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Original Article

Ultrasound investigation into the relationship between hip adduction and the patellofemoral joint

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Abstract. [Purpose] Patellofemoral pain (PFP) is a common musculoskeletal complaint. It has been suggested that hip adduction creates a load on the iliotibial band and causes lateral displacement of the patella (patella tilt). However, data gathered in a previous study were derived from a small sample of males, while the condition predominantly affects females. We assessed the relationship between hip adduction and patellar position with a larger sample size, including males and females. [Participants and Methods] Forty healthy, asymptomatic females and males (age 21.5 ± 1.3 years) were recruited. Their knees were passively flexed by 20°. Using ultrasound, the distance between the lateral edge of the patella and the lateral condyle of the femur was measured in the neutral position and at 20° adduction. [Results] Hip adduction produced a smaller patella-lateral femoral condyle measurement than in the neutral position. The mean difference in the patella-condyle distance between the neutral position and 20° hip adduction was 0.18 cm. No statistically significant difference was found between the right and left limbs, genders, Tegner scores, or BMI of the study participants. [Conclusion] The results of the study showed that hip adduction causes lateral displacement of the patella. Ultrasound is an effective means of assessing patella tilt.
Key words: Patellofemoral joint, Patellar tilt, Ultrasound

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INTRODUCTION

Patellofemoral pain (PFP) is one of the most common musculoskeletal complaints seen clinically, with an estimated annual prevalence in the general population of 22.7%, (females 29.2%, males 15.5%) in the UK[1)]. The aetiology of PFP is multifactorial, and patellar malalignment, where the patella is in an abnormal position in the flexion-extension cycle, is thought to be one of the major causes[2, 3)]. This puts uneven stress on the patella, increases pressure on the patellar articular surface, and can cause pain[4)]. Other contributing factors include decreased strength and flexibility of the quadriceps, hamstrings, iliotibial band (ITB) and tensor fasciae latae, and congenital abnormalities[5)].

The patella achieves its greatest stability beyond 45° knee flexion, where it is fully engaged in the trochlear groove[6)]. The joint capsule, patellofemoral ligament, ITB and lateral patellar retinaculum help to maintain the static stability of the patellofemoral joint (PFJ)[7)]. Surrounding muscles, including the vastus medialis oblique (VMO), vastus medialis longus, vastus lateralis, rectus femoris, vastus intermedius and biceps femoris, contribute to the dynamic stability of the joint[7, 8)]. The patella usually remains in the centre when it glides along the trochlear groove, however, when these stabilizing structures are weakened or damaged, it may lead to patellar displacement, which, in turn, may result in PFP[9)].

Clinicians have assessed the ITB using Ober's test, with the hypothesis that tightness in the ITB with its contractile origins

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can lead to increased patella tilt[10]. However, the exact relationship between hip adduction and patellar position has not been established. Excessive hip adduction can lead to knee valgus, which increases the Q-angle and predisposes to patellar displacement[11]. It has been suggested that increased Q-angle increases contact pressure on the lateral PFJ. Herrington et al.[12] studied 12 asymptomatic males and found that 20° hip adduction created loads on the ITB, which led to significant lateral patellar displacement.

Different radiological techniques have been used to evaluate patellar position. Ultrasonography has been shown to be a reliable method to measure patellar position in *in vivo* investigations[13–15]. Shih et al.[16] followed patellar position during knee movement with ultrasound (US) and magnetic resonance imaging (MRI) scans, and concluded that US measurement has good intra-observer and inter-observer reproducibility; the results also closely matched those obtained from MRI, and had high accuracy. It is also an inexpensive and non-invasive method that is widely used to investigate the knee joint.

This study aimed to add to Herrington et al.'s[12] data by recruiting a larger sample population, including both males and females, to establish the relationship between hip adduction and patellar position. Data on activity level, using the Tegner activity score[17], and BMI were also collected to allow comparison between these variables. The patella-femoral condyle distance was found by measuring the distance between the lateral edge of patella and the lateral condyle of the femur, in two positions: neutral, and 20° hip adduction. This study could provide a greater insight into the role of the ITB in the biomechanics of the PFJ, and aid understanding of when hip training may be required to facilitate optimum PFJ contact pressure, and thus improve treatment outcomes.

PARTICIPANTS AND METHODS

Forty asymptomatic participants, 20 males and 20 females (age 21.5 ± 1.3 years) were recruited. Exclusion criteria included previous knee or hip surgery or pathology, current or previous treatment for hip or knee conditions, and current or previous pregnancy. Anthropometric data were gathered by a questionnaire (Table 1). Activity level was assessed with the Tegner score[17].

Ethical approval was obtained from the host university, and all participants gave informed written consent. A SonoSite Edge II ultrasound machine (SonoSite, Bothell, WA, USA) with a SonoSite HL50 × 15–6 MHz linear-array probe (6 cm) was utilised.

Each participant was asked to lie in a supine position with both lower limbs fully relaxed and extended. A 15 × 30 cm foam roller (PhysioRoom, PhysioRoom.com) was placed under the knee to ensure 20° knee flexion, so that the patella was engaged in the trochlear groove[18]. A metre rule was placed between the apex of the patella and the ASIS. A straight line was then drawn from the mid-point of the patella to the mid-thigh. A horizontal line was drawn across the mid-point of the patella. A standard 360° goniometer was used to measure the angle of adduction (Fig. 1).

Using minimal pressure, the ultrasound (US) probe was placed perpendicular to the skin, on the lateral half of the horizontal line across the patella. The probe was then moved laterally to identify the edge of the patella and the lateral femoral condyle. B-mode real-time ultrasonography was used to measure the patella-condyle distance in the neutral position and 20° hip adduction (Fig. 2). To minimise errors, each measurement was repeated 3 times, by the same observer; the same equipment was used throughout the study. One participant was randomly selected for an intra-observer reliability study; their knees were assessed 9 times over 3 different days.

A total of 79 knees from 40 participants were examined (1 limb was excluded due to previous knee injury). The mean patella-to-femoral condyle distance was calculated. Paired t-tests were used to determine any significance differences between right and left limbs, and adducted and neutral positions. An unpaired t-test was used to determine any significant difference between genders. One-way analysis of variance (ANOVA) was used to identify significant differences between Tegner scores and BMI. The correlation coefficient was also calculated to determine the relationship between the above factors. The mean, standard deviation (SD) and range were also calculated. The level of statistical significance was set at $p<0.05$.

Table 1. Anthropometric details of the study participants (n=40)

	Age (years)	Weight (kg)	Height (cm)	Body Mass Index (kg/m^2)	Tegner score
Mean ± SD (range) TOTAL n=40	21.5 ± 1.3 (20–26)	65.3 ± 12.9 (50–105)	17.0 ± 0.1 (15.6–18.5)	22.6 ± 3.5 (17.8–34.3)	5.0 ± 1.9 (2–9)
Mean ± SD (range) FEMALES n=20	21.5 ± 0.8 (20–23)	58.5 ± 7.62 (50.0–75.0)	16.3 ± 0.1 (15.6–17.7)	21.9 ± 2.6 (18.1–29.3)	4.5 ± 1.8 (2–8)
Mean ± SD (range) MALES n=20	21.6 ± 1.8 (20–26)	72.1 ± 13.6 (56–105)	17.6 ± 0.1 (16.5–18.5)	23.3 ± 4.1 (17.8–34.3)	5.6 ± 1.8 (3–9)

Mean ± SD (range). BMI: Body Mass Index.

RESULTS

In the intra-observer reliability study, the coefficient of variability (CV) was 0.005 (0.5%) for neutral position and 0.01(1%) for hip adduction. These values were all <5%, which indicates highly reliable readings (Table 2).

In both genders, there was no statistically significant difference between the left and right limbs in the neutral position

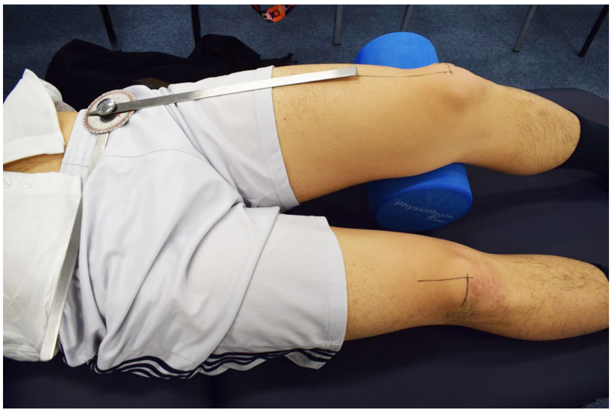

Fig. 1. A standard 360° goniometer was used to measure the angle of adduction.

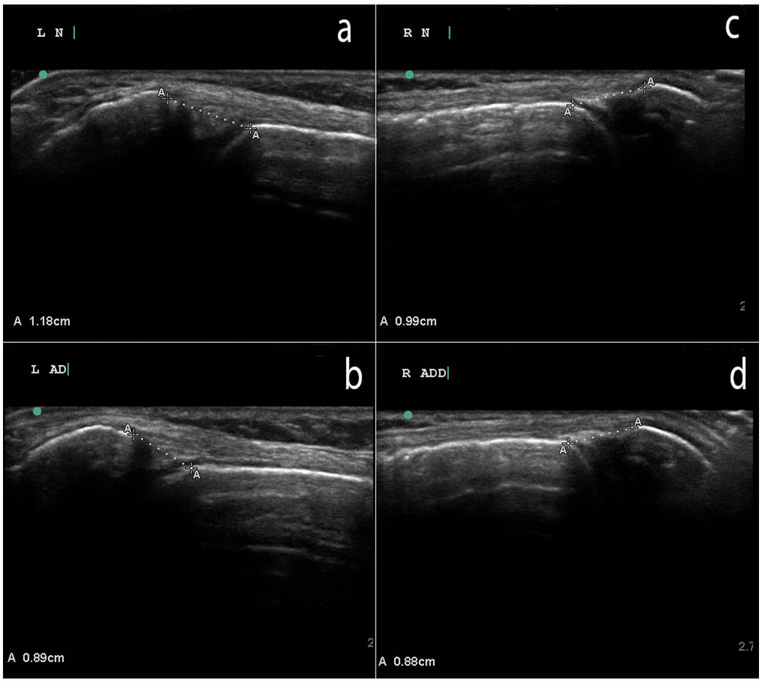

Fig. 2. Ultrasound images, showing: a, left, and b, right knees in the neutral position; c, left, and d, right knees in 20° adduction. The dotted line 'A-A' represents the patella-femoral condyle distance; 'A' shows the distance in cm.

Table 2. Intra-observer reliability test

	Mean (cm)	SD	CV (SD/Mean)	Variance	Range (cm)
Neutral	1.30	0.006	0.005	0.00002	1.30–1.31
20° hip adduction	1.17	0.012	0.01	0.00009	1.16–1.18

The mean, standard deviation (SD), coefficient of variation (CV), variance and range, in two hip positions, neutral and 20° hip adduction, were measured nine times over three days on the same participant.

and in hip adduction ($p > 0.05$) (Table 3). Therefore, when analysing the change of patella-condyle distance relative to other factors, the data collected from the left and right limbs were not considered as 2 independent variables.

The combined (male + female, left + right) mean patella-condyle distance was 1.20 cm (± 0.14 cm) in the neutral position, and 1.02 cm (± 0.14 cm) in 20° hip adduction (Fig. 3). The mean difference in the patella-condyle distance between neutral and 20° hip adduction was 0.18 cm ($p < 0.05$). In all subjects, hip adduction consistently produced a smaller patella-condyle distance. No statistically significant differences were found between genders ($p = 0.87$), Tegner scores ($p = 0.68$), and BMI ($p = 0.74$).

A very weak correlation ($R^2 = 0.000026$) was found between the change in patella-condyle distance and Tegner scores; the difference was not statistically significant ($p = 0.68$). A weak correlation ($R^2 = 0.0072$) was found between the change in patella-condyle distance and BMI; the difference was not statistically significant ($p = 0.74$).

DISCUSSION

In all participants, hip adduction consistently produced a smaller patella-condyle distance than in the neutral position. This indicates that hip adduction leads to lateral tilt of the patella, which is consistent with Herrington et al.'s study on 12 male participants[12]. The current study increased the power of the result by using a larger sample size, including both genders. The intra-observer reliability study showed that the measurements were reliable, so it can be concluded that the differences in patellar position between the neutral position and hip adduction were due to the movement of the hip into adduction. It was suggested by Herrington et al.[12] that this is due to tightening of the ITB during hip adduction, creating tension and stress on the lateral retinaculum, and hence leading to lateral patellar movement.

Although no differences between genders was observed, it is important to note that some conditions that affect the knee (e.g. PFP and anterior cruciate ligament tear), are more predominant in females[19–21]. A very weak, statistically insignificant, correlation was found between change in patella-condyle distance and Tegner score, suggesting that the change in patellar position is independent of the participants' activity level. However, this result should be viewed with caution, as the majority of participants reported a Tegner score of 6, giving an uneven sample distribution.

There was no significant correlation between the change in patella-condyle distance and BMI, which is consistent with results from previous studies[22, 23]. It appears that BMI does not affect patellar position, and is unlikely, therefore, to play a role in the development of PFP.

Table 3. Mean patella-condyle distances, p values, mean, and variance of the measurements

Position male/female	p values	Mean distance (R) (cm) ± SD	Mean distance (L) (cm) ± SD	Variance (R)	Variance (L)	t Critical two-tail	Range (cm)
Male, neutral position	0.15	1.23 ± 0.13 (n=20)	1.21 ± 0.13 (n=19)	0.02	0.02	2.10	0.9–1.39
Male, hip adduction	0.47	1.04 ± 0.12 (n=20)	1.03 ± 0.15 (n=19)	0.01	0.02	2.10	0.69–1.27
Female, neutral position	0.77	1.19 ± 0.18 (n=20)	1.18 ± 0.13 (n=20)	0.03	0.02	2.09	0.74–1.52
Female, hip adduction	0.42	1.01 ± 0.17 (n=20)	1.00 ± 0.13 (n=20)	0.03	0.02	2.09	0.60–1.26

n: number of limbs analysed; SD: standard deviation; R: Right limb; L: left limb.

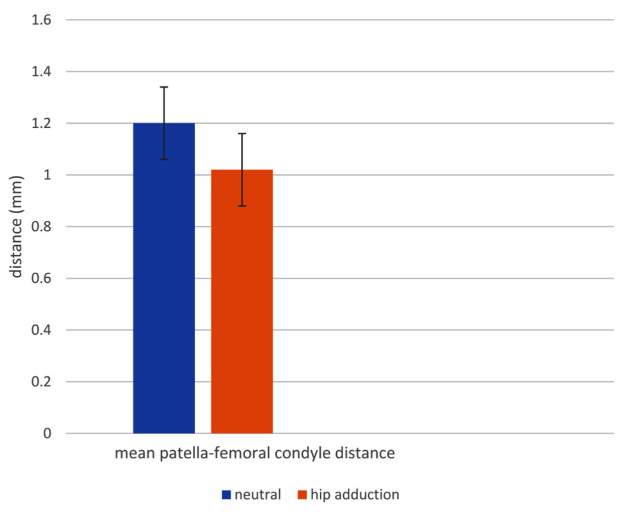

Fig. 3. Bar chart showing mean combined patella-femoral condyle distance in the neutral position and in 20° adduction.

Further work is needed to investigate whether the reduced patella-condyle distance on adduction is altered by a stretching programme aimed at the contractile origins of the ITB. This would be of clinical interest, as stretching exercises for the tensor fasciae latae and gluteus maximus are commonly given as part of a physiotherapy programme aimed at treating PFP[26)]. This treatment is undertaken in an attempt to reduce pressure in the lateral compartment of the PFJ, which has been shown to demonstrate a chondral wear pattern that correlates with pain[27)]. In addition to creating more length through the ITB and its contractile origins, much rehabilitation for PFP is based around the concept of reducing unwanted and uncontrolled hip adduction[28)]. The study reported here substantiates the relevance of reducing hip adduction, as it will reduce the likelihood for an unwanted increase in lateral PFJ load through hip adduction, causing patella tilt.

This study also presents a novel, reliable way of assessing patella tilt. Ultrasound is increasingly common in the clinical setting, and this study demonstrates how it could be used reliably to assess patella tilt. There is extensive literature demonstrating the importance of patella tilt assessment for surgical planning both for arthroplasty and patella instability surgery[24, 25)]. The imaging used in these studies was X-ray, which may not always be easily available, and creates undesirable exposure to ionising radiation. Our paper presents a reliable, non-invasive assessment tool that could be performed in the clinic without any ill effects.

While the data we present here on activity levels is limited, as far as we are aware, no study has yet been conducted to investigate the relationship between activity level and patellar position on adduction. As PFP usually affects young athletes[29)], future studies could explore the difference between the patellar positions of elite athletes and people who are sedentary. Furthermore, PFP and ITB problems are particularly prevalent in runners, with a prevalence of 20.8% reported in recreational runners[30)]. It would be of interest to investigate this subgroup to assess for both a different starting angle, and the effect of hip adduction on the angle. Type and volume of training should be investigated to see whether activity levels have any significant effect on the change of patella position during hip adduction.

The findings of this study showed that hip adduction in male and female asymptomatic participants consistently produced a smaller patella-condyle distance than the neutral position, which indicates a lateral patellar displacement, or patella tilt. The displacement of the patella could increase the relative load on the lateral PFJ and cause PFP. This study also demonstrated that ultrasound was a reliable assessment tool for patella tilt.

Conference presentation

A summary of this study was presented at the British Association of Clinical Anatomists Conference 2nd July 2019, University of Central Lancashire, Preston, UK.

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Conflict of interest

The authors have no conflict of interests to declare.

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