r = 0.80$) in cohorts of healthy participants [32]. Previous studies assessing angle reproduction in healthy controls have suggested that asymptomatic populations typically report mean deviations of 0.8 to 3.9 from the target angle [12,33]. Therefore the majority of the differences presented in our cohort of 2.0 to 3.9 (Table 2) are not different from healthy participants, but demonstrate the natural variability in measurement error for this technique. Therefore, measurement error as opposed to clinical difference may account for the small errors in angle reproduction from the target angle for each of the JPS measurements during the initial 12 post-operative months (Table 3). However, whilst other methods of measuring proprioception such as active reproduction methods,

Table 5
Within-group difference in clinical outcome during initial first post-operative year.

Outcomes	Within-group differences (p-value; 95% CI)			
	Baseline–6 weeks	6 weeks–3 months	3 months–12 months	Baseline–12 months
IKDC	0.66 (−5.70,8.87)	0.10 (−20.54,1.95)	<0.01 (−30.67,−13.88)	<0.01 (−34.91,−21.81)
VAS pain	0.22 (−4.02,16.39)	0.63 (−8.68,14.05)	0.01 (2.66,17.71)	<0.01 (12.15,24.62)
Kujala score	0.68 (5.87,3.87)	0.01 (−15.17,−2.83)	0.04 (0.47,15.36)	<0.01 (−27.99,−15.01)
Knee extension ROM	0.02 (0.33,3.84)	0.08 (−3.38,0.23)	1.00 (1.00,1.00)	1.00 (1.00,1.00)
Knee flexion ROM	0.85 (−9.51,7.93)	0.78 (−5.56,7.24)	0.52 (−1.54,6.07)	0.25 (−9.56,2.71)
Isometric 0° knee extension strength (N)	0.62 (−7.86,4.78)	0.01 (−23.20,−9.71)	<0.01 (−77.58,−21.36)	<0.01 (−38.20,−17.13)
Isometric 40° knee extension strength (N)	0.06 (−24.98,0.79)	0.12 (−27.05,3.50)	0.04 (−48.24,−1.65)	<0.01 (−69.19,−33.27)
Isometric 80° knee extension strength (N)	<0.01 (−38.73,10.97)	0.12 (−33.43,4.22)	0.02 (6.01,46.86)	<0.01 (−84.22,−35.86)

CI — confidence intervals; IKDC — International Knee Documentation Committee form; N — Newtons; ROM — range of motion; VAS — visual analogue scale.

stabiliometry and threshold detection measurements may have shown a difference, these methods have yet to demonstrate greater reliability than the chosen method in this study [18]. Further investigation on the validity and reliability of stabiliometry and other methods to assess joint awareness, balance and JPS should be undertaken.

The methods to assess JPS of the knee are knee-specific and not patellofemoral joint-specific. Therefore one reason for the non-significant findings in this study's results may be that the measurement of JPS of knee flexion does not actually measuring proprioception for patellofemoral joint. Further study to explore the properties of different knee proprioceptive measurements, and specifically the assessment of patellofemoral joint JPS is therefore warranted. Until then, the findings of investigations on patellofemoral joint JPS should be interpreted with caution.

The passive reproduction test method of assessing JPS was performed in non-weight bearing. This was justified to permit the comparison of this study's findings to the previous literature which has also used this method. However, previous work has indicated that the patellar instability is most commonly perceived in weight-bearing positions [1]. It therefore remains unknown whether the JPS findings would be similar if the tests were performed in weight bearing.

Whilst all participants in this cohort received post-operative physiotherapy, none were provided with proprioceptive-specific exercise training. Proprioceptive exercises are not routinely prescribed in the rehabilitation of patients following MPFL reconstruction [34], but are following first-time patellar dislocation [35]. However, more recently the use of proximal lower limb neuromuscular control exercises has been advocated following MPFL reconstruction [36,37]. These are based on the assumption that both populations present with proprioceptive deficits. The findings of this study suggest that this assumption may be incorrect and that there may be little proprioceptive deficit in knees pre-operatively as well as post-MPFL reconstruction. Whether these findings are typical of those following recent, or more acute patellar dislocation, remains unclear.

A significant deficit of proprioceptive capability in cohorts has been reported in people with anterior knee pain [14,38]. However, these studies have reported reproduction angle measurements of less than 3.0°. Furthermore, a recent study by Naseri and Pourkazemi [39] reported no statistically significant difference in JPS between athletes with anterior knee pain and those without this disorder. Accordingly, there remains inconclusive evidence to determine whether pain arising from the patellofemoral joint impacts on knee JPS.

Finally, none of the participants in this study presented with significant trochlear dysplasia. This morphological feature has a significant impact on normal patellar tracking [40]. Trochlear dysplasia can influence both medial and lateral soft-tissue length and tension by predisposing lateral tracking [40]. Therefore the surrounding soft-tissues may exhibit abnormal JPS through abnormal muscle spindle activity. Individuals with significant trochlear dysplasia may present with recurrent patellar dislocation from childhood, as a developmental feature [41]. Therefore it remains unclear whether JPS differs between those with or without morphological features (such as significant trochlear dysplasia) who experience patellar dislocation.

5. Conclusions

Following recurrent patellar dislocation patients exhibit minimal deficits in joint position sense as measured by actual angular error. Medial patellofemoral ligament reconstruction significantly improved clinical and functional outcomes for these patients without altering the Joint Position Sense in the first post-operative year.

6. Conflict of interests

None declared.

Funding

This study was partly funded by Action Arthritis.

Ethical approval

Ethical approval was obtained by the Norfolk Research Ethics Committee (Ref: 07/H0310/145) and the East Norfolk and Waveney Research Governance Committee (Ref: 2007PHYS03S).

Acknowledgements

None.

References

[1] Smith TO, Donell ST, Chester R, Clark A, Stephenson R. What activities do patients with patellar instability perceive makes their patella unstable? Knee 2011;18:333-9.
[2] Fithian DC, Paxton EW, Cohen AB. Indications in the treatment of patellar instability. J Knee Surg 2004;17:47-56.
[3] Smirk C, Morris H. The anatomy and reconstruction of the medial patellofemoral ligament. Knee 2003;10:221-7.
[4] Balcarek P, Walde TA, Frosch S, Schüttrumpf JP, Wachowski MM, Stürmer KM, et al. Patellar dislocations in children, adolescents and adults: a comparative MRI study of medial patellofemoral ligament injury patterns and trochlear groove anatomy. Eur J Radiol 2011;79:415-20.
[5] Balcarek P, Ammon J, Frosch S, Walde TA, Schüttrumpf JP, Ferlemann KG, et al. Magnetic resonance imaging characteristics of the medial patellofemoral ligament lesion in acute lateral patellar dislocations considering trochlear dysplasia, patella alta, and tibial tuberosity-trochlear groove distance. Arthroscopy 2010;26:926-35.
[6] Burks RT, Luker MG. Medial patellofemoral ligament reconstruction. Tech Orthop 1997;12:185-91.
[7] Steiner TM, Torga-Spak R, Teitge RA. Medial patellofemoral ligament reconstruction in patients with lateral patellar instability and trochlear dysplasia. Am J Sports Med 2006;34:1254-61.
[8] Steensen RN, Dopirak RM, Maurus PB. A simple technique for reconstruction of the medial patellofemoral ligament using a quadriceps tendon graft. Arthroscopy 2005;21:365-70.
[9] Nomura E, Inoue M. Hybrid medial patellofemoral ligament reconstruction using the semitendinosus tendon for recurrent patellar dislocation: minimum 3 years' follow-up. Arthroscopy 2006;22:787-93.
[10] Siebold R, Chikale S, Sartory N, Hariri N, Feil S, Pässler HH. Hamstring graft fixation in MPFL reconstruction at the patella using a transosseous suture technique. Knee Surg Sports Traumatol Arthrosc 2010;18:1542-4.
[11] Schöttle PB, Fucentese SF, Pfirrmann C, Bereiter H, Romero J. Trochleaplasty for patellar instability due to trochlear dysplasia. Acta Orthop 2005;76:693-8.
[12] Stillman BC, Tully EA, McMeeken JM. Knee joint mobility and position sense in healthy young adults. Physiotherapy 2002;88:553-60.
[13] Olsson L, Lund H, Henriksen M, Rogind H, Bliddal H, Danneskiold-Samsoe B. Test-retest reliability of a knee joint position sense measurement method in sitting and prone position. Adv Physiother 2004;6:37-47.
[14] Baker V, Bennell K, Stillman B, Cowan S, Crossley K. Abnormal knee joint position sense in individuals with patellofemoral pain syndrome. J Orthop Res 2002;20:208-14.
[15] Jerosch J, Prymka M. Knee joint proprioception in patients with posttraumatic recurrent patella dislocation. Knee Surg Sports Traumatol Arthrosc 1996;4:14-8.
[16] Jerosch J, Prymka M. Proprioception and joint stability. Knee Surg Sports Traumatol Arthrosc 1996;4:171-9.
[17] Dhillon MS, Bali K, Prabhakar S. Proprioception in anterior cruciate ligament deficient knees and its relevance in anterior cruciate ligament reconstruction. Indian J Orthop 2011;45:294-300.
[18] Al-Dadah O, Shepstone L, Donell ST. Proprioception following partial meniscectomy in stable knees. Knee Surg Sports Traumatol Arthrosc 2011;19:207-13.
[19] Barrett DS. Proprioception and function after anterior cruciate ligament reconstruction. J Bone Joint Surg Br 1991;73:833-7.
[20] Donell S. Patellofemoral dysfunction—extensor mechanisms malalignment. Curr Orthop 2006;20:103-11.
[21] Altman DG. Practical Statistics for Medical Research. London: Chapman and Hall/CRC; 1999.
[22] Harle D, Smith TO, Loveday DT, Donell ST. Medial reefing versus medial patellofemoral ligament reconstruction for patellar instability. Eur J Orthop Surg Traumatol 2010;20:547-51.
[23] Barrett DS, Cobb AG, Bentlet G. Joint proprioception in normal, osteoarthritic and replaced knees. J Bone Joint Surg Br 1991;73:53-6.

[24] Friemert B, Bach C, Schwarz W, Gerngross H, Schmidt R. Benefits of active motion for joint position sense. Knee Surg Sports Traumatol Arthrosc 2006;14:564-70.
[25] Hollis M, Fletcher-Cook P. Practical exercise therapy. 4th edition. Oxford: Blackwell Sciences; 1999.
[26] Kujala UM, Jaakkola LH, Koskinen SK, Taimela S, Hurme M, Nelimarkka O. Scoring of patellofemoral disorders. Arthroscopy 1993;9:159-63.
[27] Hefti F, Muller W, Jakob RP, Staubli HU. Evaluation of knee ligament injuries with the IKDC form. Knee Surg Sports Traumatol Arthrosc 1993;1:226-34.
[28] Paxton EW, Fithian DC, Stone ML, Silva P. The reliability and validity of knee-specific and general health instruments in assessing acute patellar dislocation outcomes. Am J Sports Med 2003;31:487-92.
[29] Beighton PH, Horan F. Orthopedic aspects of the Ehlers–Danlos syndrome. J Bone Joint Surg 1969;51-B:444-53.
[30] Wilson AS, Lee HB. Hypothesis relevant to defective position sense in a damaged knee. J Neurol Neurosurg Psychiatry 1986;49:1462-3.
[31] Capra NF, Ro JY. Experimental muscle pain produces central modulation of proprioceptive signals arising from jaw muscle spindles. Pain 2000;86:151-62.
[32] Fischer-Rasmussen T, Jensen TO, Kjaer M, Krogsgaard M, Dyhre-Poulsen P, Magnusson SP. Is proprioception altered during loaded knee extension shortly after ACL rupture? Int J Sports Med 2001;22:385-91.
[33] Stillman BC, McMeeken JM. The role of weightbearing in the clinical assessment of knee joint position sense. Aust J Physiother 2001;47:247-53.
[34] Smith TO, Donell ST. The rehabilitation following medial patellofemoral ligament reconstructions. A case report. Internet J Orthop Surg 2008;8:1.
[35] Smith TO, Chester R, Clark A, Donell ST, Stephenson RC. A national survey of the physiotherapy management of patients following first-time patellar dislocation. Physiotherapy 2011;97:327-38.
[36] Fisher B, Nyland J, Brand E, Curtin B. Medial patellofemoral ligament reconstruction for recurrent patellar dislocation: a systematic review including rehabilitation and return-to-sports efficacy. Arthroscopy 2010;26:1384-94.
[37] Fithian DC, Powers CM, Khan N. Rehabilitation of the knee after medial patellofemoral ligament reconstruction. Clin Sports Med 2010;29:283-90.
[38] Akseki D, Akkaya G, Erduran M, Pinar H. Proprioception of the knee joint in patellofemoral pain syndrome. Acta Orthop Traumatol Turc 2008;42:316-21.
[39] Naseri N, Pourkazemi F. Difference in knee joint position sense in athletes with and without patellofemoral pain syndrome. Knee Surg Sports Traumatol Arthrosc 2012;20:2067-72.
[40] Bollier M, Fulkerson JP. The role of trochlear dysplasia in patellofemoral instability. J Am Acad Orthop Surg 2011;19:8–16.
[41] Lippacher S, Reichel H, Nelitz M. Radiological criteria for trochlear dysplasia in children and adolescents. J Pediatr Orthop B 2011;20:341-4.